QUALITY INTEGRATED EARNED VALUE MANAGEMENT FOR CONSTRUCTION PROJECTS

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

ERAY AKGÜN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
CIVIL ENGINEERING

SEPTEMBER 2019

Approval of the thesis:

QUALITY INTEGRATED EARNED VALUE MANAGEMENT FOR CONSTRUCTION PROJECTS

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ABSTRACT

QUALITY INTEGRATED EARNED VALUE MANAGEMENT FOR CONSTRUCTION PROJECTS

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September 2019, 176 pages

Today, construction sector is one of the leading sectors in the world employing millions of people and creating an economy of billions of dollars. Therefore, such a huge sector must be under control during its all stages in terms of its main components namely; cost, time and quality to achieve a unique scope. Numerous studies focus on tracking the components of cost and schedule. One of the most commonly used methods is EVM (Earned Value Management). EVM is a powerful progress measurement method, integrating cost, schedule and scope successfully. However, the EVM method lacks one of the major components of the iron triangle, namely the quality component. Thus, this study aims to develop a framework which enables "Quality integrated Earned Value Method (QEVM)". With the integration of quality to EVM, an extendible, elaborate, and practical quality tracking system is proposed. In the literature, several valuable studies focused on the quality or performance included Earned Value Management, in recent years; however, the proposed systems show significant differences in terms of the employed key performance indicators, benchmarks, quality scoring methods and visualization of the QEV. Hence, there is a need to compare these systems and identify the areas of modification and improvement in order to propose a QEVM framework that is practical, extendible, and

elaborate for different stakeholders/tasks, integrating the “quality cost” and “productivity of quality” concepts. In this study, after reviewing and analyzing literature in terms of QEVM requirements and components, quality tracking checklist forms were improved, quality cost and quality productivity concepts were explored. Framework components were identified for different level of details of stakeholders/tasks, quality scoring methods were compared, and value functions were derived to determine the relationship of productivity of quality and cost. Four case studies on two different projects were executed to develop and verify the components of the framework. As a result of this study, a quality embedded EVM framework was suggested. The results of this study can be used to pave the way for more sophisticated and software-integrated applications and future studies.

Keywords: Quality Earned Value Management, Quantification of Construction Quality, Quality Cost, Quality Productivity, Construction Quality Assessment

ÖZ

İNŞAAT PROJELERİ İÇİN KALİTE İLE BÜTÜNLEŞİK KAZANILMIŞ DEĞER YÖNETİMİ

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Eylül 2019, 176 sayfa

Bugün, inşaat sektörü milyonlarca insana iş sağlayan ve milyarlarca dolarlık bir ekonomi yaratan dünyada öncül sektörlerden birisidir. Buna binaen, böylesi devasa bir sektör tek hedefini başarabilmek için; maliyet, zaman ve kalite olarak adlandırılan ana bileşenleri açısından onun tüm aşamaları süresince kontrol altında olmalıdır. Pek çok çalışma maliyet ve planlama bileşenlerinin takibine odaklanmaktadır. En yaygın kullanılan yöntemlerden birisi KDY (Kazanılmış Değer Yönetimi)'dir. KDY; maliyet, planlama ve amacı başarılı bir şekilde bütünleştiren güçlü bir ilerleme ölçüm yöntemidir. Fakat, KDY yöntemi, demir üçgenin en esas bileşenlerinden birisi olan kalite bileşeninden yoksundur. Buna binaen, bu çalışma, "Kalite ile Bütünleşik Kazanılmış Değer Yöntemi (KKDY)"ne olanak sağlayan bir çerçeve geliştirmeyi amaçlamaktadır. Kalitenin KDY ile bütünleştirilmesi ile beraber, genişletilebilir, ayrıntılı, ve uygulanabilir bir kalite takip sistemi önerilmektedir. Literatürde, özellikle son yıllarda, kalite ya da performans içerikli KDY alanında birçok değerli çalışmalar vardır; fakat önerilen sistemler kullanılan anahtar performans göstergeleri, ölçütleri, kalite puanlama yöntemleri ve KKDY'nin görsellenmesi açılardan önemli farklılıklar göstermektedir. Bundan dolayı; farklı paydaşlar ya da görevler için "kalite maliyeti" ve "kalite verimliliği" kavramlarını da bütünleştiren, kullanışlı, genişletilebilir ve

esnek bir KKDY çerçevesi önerebilmek adına, bu sistemleri kıyaslamaya ve değişiklik ve gelişim alanlarını belirlemeye ihtiyaç vardır. Bu çalışmada literatürün KKDY gereksinimleri ve bileşenleri açısından gözden geçirilmesi ve analiz edilmesinden sonra, birtakım kalite takibi kontrol listeleri geliştirildi, kalite maliyeti ve kalite verimliliği kavramları keşfedildi. Çerçeve bileşenleri, paydaşların veya görevlerin farklı ayrıntı düzeyleri için belirlendi, kalite puanlama yöntemleri karşılaştırıldı ve kalite verimliliği ve maliyeti ilişkilerini kararlaştırmak için değer fonksiyonları türetildi. Çerçevenin bileşenlerini doğrulamak ve geliştirmek üzere iki farklı proje üzerinde dört vaka çalışması yerine getirildi. Bu çalışmanın bir sonucu olarak, bir kalite yerleştirilmiş KDY çerçevesi önerildi. Bu çalışmanın sonuçları, daha sofistike ve yazılımla bütünleştirilmiş uygulamalar ve gelecek çalışmalarına yol açmak için kullanılabilir.

Anahtar Kelimeler: Kalite Kazanılmış Değer Yönetimi, İnşaat Kalitesinin Nicelleştirilmesi, Kalite Maliyeti, Kalite Verimliliği, İnşaat Kalitesi Değerlendirilmesi

Dedicated to my family …

ACKNOWLEDGMENTS

I would like to gratefully thank to my advisor Assist. Prof. Dr. Güzide Atasoy Özcan, without whom I would not be able to complete my thesis, for her invaluable support, unrequited guidance, permanent encouragement, infinite and limitless patience and tolerance at each stage of this study.

I would also like to express appreciation to the members of my examining committee who agreed to participate on a short notice.

I am also indebted to my family; my father, my mother and my sister; who embraced me with love, care, encouragement and remarkable support without which I would not be who I am today.

I wish to thank all experts, professionals and company members, colleagues - especially to Oğuzhan- for their help and support throughout my study. I owe special thanks to the all sides and respondents of my questions during sectoral survey of this thesis.

I would like to express my especial appreciation to my dear friends Ebru, who has just submitted her master of science thesis, always encouraged me to conclude my study and Süheyl, Emre and Tohir who have always cared with me and motivated me during my study. I would like also thank my dear friends Cüneyt, Ahmet, Erkam and Oğuzhan for their invaluable fellowships. Finally, I wish to thank to my dear friends and colleagues; Serdar, Sarp, İhsan, Melih, Ali, Hikmet, İsmail and Emre for their endless love, unlimited support, understanding and efforts that encouraged me to realize my goals.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACWP	Actual Cost Work Performed
AQVWP	Actual Quality Variation Work Performed
AQWP	Actual Quality Work Performed
BCWP	Budgeted Cost Work Performed
BCWS	Budgeted Cost Work Scheduled
BQWP	Budgeted Quality Work Performed
BQWS	Budgeted Quality Work Scheduled
CPI	Cost Performance Indicator
EQV	Earned Quality Value
EV	Earned Value
EVM	Earned Value Management
GM	General Manager
KDY	Kazanılmış Değer Yönetimi
KPIs	Key Performance Indicators
PBEV	Performance Based Earned Value
PM	Project Manager
QC	Quality Cost
QCEV	Quality Cost Included Earned Value
QV	Quality Variance
QEVM	Quality integrated Earned Value Management
QPI	Quality Performance Indicator

SPI	Schedule Performance Indicator
TL	Turkish Lira
TQM	Total Quality Management

CHAPTER 1

INTRODUCTION

1.1.1. Definition of Project Management

Project management is the ability to meet project requirements by applying the tools, skills, techniques & knowledge to project activities and the "initiating, planning, executing, controlling and closing" stages should be the accomplished process.

On the other hand; scope, time, cost, risk and quality demands, identified requirements and the differing expectations and needs of the stakeholders are the works those shall be managed in project management ("PMBOK® Guide", 2000, p. 6).

1.1.1. Components of Project Management

According to Project Management Institute; *"the more you know about your project, the better you are able to manage it"* ("PMBOK® Guide", 2000, p. 6). Thus, in order to manage any kind of project properly, the components of project management shall be analyzed in detailed.

According to PMBOK® Guide" (2000), there are nine different project management knowledge areas as illustrated in ***Figure 1.1***.

Figure 1.1 Project Management Knowledge Areas (PMBOK, 2000)

1.1.2. Mostly Tracked Project Management Components in Practice

Even though those nine knowledge areas shown in the ***Figure 1.1*** are the whole components of project management, some of them, which are cost, time and quality, are tracked more carefully in practice with respect to others. Those three knowledge areas are considered as the most crucial components of project management called as "the iron triangle" (or triple constraints or golden triangle) (Atkinson, 1999, p. 338) (Ong, Wang, & Zainon, 2018, p. 1)**.**

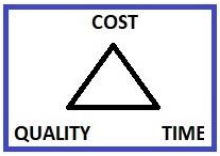

Figure 1.2 The iron triangle (Atkinson R.,1999)

1.1.3. Project Measurement Methods

There are various project measurement methods used for progress illustration of projects which are ***earned value, weighted percentage, units completed, steps (incremental milestone), cost ratio, start / finish and experience / opinion*** methods.

Among those methods, **Earned Value Management** is gaining more popularity for last decade and is used in wide range project types from aeronautics to software, any kind of research from construction, agriculture to production etc. (Dodson, Defavari, & Carvalho, 2015, p. 933). Having objective characteristic, serving simple and powerful time, budget and scope tracking and predicting future outcomes by providing feedback are the most outstanding features of EVM (Efe, 2015, p.7).

1.2. Statement of the Problem

In the construction sector, controlling the cost and time components in project management is done systematically and most of the attention is paid to tracking of these components; however, quality component is not tracked in a systematic manner while project process is going on, in practice. Moreover, many studies, models, tools, systems, and software tools exist regarding integration of cost and schedule (such as

Earned Value Management) in the literature, which makes it easier and systematic to control them. However, there are a limited number of studies that integrate quality component into the other two components. Among them, there are some QEVM studies, as well. In those studies, various KPIs, benchmarks, quantification methods, data collection and visualization methods are used. However, their comparison, practicality and suitability for construction projects are not known. In addition, these limited number of studies need to be improved, adapted, and elaborated for various stakeholders, sectors, and countries, as well. Hence, this situation leads to some inefficiency in controlling of quality component of project management, in a practical and systematical way.

1.3. Purpose of the Study

This study aims to develop a framework for Quality integrated Earned Value Management to support project managers to track the quality together with cost and time components in a systematical, extendible, elaborate and customizable way for different level of details of project stakeholders/tasks.

1.4. Organization of the Study

The organization of this research study is illustrated in ***Table 1.1***. In this study; definition and components of project management, the statement of the problem and the purpose of this study are stated in the **Introduction** section. In the **Literature Review** section, current studies related with Key Performance Indicators, metrics / benchmarks, data collection methods / data sources, data analysis methods, quality evaluation systems, data communication methods, and quality earned value methods are analyzed.

The research tasks performed to develop the QEVM model, creation steps of framework and its related components are explained in the **Methodology** section. The developed QEVM Framework and its details are explained in the **QEVM Framework / Model** section. Moreover, Case Studies 1, 2 & 3, which tests and compares end product quality measurement according to different kind of scoring methods, and

according to different perspectives (owner, client and expert satisfaction) are discussed in this section. Case Study 4 presents the final scoring and quantification methods decided after the comparison and verification of Case Studies 1, 2 & 3. Final QEVM Framework / Model is also proposed in 4th case study with the integration of Quality Cost and Quality Productivity. Finally, the deductions and future research suggestions are located in the **Conclusion & Discussion** section.

Table 1.1 The Organization Structure of the Study

1	**Introduction**	Definitions, Problem & Purpose Statement, Organization Illustration
2	**Literature Review**	*Key Performance Indicators *Metrics / Benchmarks *Data Collection Methods / Data Sources *Data Analysis Methods *Quality Evaluation Systems *Data Communication Methods *Quality Earned Value Methods
3	**Methodology**	
4	**QEVM Framework / Model**	Case Studies 1, 2, 3 & 4
5	**Conclusion & Discussion**	Deductions & Future Research Suggestions

CHAPTER 2

LITERATURE REVIEW

Project management is the ability to meet project requirements by applying the tools, skills, techniques & knowledge to project activities as stated in introduction part ("PMBOK® Guide", 2000, p. 6). Powerful methods shall be preferred in project management stages, in order to achieve these requirements systematically and successfully.

According to Boydak (2013, p.1) “Earned Value Management (EVM) is a powerful project management method that is implemented in engineering and construction projects” and he states that there are various frameworks and adaptations of EVM according to participants needs such as ANSI/EIA-748, PMI's A Guide to the Project Management Body of Knowledge (PMBOK® Guide) and Practice Standard.

The scope of this study is specially to track quality component of project management and to integrate it into the other components in a systematic manner. Thus, since EVM is both open to modification and a powerful method to help monitor the progress of project management, EVM was considered to be integrated with quality component of project management. Eventually, this consideration leaded a literature review in order to examine the studies related with Earned Value Management to track quality component of project management.

Firstly, in Scopus, “Quality Earned Value” and “QEV” keywords in the “title” part was searched and 11 studies were reached. When those studies were analyzed, it was seen that some of the certain studies were unsuitable in sectoral norms and some of them were not in project-based. Thus, a second research was run by “project quality earned value” keyword in “keyword, title and abstract” part. 116 related studies were

acquired in this search. Those studies were extracted in terms of the suitability to concept of “a practically applicable quality tracking EVM systems for construction projects”. After the extraction and analyses of related studies, other related studies were also reached from the citations and references of those studies to be examined. The final 101 studies out of ~200 studies were analyzed and the findings are explained in the upcoming sections. Those studies include books, journals papers, conference papers, sources of governmental agencies, and thesis.

Afterwards, the content of these identified studies was analyzed in-depth, and integrated to determine the system requirements and especially system components of a QEVM framework.

Firstly, the main components of the study were identified and grouped under six main topics namely; **KPIs of quality component, metrics / benchmark for quality perception, data collection methods / data sources for quality measurement, data analysis methodology, quality evaluation system and data communication methods** as summarized in ***Table 2.1***. In the next subsections of literature review part, the prominent studies related with those main components of the system are explained, in detailed.

Table 2.1 The Components of a Quality Measurement System

(MEASURE WHAT)	**KPIs OF QUALITY COMPONENT**
	***FINANCIAL DATA** (HUMAN RES, MATERIAL, ... / QUALITY COST) ***SERVICE QUALITY FACTORS** (MIN.PROJECT DURATION, TIMELINESS, COMPLETENESS, ..) ***CORPORATE / SYSTEM QUALITY FACTOR** (LEADERSHIP, CLIENT FOCUS, ..) ***BUILDING (OR END PRODUCT) QUALITY FACTOR** (TECHNICAL, FUNCTIONAL, BEHAVIORAL)
(MEASURE W.R.T. WHAT)	**METRICS / BENCHMARKS OF QUALITY PERCEPTION**
	***STANDARDS, SPECIFICATIONS, CODES & TECHNICAL REQUIREMENTS** ***FINANCIAL DATA** (FINANCIAL EXPENDITURE & QUALITY COST) ***SUBJECTIVE SATISFACTION** (CLIENT, OWNER & EXPERT SATISFACTION) *** CORPORATE DATA** (ADMINISTRATIVE DATA, PROJECT DATA)
(HOW TO COLLECT DATA)	**DATA SOURCES & DATA COLLECTION METHODS**
	***TESTING & INSPECTION RESULTS** (MATERIAL TESTING, VISUAL OR HIGH-TECH. INSPECTION) ***DATA BASE** (CORPORATIVE, FINANCIAL, STATISTICAL PAST DATA) ***PERCEPTION** (CLIENT, OWNER & EXPERT OPINION) ***MEANS** (QUESTIONNARIE, CHECKLISTS, FEEDBACKS)
(HOW TO MEASURE)	**DATA ANALYSIS METHODS**
	***PERCEPTIVE** METHODS (QUESTIONNARIE, CHECKLISTS) ***SOFTWARE BASED** METHODS (CAD, SIMALITION, BIM, PRIMAVERA, MS OFFICE ...) ***CONCEPTUAL** METHODS (FUZZY, MAUT, AHP, HEURISTIC ...) *** MATHEMATICAL & STATISTICAL** METHODS (DESCRIPTIVE, BIVARIATE, REGRESSIONAL ...)
(OUTPUT / RESULT)	**EVALUATION SYSTEM FOR QUALITY**
	***** QUALITY / PERFORMANCE - EVM** ***** WIDELY ACCEPTED GENERIC SYSTEMS** (QUALITY FUNCTION DEPLOYMENT / QUALITY MATRICES, TQM, LEAN PRODUCTION, SIX SIGMA, BEST VALUE, SOFTWARE /CAD /BIM BASED..) ***** SYSTEM BASED ON STANDARDS** (ISO, EFQM, MALCOLM BALRIDGE, CONQUAS, PASS, QLASSIC, ..) ***** SPECIFICALLY DEVELOPED SYSTEMS** (SERVQUAL, QUALITY GATES, QIDMS, QUALICON, ..)
(HOW TO COMMUNICATE DATA)	**DATA COMMUNICATION METHODS**
	***** DATA SCORING METHODS** (FUZZY, LIKERT SCALE, PASS OR FAIL) ***** REPRESENTATION RESULTS** (NUMERICAL, TABULAR , GRAPHICAL)

2.1. Key Performance Indicators (KPIs) of Quality

Quality component of project management is one of the most embraced leg needed to be tracked systematically. Before the systematic part, firstly the question of "WHAT does reflect or indicate quality?" should be answered. That is, the KPIs of quality shall be defined and decided. The KPIs respond to track or to measure **WHAT**. Firstly, the definition of quality was searched before moving onto KPIs and identified that quality has many kinds of acceptable definitions. A demonstrative set of definitions can be found in ***Table 2.2***. Seymour and Low (1990) explains this fact as "there are no absolute definition of quality" due to different kind of perception of people over quality goal (Low, S.P., Wee, D.,2011, p.368).

Table 2.2 Various definitions of quality in literature

DEFINITION	REFERRED DEFINITION	STUDY
Totality of features and characteristics of a product or a service that bear on its ability to satisfy the stated and implied needs	Client/ Owner Needs	ISO 8402 & American Society for Quality
Objective of QEV is to measure the project's ability to deliver the quality requirements defined by the project's stakeholder…		Dodson et.al, 2015, p.3
Factors used for measuring quality should be directly related to customers' needs and expectations and should be easily quantifiable.		Lee & Arditi, 2006, p. 51
… meeting full conformance to requirements	Conformance to Specifications/ Codes/ Requirements	Solomon, 2015, p.16
Compliance with construction codes& specifications		Chen, L., & Luo, H. 2014, p.64
quality is conformance to requirements		Crosby, 1979
(inspired from Crosby's quality approach) doing it right the first time and measure it by the cost of nonconformance	Financial Data	Efe, 2015, p.3
.. analyses accounting information reflects the quality of the project		Xi, 2014, p.4
"meeting the customer's need, fitness for use and conforming to requirements" AND quality for construction works is "the fulfillment of the owner's needs in defined scope within budget and schedule"	*Owner Needs *Conformance to Requirements *Fulfilling Project Management	Rumane, 2018, p.8

Existence of various definitions of quality concept brings along various types of key performance indicators, as well. In other words, there are more than one KPI reflecting quality, because there are several quality perceptions, as well. When literature was scanned in order to define the KPIs of quality, numerous results were obtained in different level of details. In order to proceed systematically, initially, the highest-level KPIs were identified. The reason behind this is that the main KPIs shall be embraced in all kind of projects and the lower level KPIs can be altered and extended according to each project.

Some of the highest-level KPIs were noticed as the main components of Total Quality Management (TQM). Graves (1993, p.2) explains TQ is TOTAL due to its inclusion to everyone and to all aspects of the business. Thus, since they are including a very-wide range of projects, they are considered as suitable KPIs. According to Arditi & Lee (2006, p.1) Total Quality consists of **Project Service Quality, Corporate Level Quality and Building (end product) Quality.** Those 3 KPIs are consistent to be applied in a wide range of projects and have been used in numerous studies (e.g., Arditi et.al, 2006; Yasamis et.al, 2012; Stukhart, 1989; Lee et.al, 2008; Chow et.al, 2006; Tam et.al, 2000; Chan et.al, 2004; Ahmed et.al, 2016; and Rumane, 2018).

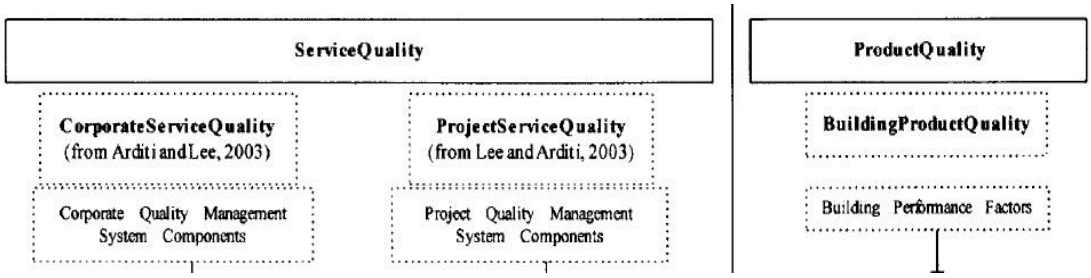

Figure 2.1 Total Quality components according to Lee and Arditi (2006, p.3)

Moreover, another outstanding result of KPI research was that financial data including quality cost is used directly in lots of studies as quality indicator. Xi (2014, p.1) suggests Financial Information as a practical quality KPI. He considers that accounting information reflects quality characteristics and indicates construction engineering quality, roughly.

On the other hand, Ma and Yang (2012) and Gao and Ye (2011) take the Quality Cost analysis as the core (Gao, Ye,2011, p.2) of their studies. Ma and Yang (2012) states the lack of quality component in Earned Value Management, and explains the solution as introducing quality cost concept in order to solve the lack of quality concept. Similarly, Khalid and Yeoh (2015) introduces the cost of rework, after stating the lack of quality component in EVM, as well. Efe (2012, p.3) measures the quality by cost of nonconformance (quality cost) in her doctorate level thesis study.

Actually, there are some similarities between "financial data" and "service & corporate quality factors", and "building (end product) quality factor" as well, in terms of their low level KPIs. For example; cost of loss (or fault) is leaded due to low-level of end product quality, so through this perspective, this sub-component of quality cost may be considered in "building (end product)" KPI. For another illustration, appraisal and prevention costs of "quality cost" and accounting data for employers of corporate can be considered in "service & corporate quality factors" KPIs. On the other hand, lots of studies preferring financial data are directly taking into account this data and are proceedings without using any other KPIs.

In the scope of this study, Financial Data was used as a KPI linked with the other three KPIs as illustrated in Figure 2.2.

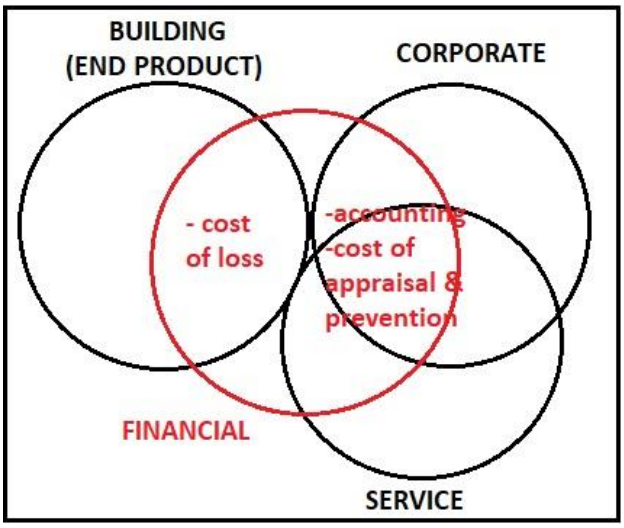

Figure 2.2 Illustration of KPIs

Overall, some studies use **financial data** as a KPI such as cost of human, material, equipment, method (or process) and environment factors (Xi, 2014, p.4) in management or directly with quality cost (Ma et.al, 2012, Davis et.al, 1989, Arditi & Günaydın, 1997) concept, some others are centered on **service quality factor** (Lee et.al, 2006, Chan et.al, 2004) by developing a generic service quality measurement instrument (Hoxley, 2000). Moreover, while some studies defend **corporate / system quality factor** (Bubshait, 1999, Lee et.al, 2006, Deffenbaugh, 1993 , Burati et.al, 1992, Sulivan, 2011, Hensey, 1993, Pheng et.al, 2011, Arditi et.al, 1997) as KPI, the rest vast majority considers **building (or end product) quality factor** (Solomon, 2005, Paquin et.al, 2000, Zhong et.al, 2012, Boukamp et.al, 2007, Tam et.al, 2000, Kim et.al, 2007, Taneja et.al, 2011, CONQUAS, BRANZ, General Specification of Ministry of Environment & Urbanization of Republic of Turkey, Rumane et.al, 2018). However, trying to choose one/ a specific number of correct KPIs for quality concept of construction works is not the correct approach. Actually, all of the KPIs stated in the literature are the correct ones through different perspectives as; "client, consultant, contractor, subcontractor, independent auditor (Paquin et.al, 2000, Lam et.al, 2005), supplier (Almaian, 2016), occupant (Hammad, 2014), participant (Vhan et.al, 2004)". Thus, choosing a "suitable" KPI rather than "correct" one is a reasonable approach. Moreover, as any individual KPI may be considered as the suitable one, several or all of them may also be combined (e.g., Tam et.al (2000), Ahmed et.al (2016)). There are various studies using different KPIs together (e.g., Lee et.al, 2006, Yasamis et.al, 2012, Stukhart, 1989, Lee et.al, 2008, Chow et.al, 2006, Tam et.al 2000, Chan et.al, 2004, Ahmed et.al 2016, Rumane et.al, 2008 use service+corporate+building at the same time). Moreover, Tam et.al (2000) and Ahmed et.al (2016) develops quantitative relations among them. In Ahmed et.al (2016), a questionnaire was employed through the point of view of managers, designers and contractors and the results were extracted by statistical data analysis method and finally the relationship between the components of KPIs as shown in ***Figure 2.3*** is suggested as the correct approach.

Table 2: Summary Mean Score

NO.	Factor	Mean
1.	Quality systems	3.74
2.	Owner	3.71
3.	Materials	3.82
4.	Design	3.75
5.	Equipment	3.71
6.	Labors	3.69
7	Site staff	3.19
8	Contractor	3.72

$$Quality\ In\ Construction\ Projects = \beta 0 + \beta 1\ (Design) + \beta 2\ (Labor) + \beta 3\ (Materials) + \beta 4\ (Equipment) + \beta 5\ (Site\ Staff) + \beta 6\ (,\ Quality\ Systems) + \beta 7\ (Owner) + \beta 8\ (Contractor) +$$

Figure 2.3 Quality function developed in Ahmed et.al, 2016

On the other hand, the study of Tam et.al (2000) focuses on PASS -which is the building and service quality assessment system used by Hong Kong Housing Authority- and uses a relation of 0,75*(end product quality) + 0,25*(corporate quality factor) weighting. After occupation of the buildings, PASS controls the serviceability and penalizes over the having final score if there are some adverse serviceability situations occur.

After determining the highest-level KPIs, the lower-level KPIs were searched and a demonstrative list of KPIs obtained from existing studies are presented in ***Table 2.3***. Those low-level KPIs were commonly taken from the studies Lee et.al. (2006), Yasamis et.al. (2012) and Lee et.al. (2008) for Corporate, Service & Building Quality Factors, and from Xi (2014), Gao et.al. (2011), Ma et.al. (2012), and Efe (2015) for Financial Data. It should be emphasized that this is not a comprehensive list, the data presented here was gathered from sources where the widely-accepted factors are presented. For instance, the low-level of KPIs of Corporate, Service & Building Quality Factors are acquired from the studies of Arditi & Lee (2003) and Arditi & Lee (2004), in which the quality factors were proposed according to the widely accepted sources of Malcolm Baldrige National Quality Awards & PMI (2000). The levels of details and the inclusions of these KPIs may be customized and modified.

Table 2.3 Demonstrative Set of Low-level of KPIs

<table>
<tr><th>Financial Data</th><th>Service Quality Factors</th><th>Corporate / System Quality Factors</th><th colspan="2">Building (Or End Product) Quality Factors</th></tr>
<tr><td>(16)
Accounting of
*Human Resource
*Material
*Equipment
*Method
*Environment</td><td rowspan="2">(25,26,65)
*Minimum Project Duration
*Timeliness
*Completeness
*Courtesy
*Consistency and Dependability
*Accessibility and Convenience
*Accuracy
*Responsiveness
*Communication
*Understanding the Customer</td><td rowspan="2">(25,26,65)
*Leadership
*Client Focus
*Information & Analysis
*Human Resources Development & Management
*Process Management
----
(26)
*Business Results
*Employee Empowerment
*Partnership Development
*Continuous Improvement</td><td rowspan="2">Technical / Functional / Behavioral</td><td rowspan="2">(25,26,65)
*Performance
*Usability
*Dependability
*Conformance
*Safety
*Economics
*Aesthetics
*Perceived Quality
----
(26)
*Features
*Reliability
*Durability
*Serviceability
*Visual Appeal</td></tr>
<tr><td>*Quality Cost</td></tr>
<tr><td colspan="3"></td><td colspan="2">Design / Construction / Handover Stages</td></tr>
<tr><td colspan="5">16-Xi,2014, 25-Lee et.al,2006 ,26- Yasamis et.al, 2012, 65- Lee et.al, 2008</td></tr>
</table>

The literature studies include various types of low-level KPIs, under the different definitions. For example; some studies named the performance indicators as success criteria, and some did as critical success factors, and the others named them directly as indicators. For example, the studies Koziolek et.al (2011), Yerabolu (2010), Chen et.al (2014), and Daher et.al (2018) take the nonconformance as quality indicators. Hammad et.al (2014) considers as KPI as well and categorizes the criticality of a building system as shown in ***Figure 2.4***. Except KPI definition, various studies have used various definitions as performance criteria such as; quality measures (Wanberg et.al, 2013), project success (Chan et.al, 2004), critical success factors (Atasoy, 2007), quality factors (Ahmed et.al, 2016), fundamental concepts of excellence (EFQM). These definitions seem as low-level KPIs under the defined highest level KPIs, and

they are interchangeable (i.e. they may be included or excluded with respect to specific needs). However; the main common point of them is their illustrating quality criteria.

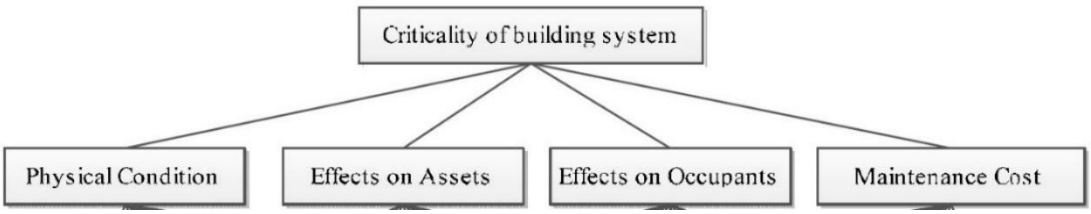

Figure 2.4 KPIs according to Hammad et.al, 2014

Wanberg et.al (2013) consider total number of defects/reworks, the total cost of rework, the total hours related to rework as performance criteria. Wanberg et al. (2013, p.4) developed six quality measures as shown in ***Table 2.4.***

Table 2.4 Quality Measures (Wanberg et al. 2013)

Q#	Definition
Q1	Number of defects per $1 million project scope completed
Q2	Number of defects per 200,000 worker hours
Q3	Cost of rework per $1 million project scope completed
Q4	Cost of rework per 200,000 worker hours
Q5	Number of worker-hours spent on rework per $1 million project scope completed
Q6	Number of worker hours related to rework per 200,000 worker hours

Ahmed and Yusuff (2016, p.7976-7977) prepare a summary table (***Table 2.5***) from literature research for quality factors. (In the original table, there are the references part as well. It is extruded here in order to make the list shorter).

Table 2.5 Quality Factors (Ahmed and Yusuff, 2016, p.7976-7977)

Quality Factors Table by Ahmed and Yusuff (2016, p.7976-7977)			
Design	Experience and knowledge of designers	Site staff	Project manager competence
	Unclear owner's requirements for design		Lack of training on quality staff
	Conformance to codes and standards		Cooperation between supervision and contractor staff
	Drawings and specifications are prepared in full details		Lack of communications and interaction between parties
	Completeness and consistency of design documents		Management commitment and leadership
Labors	Un skilled labor		Lack of timely supervision
	Income level and wages of labors		low experience and competence of supervision staff
	Using Motivation System	Owner	Condition for selecting the contractor and designer by the owner
	Training courses for labors		The owner not delaying to make decisions
Materials	Material checking and testing before usage		Owner emphasis on quality
	Poor management of storage and usage		A written contract condition with unclear specifications by the owner
	Price of materials		lack of coordination between designer and owners
	Improper material selection in accordance with specifications in contract		Change orders during construction by owner
	Availability of good quality construction materials		The delay of interim payments
Equipment	availability of equipment	Contractor	Lack of training course for personnel
	Measurement of equipment productivity		Improper personnel allocation to their tasks
	Equipment maintenance		Lack of complying with specification identified in contract conditions
	The equipment or a machine-operator's skill		lack of supervision of the sub-contractor
	Use of improper equipment or a machine for construction		Low experience and competence of contractor
Quality systems	Lack of quality control, assurance system and feedback		Limitation of finance and budget
	Implement and using time schedule		
	poor safety and health program		
	poor checking and inspection		
	Using computer software and management techniques		

Finally, in EFQM excellence model, the 8 fundamental concepts of excellence are defined as in the ***Figure 2.5***.

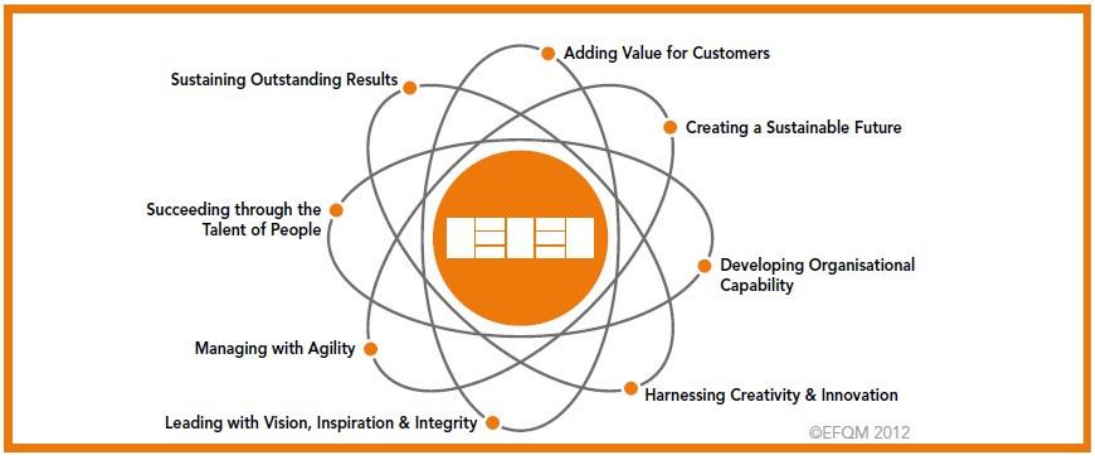

Figure 2.5 EFQM Excellence Model (EFQM, 2012)

Moreover, the KPIs based on scanned studies in the literature is presented in ***Table 2.6.*** The ratio of referred KPIs occurrences: **financial** data is ~**11%**, **service** component is ~**10%, corporate** level is ~**30%** and **building** quality factor is ~**49%** (see ***Figure 2.6***). From a basic point of view, according to usage frequency in related literature studies; *building quality factors (quality of end product)* and *corporate quality factor* management components seem widely-used as KPIs for quality determination of construction works.

Table 2.6 The distribution of KPIs in literature studies

KPIs IN RELATED STUDIES (See Appendix C for Numbered Studies)				
SEQUENCE # OF STUDY	FINANCIAL DATA	SERVICE QUALITY FACTOR	CORPORATE / SYSTEM QUALITY FACTOR	BUILDING (OR END PRODUCT) QUALITY FACTOR
1				1
2				1
5	1			
7	1			
8				1
12				1
13			1	
14				1
16	1			
18			1	
21				1
25		1	1	1
26		1	1	1
29			1	
30			1	
31		1		
33			1	
34		1	1	1
37			1	
40				1
41				1
44			1	
45			1	
47			1	
48	1			
51	1			
53	1		1	
55			1	
56			1	
59				1
60				1
61			1	
62				1
63			1	1
64			1	
65			1	
66				1
67				1
70				1
71				1
73				1
75				1
77				1
78				1
79				1
81			1	1
82		1	1	1
83				1
84				1
87		1		
88			1	
89		1	1	1
90				1
91			1	
93		1	1	1
95	1		1	
96		1	1	
97			1	1
98				1
99			1	
100		1	1	1
101				1
102				1
103			1	1
104				1
105				1
106				1
107				1
109	1			
110				1
113	1			
122	1			
127				1
129				1
130				1
131				1
133	1			
134			1	
135			1	1
139			1	
141				1
142				1
143				1
144				1
145				1
146	1	1	1	1
150				1
151				1
156				1
157	1			
TOTAL SCORE	**13**	**11**	**35**	**56**
RATIO	**11,30%**	**9,57%**	**30,43%**	**48,70%**

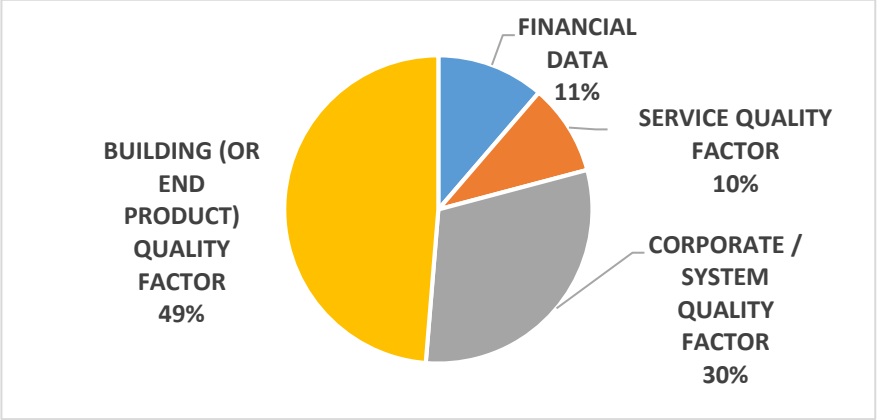

Figure 2.6 Frequency of KPIs in the literature

Overall, in this part, the highest-level KPIs were defined explicitly. On the other hand, the lower-level KPIs founded in literature research were presented, as well. However, since the applicability of the lower-level KPIs may vary from project to project, modifications are needed for each case. Thus, no certain definition or list of low-level KPIs are suggested in this study.

2.2. Metrics / Benchmarks for Quality Perception

As stated in section 2.1, KPI is the answer to measuring WHAT; on the other hand, in this study metric is used as the answer of measuring **WITH RESPECT TO WHAT**. In other words, KPIs are measured according to metrics or benchmarks. Within the scope of this study, literature research was performed to determine which metrics are suitable/ applicable for the KPIs stated in the previous section. Four main metrics / benchmarks were identified as illustrated in ***Table 2.7*** namely, **standards / specifications / codes / technical requirements, financial data, subjective satisfaction and data base**.

Table 2.7 Metrics / Benchmarks

STANDARDS / SPECIFICATIONS / CODES / TECHNICAL REQUIREMENTS		FINANCIAL DATA		SUBJECTIVE SATISFACTION		CORPORATE DATA
FOR BUILDING (OR END PRODUCT) QUALITY	FOR ORGANIZATIONAL / CORPORATIVE / SERVICE	QUALITY COST	FINANCIAL EXPENDITURES	EXPERT SATISFACTION	CLIENT / OWNER SATISFACTION	OTHER DATA EXCEPT FINANCIAL

Initially, the metrics used in the studies that determined the KPIs were analyzed. According to this analysis, the frequencies presented in ***Table 2.8*** were obtained.

Table 2.8 Metrics frequency with respect to KPIs in literature

METRICS / BENCMARKS / KPIs	STANDARDS / SPECIFICATIONS / CODES / TECHNICAL REQUIREMENTS		FINANCIAL DATA BASE		SUBJECTIVE SATISFACTION		CORPORATE DATA BASE	
BUILDING (END PRODUCT)	35	53,8%	2	3,1%	21	32,3%	7	10,8%
SERVICE	3	27,3%	0	0,0%	7	63,6%	1	9,1%
CORPORATE	16	39,0%	1	2,4%	19	46,3%	5	12,2%
FINANCIAL	3	18,8%	10	62,5%	2	12,5%	1	6,3%

For building quality factor (the first row of ***Table 2.8***); standards and subjective satisfaction are the most commonly used ones. Financial data and corporate database are not strongly-used benchmarks for this KPI. Indeed, Khalid and Yeoh (2015, p.2) considers using past data in project-based controls (e.g., end product quality factor) is not a correct approach due to the uniqueness of projects. For corporate quality factor; a similar variance of service quality factors is observed for corporate quality factor (the third row of ***Table 2.8***.). For service quality factor (the second row of ***Table 2.8***); subjective satisfaction (expert, client and owner) is the strongest metric, and the standards and the data base benchmarks are following it, respectively. For financial data factor (the last row of ***Table 2.8***); financial data base is the strongest metric as expected.

According to the findings of ***Table 2.8***, a trend among KPIs & metrics / benchmarks is observed as shown in ***Figure 2.7***. *In this figure,* the thicknesses of the lines represent the strength of the relation.

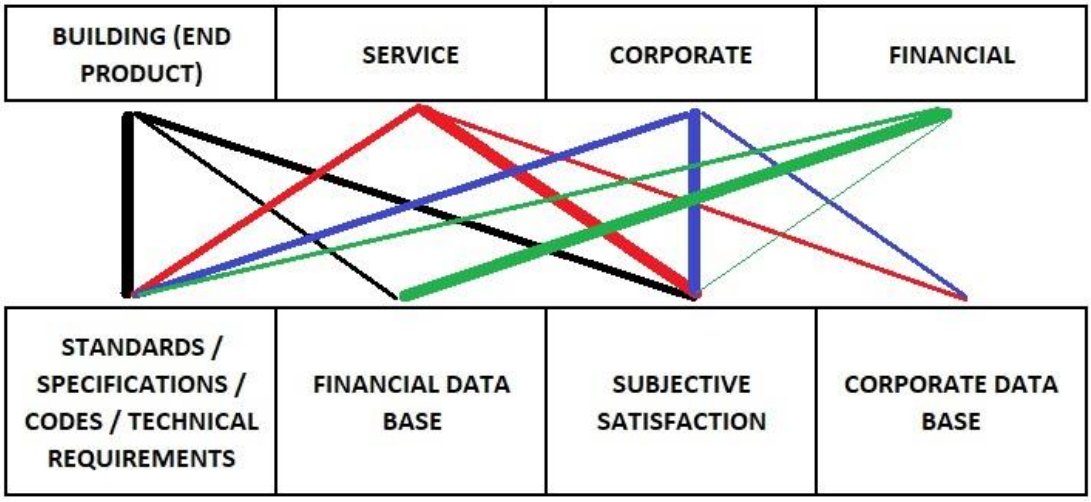

Figure 2.7 Relations between KPIs and metrics in literature

The combination frequency table is summarized in ***Table 2.9***.

Table 2.9 Combination frequency table of metrics / benchmarks

STUDIES	STANDARDS	SUBJECTIVE SATISFACTION	FINANCIAL DATA	CORPORATE DATA	TOTAL	RATIO
1,2,14,18,29,34,37,55, 63,78,91,110,130,139,156	+	+			15	16,7%
44,60,87,93,96,97,98,100		+		+	8	8,9%
144	+	+	+		1	1,1%
45	+	+	+	+	1	1,1%
51			+	+	1	1,1%
8,79	+			+	2	2,2%
16		+	+		1	1,1%
122	+		+		1	1,1%
5,7,48,53,109,131,133,157			+		8	8,9%
61,77				+	2	2,2%
12,13,21,26,41,56,65,82, 88,99,103,113,151		+			13	14,4%
25,30,31,33,38,40,47,59,62 64,66,67,70,71,73,75,81, 84,89,90,95,101,102,104, 105,106,107,127,129,134, 135,137,141,142,143, 145,146	+				37	41,1%

It can be seen that the mostly used metric is standards, followed by subjective satisfaction. Moreover, the mostly preferred two benchmarks together with are

standards and subjective satisfaction. The second mostly preferred two benchmarks together with are subjective satisfaction and corporate data. It is seen that all individual, binary, triple or quadruple possible combinations of metrics are preferred in the literature studies.

Finally, a summary table was prepared including all related studies as seen in ***Table 2.11***. The results of this table were illustrated in the ***Table 2.10***.

Table 2.10 Frequency table for metrics in literature

SEQUENCE # OF STUDY	STANDARDS / SPECIFICATIONS / CODES / TECHNICAL REQUIREMENTS		FINANCIAL DATA		SUBJECTIVE SATISFACTION		CORPORATE DATA
	FOR BUILDING (OR END PRODUCT) QUALITY	FOR ORGANIZATIONAL / CORPORATIVE / SERVICE	QUALITY COST	FINANCIAL EXPENDITURES	EXPERT SATISFACTION	CLIENT / OWNER SATISFACTION	OTHER DATA EXCEPT FINANCIAL
TOTAL SCORE	46	23	12	1	30	19	14
RATIO	31,72%	15,86%	8,28%	0,69%	20,69%	13,10%	9,66%
GROUP RATIO	47,59%		8,97%		33,79%		9,66%

Standards, specifications, codes, technical requirements are used as the metrics for manufacturing, building (end product) or corporative factors in one of two studies. Financial data is another metric taking into financial expenditures or quality costs account used about 9%. Expert or client perception is the benchmark used in ratio as 33% in the studies namely subjective satisfaction. Another metric is corporate data used in literature as the ratio of 9%. According to using frequency of existing studies, *standards / specifications / codes / technical requirements****** and *subjective satisfaction* metrics are the mostly used benchmarks.

(*ASTM, EuroCode, British Standards, Turkish Standards, ISO Standards are some examples for general standards. There are lots of general, official, private and special standards, codes, specifications or requirements generated by related sides. The inclusions of these specifications are not explained in detailed in this study in order not to deviate from the aim of the study.)

Table 2.11 The distribution of metrics or benchmarks in literature studies

METRICS / BENCHMARKS IN RELATED STUDIES (See Appendix C for Numbered Studies)							
SEQUENCE # OF STUDY	STANDARDS / SPECIFICATIONS / CODES / TECHNICAL REQUIREMENTS		FINANCIAL DATA		SUBJECTIVE SATISFACTION		CORPORATE DATA
	FOR BUILDING (OR END PRODUCT) QUALITY	FOR ORGANIZATIONAL / CORPORATIVE / SERVICE	QUALITY COST	FINANCIAL EXPENDITURES	EXPERT SATISFACTION	CLIENT / OWNER SATISFACTION	OTHER DATA EXCEPT FINANCIAL
1	1					1	
2	1					1	
5			1				
7			1				
8	1						1
12					1		
13					1	1	
14	1				1	1	
16				1	1		
18	1	1				1	
21					1		
25		1					
26					1		
29	1	1			1		
30	1	1					
31		1					
33	1	1					
34	1	1			1		
37		1				1	
38		1					
40	1						
41					1		
44					1		1
45	1	1	1		1	1	1
47		1					
48			1				
51			1				1
53			1				
55		1			1	1	
56						1	
59	1						
60					1		1
61							1
62	1						
63	1	1			1	1	
64	1	1					
65					1		
66	1						
67	1						
70	1						
71		1					
73	1						
75	1						
77							1
78	1				1		
79	1						1
81		1					
82					1		
84	1						
87					1	1	1
88					1		
89	1	1					
90	1						
91		1				1	
93					1	1	1
95		1					
96					1		1
97					1		1
98					1		1
99						1	
100					1		1
101	1						
102	1						
103					1		
104	1						
105	1						
106	1						
107	1						
109			1				
110	1					1	
113						1	
122	1		1				
127	1						
129	1						
130	1				1		
131			1				
133			1				
134	1	1					
135		1					
137	1						
139	1	1			1		
141	1						
142	1						
143	1						
144	1	1	1		1	1	
145	1						
146	1						
151					1	1	
156	1				1	1	
157			1				
TOTAL SCORE	46	23	12	1	30	19	14
RATIO	31,72%	15,86%	8,28%	0,69%	20,69%	13,10%	9,66%
GROUP RATIO	47,59%		8,97%		33,79%		9,66%

2.3. Data Collection Methods / Data Sources

Data collection methods or data sources respond to the question of **FROM WHERE** the data needed to be collected. Thus, data is collected by the help of data collection methods, according to metrics to measure KPIs. In accordance, the literature research was done to determine which data collection methods are suitable or applicable for the metrics stated in the previous part. According to this research, data collection methods were grouped under the 4 main categories in the ***Table 2.12*** namely, **testing & inspection results, data base, perception and means.**

Table 2.12 Data collection methods / data sources

TESTING & INSPECTION RESULTS			DATA BASE			PERCEPTION		MEANS	
MATERIAL / SAMPLE TESTING	VISUAL INSPECTION	HIGH-TECH.INCLUDED INSPECTION	CORPORATE ADMINISTRATIVE / MANAGERIAL DATA	FINANCIAL DATA	OTHER DATA BASE	EXPERT OPINION	CLIENT / OWNER OPINION	QUESTIONNARIE / DELPHI / SURVEY	CHECKLISTS / DATA SHEETS

The studies that metrics determined from were analyzed. According to this analysis, the ***Table 2.13*** was obtained.

Table 2.13 Data sources frequency with respect to metrics in literature

DATA COLLECTION METHODS/ SOURCES / METRICS / BENCMARKS		TESTING & INSPECTION RESULTS			RECORDED DATA			PERCEPTION		MEANS	
		MATERIAL / SAMPLE TESTING	VISUAL INSPECTION	HIGH- TECH. INCLUDED INSPECTION	CORPORATE ADMINISTRATIVE / MANAGERIAL DATA	FINANCIAL DATA	OTHER DATA BASE	EXPERT OPINION	CLIENT / OWNER OPINION	QUEST. / DELPHI	CHECKLISTS
STANDARDS	FREQ.	11	15	27	13	5	7	23	17	12	13
	RATIO	7,7%	10,5%	18,9%	9,1%	3,5%	4,9%	16,1%	11,9%	8,4%	9,1%
	GROUP	**53**	**37,1%**		**25**	**17,5%**		**40**	**28,0%**	**25**	**17,5%**
FINANCIAL DATA	FREQ.	0	0	0	0	13	5	3	2	1	0
	RATIO	0,0%	0,0%	0,0%	0,0%	54,2%	20,8%	12,5%	8,3%	4,2%	0,0%
	GROUP	**0**	**0,0%**		**18**	**75,0%**		**5**	**20,8%**	**1**	**4,2%**
SUBJECTIVE SATISFACTION	FREQ.	4	2	6	1	4	10	30	19	15	11
	RATIO	3,9%	2,0%	5,9%	1,0%	3,9%	9,8%	29,4%	18,6%	14,7%	10,8%
	GROUP	**12**	**11,8%**		**15**	**14,7%**		**49**	**48,0%**	**26**	**25,5%**
CORPORATE DATA BASE	FREQ.	1	0	2	0	2	14	9	3	6	1
	RATIO	2,6%	0,0%	5,3%	0,0%	5,3%	36,8%	23,7%	7,9%	15,8%	2,6%
	GROUP	**3**	**7,9%**		**16**	**42,1%**		**12**	**31,6%**	**7**	**18,4%**

For the metric of standard / code / specification / technical requirement; testing & inspection results are shown as major sources. Then the perception of expert, client and owner is shown as the mostly used data collection method after test and inspection results. Finally, usage of recorded data and means were preferred least. For the metric

of financial data; usage of financial data and other corporate data is used strongly as data source. Perception is also another preferred data collection method and means is having less weight. For the benchmark of subjective satisfaction; subjective perception as expert and client, owner opinion was used as expected, mostly. Means also has high usage frequency. Then, recorded data and testing & inspection results are located with a slight usage ratio different with respect to each other. For the benchmark of corporate data; usage of recorded past data and perception are preferred, in sequence with respect to preference ratio. After means usage, testing & inspection results are the less preferred methods. According to this table, a trend among metrics / benchmarks & data collection methods / data sources occurs as in the ***Figure 2.8***. In this figure, the thickness of the lines represents the strength of the relation.

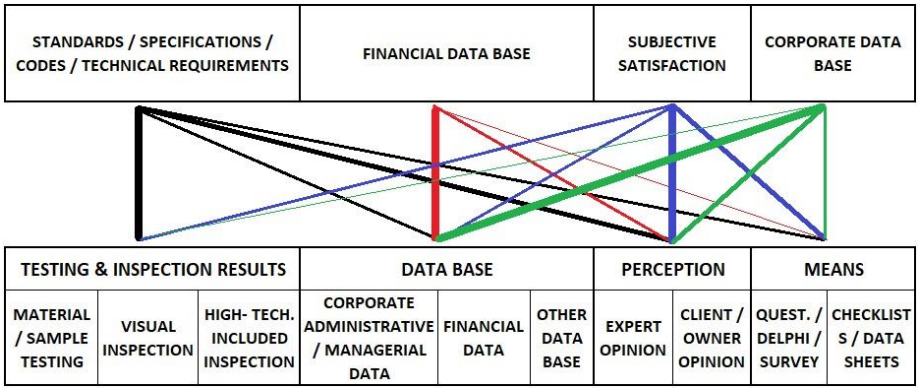

Figure 2.8 Relations between metrics and data sources in literature

Afterwards, the binary, triple and quadruple patterns for usage combinations were regulated in order to follow trends and the ***Table 2.14*** was obtained.

Table 2.14 Combination frequency table of data sources / collection methods

STUDIES	TESTING & INSPECTION RESULTS	ADMINISTRATIVE DATA	FINANCIAL DATA	OTHER DATA OF PROJECT	EXPERT OPINION	CLIENT / OWNER OPINION	QUEST.	CHECKLIST	TOTAL	RATIO
1,8,21,30,41,65,78,89,98,106,127, 130,134,143,145,146	+				+				16	6,3%
1,2,40,95,139,145	+					+			6	2,4%
8,31,41,71,98,130,134,139	+						+		8	3,1%
21,31,40,41,64,71,89,98,105,127 ,130,134	+							+	12	4,7%
30,31,33,89,95,127,139,142,145	+	+							9	3,5%
95,139	+		+						2	0,8%
8,40,77,89,98,134,145	+			+					7	2,7%
30,38,89,127,145		+			+				5	2,0%
25,38,95,139,145		+				+			5	2,0%
25,31,38,135,139		+					+		5	2,0%
31,38,89,127		+						+	4	1,6%
95,139		+	+						2	0,8%
89,145		+		+					2	0,8%
7,16,45,51,157			+	+					5	2,0%
16,45,144			+		+				3	1,2%
45,95,139,144			+			+			4	1,6%
45,139,144			+				+		3	1,2%
144			+					+	1	0,4%
8,16,44,45,60,87,89,93,96, 97,98,100,134,145				+	+				14	5,5%
40,45,87,93,145				+		+			5	2,0%
8,44,45,87,96,98,134				+			+		7	2,7%
40,89,98,134				+				+	4	1,6%
1,13,14,38,45,55,63,87,93, 144,145,151					+	+			12	4,7%
8,14,26,34,38,41,44,45,55,87,96,98,1 03,130,134,137,144,156					+		+		18	7,1%
12,21,29,34,38,41,63,89,98,103,127,1 30,134,144					+			+	14	5,5%
95,139	+	+	+						2	0,8%
89,145	+	+		+					2	0,8%
30,89,127,145	+	+			+				4	1,6%
95,139,145	+	+				+			3	1,2%
31,139	+	+					+		2	0,8%
31,89,127	+	+						+	1	0,4%
95,139	+		+			+			2	0,8%
139	+		+				+		1	0,4%
8,89,98,134,145	+			+	+				5	2,0%
8,98,134	+						+		3	1,2%
40,89,98,134	+							+	4	1,6%
40,145	+			+		+			2	0,8%
1,145	+				+	+			2	0,8%
8,41,98,130,134	+						+		5	2,0%
41,98,130,134	+							+	4	1,6%
139	+					+		+	1	0,4%
31,41,71,98,130,134	+						+	+	6	2,4%
95,139		+	+			+			2	0,8%
139		+	+				+		1	0,4%
89,145		+		+	+				2	0,8%
145		+		+		+			1	0,4%
89		+		+				+	1	0,4%
38,145		+			+	+			2	0,8%
38		+			+		+		1	0,4%
38,89,127		+			+			+	3	1,2%
16,45			+	+	+				2	0,8%
139			+	+			+		1	0,4%
45			+	+		+			1	0,4%
45,87,93,145				+	+	+			4	1,6%
8,44,45,87,98,98,134				+	+		+		7	2,7%
89,98,134				+	+			+	3	1,2%
95,139	+	+	+			+			2	0,8%
139	+	+	+				+		1	0,4%
89	+	+		+				+	1	0,4%
89,127	+	+			+			+	2	0,8%
139	+	+				+	+		1	0,4%
139		+	+			+	+		1	0,4%
89		+		+	+			+	1	0,4%
145		+		+	+	+			1	0,4%
38		+			+	+	+		1	0,4%
38		+			+	+		+	1	0,4%
45			+	+	+	+			1	0,4%
45			+	+	+		+		1	0,4%
45,87				+	+	+	+		2	0,8%
38,144					+	+	+	+	2	0,8%
139	+	+	+			+	+		1	0,4%
89	+	+		+	+			+	1	0,4%
145	+	+		+	+	+			1	0,4%
98,134	+			+	+		+	+	2	0,8%
45			+	+	+	+	+		1	0,4%

According to ***Table 2.14***:

- **For binary combinations; the testing & inspection results and expert opinions are two coherent data sources used together, widely.** Testing + administrative data, testing + other data, testing + client opinion combinations are used in average frequency. Testing results & financial data are preferred together in less study. Administrative data + expert opinion and administrative data + client opinion are mostly used combinations contrary to administrative data + financial data and administrative data + other project data. Financial data + other data of project, financial data + expert opinion and financial data + client opinion combinations are preferred in close frequency. **Other data of project + expert opinion is other mostly used source like testing + expert opinion.**
- When moving on the **triple combinations**; **testing results + other data + expert opinion** and **other data + expert opinion + client opinion** are the two mostly preferred ones. Following them, testing + administrative data + expert opinion and testing + administrative data + client opinion are the other mostly used combinations. The 4 combinations namely, testing + financial data + other data, testing + financial data + expert opinion, administrative data + financial data + other data, administrative data + financial data + expert opinion are not used in studies together with.
- The only used **quadruple combination** is **testing +administrative data +financial data +client opinion**.
- For the **quinary combinations**; there are 3 possibilities to prefer which are testing + administrative data +financial data+ other data+ expert opinion, testing + administrative data +financial data+ other data+ client opinion and testing + financial data+ other data+ expert opinion + client opinion. However, none of them are used together in literature.

Finally, a summary table was prepared including all related studies as seen in ***Table 2.16.*** The results of this table were summarized as in the ***Table 2.15***. When these results

are analyzed; **testing & inspection results** are preferred in the literature about **35%**,**data base usage** is used as the ratio of **%28**,**and perception** is used close to ratio of **%37** in related studies as data collection methods.

Table 2.15 Frequency table for data sources in literature

DATA COLLECTION METHODS / SOURCES	TESTING & INSPECTION RESULTS			RECORDED DATA			PERCEPTION	
	MATERIAL / SAMPLE TESTING	VISUAL INSPECTION	HIGH-TECH.INCLUDED INSPECTION	CORPORATE ADMINISTRATIVE / MANAGERIAL DATA	FINANCIAL DATA	OTHER DATA OF PROJECT	EXPERT OPINION	CLIENT / OWNER OPINION
FREQUENCY IN ANALYZED LITERATURE STUDIES	13	15	32	13	15	21	41	24
RATIO	7,47%	8,62%	18,39%	7,47%	8,62%	12,07%	23,56%	13,79%
GROUP RATIO	34,48%			28,16%			37,36%	

The lower-level metrics or the details of testing & inspection benchmark may be seen in the ***Table 2.17***. Some low-level of metrics:

- Financial data; quality cost (cost of loss, appraisal & prevention) accounting,
- Corporate; administrative, managerial data, hierarchy breakdown structure etc.
- Other data; schedule, cost, contract, site, locational, regional information etc.

Table 2.16 The distribution of data sources in literature studies

DATA COLLECTION METHODS / DATA SOURCES IN RELATED STUDIES (See Appendix C for Numbered Studies)										
SEQUENCE # OF STUDY	TESTING & INSPECTION RESULTS			DATA BASE			PERCEPTION		MEANS	
	MATERIAL / SAMPLE TESTING	VISUAL INSPECTION	HIGH-TECH.INCLUDED INSPECTION	CORPORATE ADMINISTRATIVE / MANAGERIAL DATA	FINANCIAL DATA	OTHER DATA BASE	EXPERT OPINION	CLIENT / OWNER OPINION	QUESTIONNARIE / DELPHI / SURVEY	CHECKLISTS / DATA SHEETS
1	1		1				1	1		
2	1							1		
5					1					
7					1	1				
8	1					1	1		1	
12							1			1
13							1	1		
14							1	1	1	
15	1									
16					1	1	1			
18								1		1
21			1				1			1
25				1				1	1	
26							1		1	
29							1			1
30	1	1		1			1			
31		1		1					1	1
33		1		1						
34							1		1	1
37								1		
38				1			1	1	1	1
40		1				1		1		1
41	1						1		1	1
44						1	1		1	
45					1	1	1	1	1	
47				1						
48					1					
51					1	1				
53					1					
55							1	1	1	
56								1	1	1
59			1							
60						1	1			
61						1				
62			1							
63							1	1		1
64			1							1
65			1				1			
66			1							
67			1							
70			1							
71			1						1	1
73			1							
75			1							
77			1			1				
78			1				1			
79						1				
81			1							
82							1			
83			1							
84			1							
87						1	1	1	1	
88							1			
89	1	1	1	1		1	1			1
90			1							
91								1		
93						1	1	1		
95		1		1	1			1		
96						1	1		1	
97						1	1			
98			1			1	1		1	1
99								1	1	
100						1	1			
101			1							
102			1							
103							1		1	1
104			1							
105			1							1
106		1					1			
107			1							
109					1					
110								1		
113								1		
122					1					
127	1	1	1	1			1			1
129			1							
130	1	1	1				1		1	1
131					1					
133					1					
134		1				1	1		1	1
135				1					1	
136									1	
137							1		1	
139	1	1		1	1			1		
141			1							
142		1	1	1						
143	1	1	1				1		1	1
144					1		1	1		
145	1	1		1		1	1	1		
146	1	1	1				1			
150										
151							1	1	1	
156							1			
157					1	1				
TOTAL SCORE	13	15	32	13	15	21	41	24	25	21
RATIO	5,91%	6,82%	14,55%	5,91%	6,82%	9,55%	18,64%	10,91%	11,36%	9,55%
GROUP RATIO	27,27%			22,27%			29,55%		20,91%	

Table 2.17 Testing & inspection methods

<table>
<tr><th colspan="4">Testing & Inspection Methods</th></tr>
<tr><th>Visual Or Optical Inspection</th><th colspan="3">Material Testing</th></tr>
<tr><td rowspan="19"></td><th>Permeability</th><th>High Technology Included</th><th>Strength Estimation</th></tr>
<tr><td rowspan="18">-Water Permeability
-Air Permeability
-Absorption Capacity
-Sorptivity
-Chloride Diffusion
-Rapid Chloride -Permeability
-Initial Surface -Absorbtion</td><td rowspan="18">-Resonant Frequency
-Ultrasonic Pulse Velocity
-Sonreb
-Infrared And Thermal
-Magnetic Particle
-Electromagnetic
-Radiographic
-Acoustic Emission
-Video Camera
-Barcoding
-Gprs
-Laser Scanning
-Sensoring</td><td>Destructive (Coring)</td></tr>
<tr><td>-Strain Gauge
-Piezoelectric
-Hydraulic
-Pneumatic
-Vibrating Wire
-Capacitive Load Cell</td></tr>
<tr><td>Partial Destructive</td></tr>
<tr><td>-Pull Out (Internal Fracture, Cast-In(Capo), Drilled)
-Pull Off
-Break Off
-Penetration Resistance</td></tr>
<tr><td>Non- Destructive</td></tr>
<tr><td>-Indentation (Brinell)
-Einback
Rebound (Schmidt) Hammer
-Temperature Measurement</td></tr>
<tr><td>Conceptual/ Theoretical</td></tr>
<tr><td>-Maturity</td></tr>
</table>

2.4. Data Analysis Methods

Data analysis methods respond **HOW** to analyze collected data. Thus, data collected by the help of data collection methods according to metrics are analyzed with data analysis methods to measure KPIs. Literature was explored to determine which data analysis methods are suitable or applicable for the collected data according to metrics stated in the previous part. According to this research, data analysis methods were grouped under the 4 main categories in the ***Table 2.18*** namely, **perceptive methods, software-based methods, conceptual methods, mathematical & statistical methods.**

Table 2.18 Data analysis methods

PERCEPTIVE		SOFTWARE BASED METHODS					CONCEPTUAL METHODS									MATHEMATICAL / STATISTICAL METHODS					
QUESTIONNARIE / DELPHI / SURVEY	CHECKLISTS / DATA SHEETS	SOFTWARE / CAD / MODELLING / SIMULATION / SCENARIO / MAPPING	EXPERT'S CHOICE	PROFORMA	SPSS 24	BIM BASED MODELLING	ONTOLOGY BASED SEMANTIC MODELLING	FUZZY	MULTI - ATTRIBUTE UTILITY THEORY (MAUT)	ANALYTICAL HIERARCHY PROCESS (AHP) / ANALYTICAL NETWORK PROCESS (ANP)	PAIRWISE COMPARISON (SAATY'S,)	ADDITIVE UTILITY MODEL	HEURISTIC / META- HEAURISTIC METHODS	VALUE FUNCTIONS	PARTITIONING METHOD	NEURAL NETWORK ANALYSIS	LINEER INTEGER PROGRAMMING	REGRESSIONAL ANALYSIS	DESCRIPTIVE ANALYSIS (FRUQENCY ANALYSIS, MEAN, STANDARD DEVIATION, VARIANCE)	BIVARIATE ANALYSIS (SPEARMAN RANK - ORDER CORRELATION)	BASIC MATHEMATICAL METHODS	OTHER STATISTICAL METHODS (FLOW CHARTS, HISTOGRAMS, VENN DIAGRAMS, CAUSE - EFFECT DIAGRAMS, PARETO DIAGRAMS, GRAPHS, CONTROL CHARTS, SCATTER DIAGRAMS)

The studies that data collection methods determined from were analyzed. According to this analysis, the ***Table 2.19*** was obtained.

Table 2.19 Data analysis frequency with respect to data sources in literature

DATA COLLECTION METHODS/ SOURCES \ DATA ANALYSIS METHODS		PERCEPTIVE METHODS		SOFTWARE-BASED METHODS		CONCEPTUAL METHODS		MATHEMATICAL / STATISTICAL METHODS	
		FREQ.	RATIO	FREQ.	RATIO	FREQ.	RATIO	FREQ.	RATIO
TESTING & INSPECTION RES.	MATERIAL / SAMPLE TESTING	7	38,9%	2	11,1%	2	11,1%	7	38,9%
	VISUAL INSPECTION	7	38,9%	3	16,7%	0	0,0%	8	44,4%
	HIGH- TECH. INCLUDED INSPECTION	9	17,3%	20	38,5%	3	5,8%	20	38,5%
	GROUP RATIO	**23**	**26,1%**	**25**	**28,4%**	**5**	**5,7%**	**35**	**39,8%**
RECORDED DATA	ADMINISTRATIVE DATA	6	40,0%	2	13,3%	0	0,0%	7	46,7%
	FINANCIAL DATA	1	5,6%	2	11,1%	2	11,1%	13	72,2%
	OTHER DATA BASE	10	29,4%	1	2,9%	3	8,8%	20	58,8%
	GROUP RATIO	**17**	**25,4%**	**5**	**7,5%**	**5**	**7,5%**	**40**	**59,7%**
PERCEPTION	EXPERT OPINION	25	37,9%	5	7,6%	11	16,7%	25	37,9%
	CLIENT / OWNER OPINION	11	35,5%	1	3,2%	4	12,9%	15	48,4%
	GROUP RATIO	**36**	**37,1%**	**6**	**6,2%**	**15**	**15,5%**	**40**	**41,2%**

Table 2.19 demonstrates that for all data collection methods, **mathematical & statistical data analysis methods** are the mostly preferred ones. For the data source of testing & inspection results, software-based and perceptive data analysis methods are preferred mostly after mathematical and statistical methods. For the data source of recorded data; perceptive methods are used mostly after mathematical and statistical methods. Software-based and conceptual methods are used weakly. For the data source of perception; perceptive methods are used mostly after mathematical and statistical methods. Software-based and conceptual methods are used weakly as in the case of recorded data. According to ***Table 2.19***, a trend among data collection methods / data sources & data analysis methods occurs as in the following ***Figure 2.9***. The thickness of the lines represents the strength of the relation.

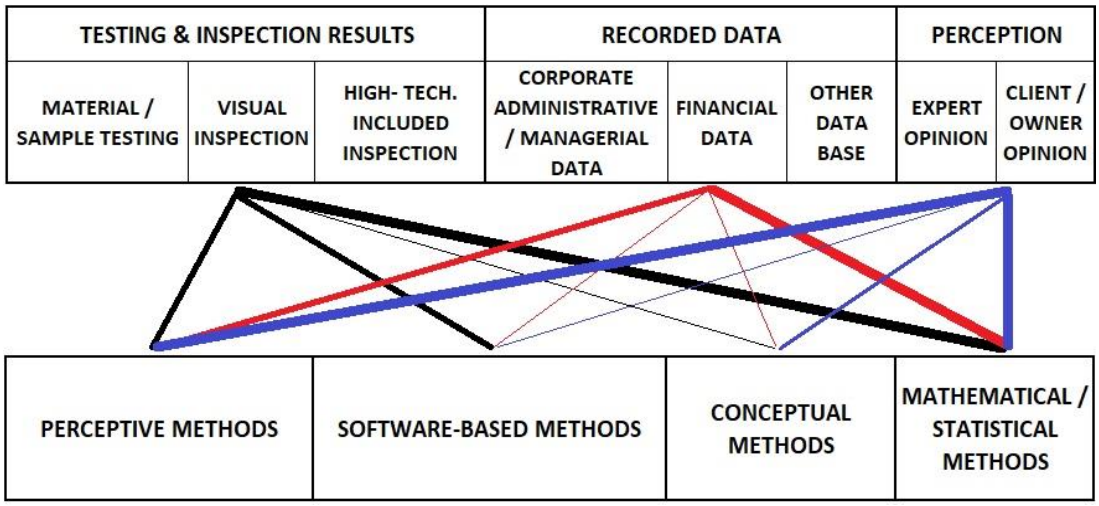

Figure 2.9 Relations between data sources and data analysis methods in literature

Afterwards, the binary, triple and quadruple patterns were regulated in order to follow trends and the ***Table 2.20*** was obtained.

Table 2.20 Combination frequency table of data analysis methods

STUDIES	PERCEPTIVE	SOFTWARE BASED METHODS	CONCEPTUAL METHODS	MATHEMATICAL / STATISTICAL METHODS	TOTAL	RATIO
21,127,130,136	+	+			4	5,3%
8,12,14,44,63,136,137,151	+		+		8	10,5%
8,12,14,18,25,29,31,34,38,40, 44,45,87,89,96,98,100, 130,134,137,143,151	+			+	22	28,9%
13,70,107,136		+	+		4	5,3%
13,59,62,66,67,70,75,84,90, 102,104,107,129,130,131, 133,142,156,157		+		+	19	25,0%
5,8,12,13,14,15,44,65,70, 79,107,109,137,151			+	+	14	18,4%
136	+	+	+		1	1,3%
130	+	+		+	1	1,3%
13,70,107		+	+	+	3	3,9%

According to ***Table 2.20,*** for binary combinations; perceptive and mathematical / statistical methods are two coherent data analysis methods according to usage frequency in scanned studies. Both software-based and conceptual methods with mathematical & statistical, combinations are also used widely. When moving on the triple combinations; all possible combinations are used in studies in lower frequency. No quadruple combination is not used in scanned studies.

The final frequency results may be seen in the ***Table 2.21***.It can be observed that p**erceptive methods** are preferred in the literature about **22%**, **software-based methods** are used as the ratio of **14%**, **conceptual methods** are used close to ratio of **14%, mathematical & statistical methods** is about **50%** in related studies as data analysis methods.

Table 2.21 Frequency table for data analysis methods in literature

SEQUENCE # OF STUDY	PERCEPTIVE		SOFTWARE BASED METHODS					CONCEPTUAL METHODS									MATHEMATICAL / STATISTICAL METHODS					
	QUESTIONNARIE / DELPHI / SURVEY	CHECKLISTS / DATA SHEETS	SOFTWARE / CAD / MODELLING / SIMULATION / SCENARIO / MAPPING	EXPERT'S CHOICE	PROFORMA	SPSS 24	BIM BASED MODELLING	ONTOLOGY BASED SEMANTIC MODELLING	FUZZY	MULTI - ATTRIBUTE UTILITY THEORY (MAUT)	ANALYTICAL HIERARCHY PROCESS (AHP) / ANALYTICAL NETWORK PROCESS (ANP)	PAIRWISE COMPARISON (SAATY'S,)	ADDITIVE UTILITY MODEL	HEURISTIC / META- HEAURISTIC METHODS	VALUE FUNCTIONS	PARTITIONING METHOD	NEURAL NETWORK ANALYSIS	LINEER INTEGER PROGRAMMING	REGRESSIONAL ANALYSIS	DESCRIPTIVE ANALYSIS (FRUQENCY ANALYSIS, MEAN, STANDARD DEVIATION, VARIANCE)	BIVARIATE ANALYSIS (SPEARMAN RANK - ORDER CORRELATION)	BASIC MATHEMATICAL METHODS	OTHER STATISTICAL METHODS (FLOW CHARTS, HISTOGRAMS, VENN DIAGRAMS, CAUSE - EFFECT DIAGRAMS, PARETO DIAGRAMS, GRAPHS, CONTROL CHARTS, SCATTER DIAGRAMS)
TOTAL SCORE	25	21	23	2	1	1	3	2	9	1	8	3	1	1	1	1	1	1	1	12	2	40	47
RATIO	12,1%	10,1%	11,1%	1,0%	0,5%	0,5%	1,4%	1,0%	4,3%	0,5%	3,9%	1,4%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	5,8%	1,0%	19,3%	22,7%
GROUP RATIO	22,2%		14,5%					13,5%									49,8%						

The frequency distribution of data analysis methods in the scanned literature studies may be seen in the ***Table 2.22***.

Table 2.22 The distribution of data analysis methods in literature studies

DATA ANALYSIS METHODS IN RELATED STUDIES (See Appendix C for Numbered Studies)																									
SEQUENCE # OF STUDY	PERCEPTIVE		SOFTWARE BASED METHODS					CONCEPTUAL METHODS											MATHEMATICAL / STATISTICAL METHODS						
	QUESTIONNARIE / DELPHI / SURVEY	CHECKLISTS / DATA SHEETS	SOFTWARE / CAD / MODELLING / SIMULATION / SCENARIO / MAPPING	EXPERT'S CHOICE	PROFORMA	SPSS 24	BIM BASED MODELLING	ONTOLOGY BASED SEMANTIC MODELLING	FUZZY	MULTI - ATTRIBUTE UTILITY THEORY (MAUT)	ANALYTICAL HIERARCHY PROCESS (AHP) / ANALYTICAL NETWORK PROCESS (ANP)	PAIRWISE COMPARISON (SAATY'S)	ADDITIVE UTILITY MODEL	HEURISTIC / META- HEAURISTIC METHODS	VALUE FUNCTIONS	PARTITIONING METHOD	NEURAL NETWORK ANALYSIS	LINEER INTEGER PROGRAMMING	REGRESSIONAL ANALYSIS	DESCRIPTIVE ANALYSIS (FRUQENCY ANALYSIS, MEAN, STANDARD DEVIATION, VARIANCE)	BIVARIATE ANALYSIS (SPEARMAN RANK - ORDER CORRELATION)	BASIC MATHEMATICAL METHODS	OTHER STATISTICAL METHODS (FLOW CHARTS, HISTOGRAMS, VENN DIAGRAMS, CAUSE - EFFECT DIAGRAMS, PARETO DIAGRAMS, GRAPHS, CONTROL CHARTS, SCATTER DIAGRAMS)
1																						1	1
2																						1	
5																1						1	1
7																						1	
8	1								1		1											1	1
12		1							1		1											1	1
13				1							1	1						1		1		1	1
14	1									1			1		1							1	1
15									1		1											1	
16																						1	
18		1																				1	
21		1	1																				
25	1																					1	1
26	1																						
29		1																					1
31	1	1																					1
34	1	1																					1
38	1	1																					1
40		1																					1
41	1	1																					
44	1													1								1	1
45	1																						1
47																				1			1
48																							1
51																				1			1
53																						1	1
55	1																						
56	1	1																					
59			1																			1	1
60																						1	
61																						1	
62			1																				1
63		1							1														
64		1																					
65									1											1			1
66			1																				1
67			1																				1
70			1					1															1
71	1	1																					
73			1																				
75			1																	1			1
77																						1	
79																	1			1			1
81			1																				
82									1														
84			1																			1	1
87	1																					1	
88									1		1												
89		1																				1	
90			1																	1			1
93																						1	1
95																				1			1
96	1																					1	
97																						1	
98	1	1																				1	
100	1																					1	
101			1																				
102			1																				1
103	1	1																					
104			1				1															1	1
105		1																					
107			1					1															1
109									1													1	1
110																						1	1
113																						1	1
122																						1	1
127		1					1																
129			1																				1
130	1	1	1																	1	1	1	1
131			1																			1	1
133			1																				1
134	1	1																	1	1		1	1
135	1																						
136	1			1	1						1	1											
137	1										1	1										1	1
141			1																				
142			1				1																1
143	1	1																				1	1
150																						1	
151	1								1		1									1		1	
156			1																			1	1
157			1			1														1	1	1	1
TOTAL SCORE	25	21	23	2	1	1	3	2	9	1	8	3	1	1	1	1	1	1	1	12	2	40	47
RATIO	12,1%	10,1%	11,1%	1,0%	0,5%	0,5%	1,4%	1,0%	4,3%	0,5%	3,9%	1,4%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	5,8%	1,0%	19,3%	22,7%
GROUP RATIO	22,2%		14,5%					13,5%											49,8%				

2.5. Quality Tracking & Evaluation Systems

After introducing the analysis of scanned research studies related with the main components of system, the final component namely quality tracking system is analyzed. This final tracking system gives the **OUTPUT** of the framework. Thus, data gathered by the help of data collection methods according to metrics are analyzed with data analysis methods to measure KPIs and an output is given by a comprehensive quality tracking system. In this part, the systems used in literature studies to track quality is analyzed such as; quality tracking, assessing systems, quality quantification and component weighting systems.

According to this research, quality tracking systems were grouped under the four main categories as shown in ***Table 2.23*** namely, **quality integrated EVM**, **widely-accepted generic systems, systems based on standards and specifically developed systems.**

Table 2.23 Quality tracking & evaluation systems

Q-EVM	WIDELY ACCEPTED GENERIC SYSTEMS						SYSTEMS BASED ON STANDARDS						SPECIFICALLY DEVELOPED SYSTEMS																
QUALITY / PERFORMANCE INCLUDED EVM	QUALITY FUNCTION DEPLOYMENT / QUALITY MATRICES	TOTAL QUALITY MANAGEMENT	LEAN PRODUCTION	SIX SIGMA	BEST VALUE	SOFTWARE / CAD / BIM BASED SYSTEMS	ISO QUALITY STANDARDS (ISO 9000,14000)	EFQM	MALCOLM BALRIDGE AWARD	CONQUAS	PASS	QLASSIC	FUZZY AHP BASED CONSTRUCTION ENGINEERING PROJECT QUALITY	SERVQUAL	QUALITY GATES	CRITICAL INCIDENT TECHNIQUE	QUALITY INSPECTION AND DEFECT MANAGEMENT SYSTEM (QIDMS)	PROJECT PERFORMANCE MONITORING SYSTEM (PPMS)	WEB BASED SYSTEM FOR WORK PERFORMANCE ANALYSIS (WPAS)	PROJECT MANAGEMENT QUALITY COST SYSTEM (PROMQACS)	QUALITY PERFORMANCE TRACKING SYSTEM (QPTS)	QUALITY PERFORMANCE MANAGEMENT SYSTEM (QPMS)	AUTOMATED PROCESSING OF CONSTRUCTION SPECIFICATIONS	CONSTRUCTION QUALITY INTEGRATION SYSTEM (CQIS)	QUALITY MANAGEMENT INFORMATION SYSTEM (QMIS)	QUALICON	QUALITY INFRASTRUCTURE SYSTEM

The studies that data analysis methods determined from were analyzed. According to this analysis, the ***Table 2.24*** was obtained.

Table 2.24 Quality evaluation methods frequency with respect to data analysis methods in literature

DATA ANALYSIS METHODS \ QUALITY TRACKING SYSTEMS		Q-EVM	WIDELY ACCEPTED GENERIC SYSTEMS	SYSTEMS BASED ON STANDARDS	SPECIFICALLY DEVELOPED SYSTEMS
PERCEPTIVE METHODS	FREQ.	5	12	8	7
	RATIO	**15,6%**	**37,5%**	**25,0%**	**21,9%**
SOFTWARE-BASED METHODS	FREQ.	4	22	2	6
	RATIO	**11,8%**	**64,7%**	**5,9%**	**17,6%**
CONCEPTUAL METHODS	FREQ.	5	5	1	4
	RATIO	**33,3%**	**33,3%**	**6,7%**	**26,7%**
MATHEMATICAL / STATISTICAL METHODS	FREQ.	16	28	10	12
	RATIO	**24,2%**	**42,4%**	**15,2%**	**18,2%**

When these results are analyzed; for any kind of data analysis methods, it is precisely seen that **generic systems** are the mostly preferred ones. For the analysis methods of perceptive methods, systems based on standards and specifically developed are preferred with lesser frequency than generic systems. For the analysis methods of software-based methods; the majority of the studies utilized widely-accepted generic systems. For the analysis methods of conceptual methods; the Q-EVM system is strongly used, with the same ratio of generic systems. For the analysis methods of mathematical & statistical methods; the Q-EVM is preferred right after the general systems.

According to ***Table 2.24***, a trend among data analysis methods and quality track systems occurs as in the ***Figure 2.10***. The thickness of the lines represents the strength of the relation.

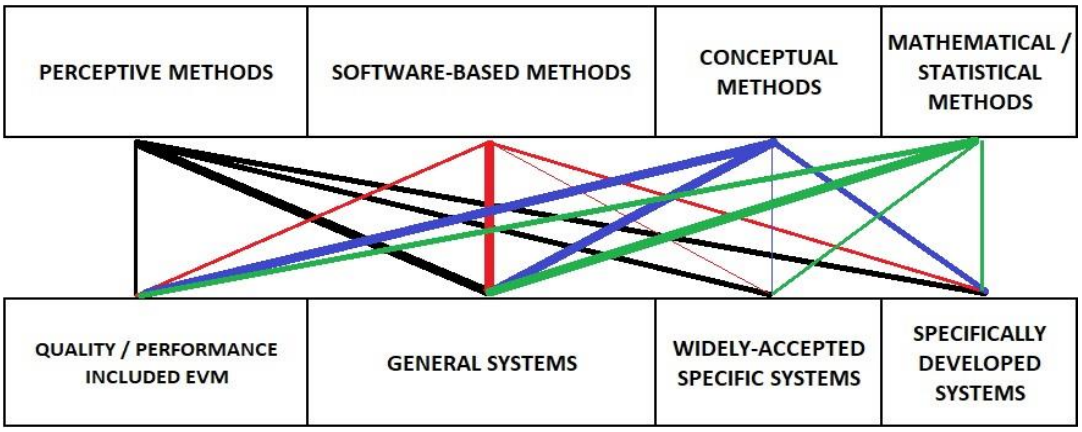

Figure 2.10 Relations between data analysis methods and quality evaluation systems in literature

Afterwards, the binary, triple and quadruple patterns were regulated in order to follow trends and the ***Table 2.25*** was obtained.

Table 2.25 Combination frequency table of quality evaluation systems

STUDIES	QUALITY OR PERFORMANCE INCLUDED EVM	GENERAL SYSTEMS	WIDELY-ACCEPTED SPECIFIC SYSTEMS	SPECIFICALLY DEVELOPED SYSTEMS	TOTAL	RATIO
131,135,157	+	+			3	12,0%
130	+		+		1	4,0%
13,18,25,33,47,99		+	+		6	24,0%
13,18,47,70,73,98,107,133		+		+	8	32,0%
13,18,47,64			+	+	4	16,0%
13,18,47		+	+	+	3	12,0%

According to ***Table 2.25***, for binary combinations; quality **included EVM systems are used with generic systems mostly and with widely-accepted specific systems in one study.** Generic systems are used with widely-accepted specific systems and specifically developed systems in great frequency. Widely accepted-systems and specifically developed systems were used together popularly, as well. All possible binary combinations were used in literature studies except quality included EVM and

specifically developed system combination. When moving on the triple combinations; general systems, widely-accepted specific systems and specifically developed systems were used together. Possible two combinations with Q-EVM are lack in studies.

The final frequency results may be seen as in the ***Table 2.26***. When these results are analyzed; **quality or performance included EVM studies** were preferred in the literature about **16%**, **widely-accepted generic systems** were used as the ratio of **46%**, **systems based on standards** were used close to ratio of **13%, specifically developed systems** is about **25%** in related studies as quality tracking systems.

Table 2.26 Frequency table for quality evaluation systems in literature

QUALITY TRACKING METHODS	Q-EVM	WIDELY ACCEPTED GENERIC SYSTEMS						SYSTEMS BASED ON STANDARDS						SPECIFICALLY DEVELOPED SYSTEMS														
	QUALITY / PERFORMANCE INCLUDED EVM	QUALITY FUNCTION DEPLOYMENT / QUALITY MATRICES	TOTAL QUALITY MANAGEMENT	LEAN PRODUCTION	SIX SIGMA	BEST VALUE	SOFTWARE / CAD / BIM BASED SYSTEMS	ISO QUALITY STANDARDS (ISO 9000,14000)	EFQM	MALCOLM BALRIDGE AWARD	CONQUAS	PASS	QLASSIC	FUZZY AHP BASED CONSTRUCTION ENGINEERING PROJECT QUALITY	SERVQUAL	QUALITY GATES	CRITICAL INCIDENT TECHNIQUE	QUALITY INSPECTION AND DEFECT MANAGEMENT SYSTEM (QIDMS)	PROJECT PERFORMANCE MONITORING SYSTEM (PPMS)	WEB BASED SYSTEM FOR WORK PERFORMANCE ANALYSIS (WPAS)	PROJECT MANAGEMENT QUALITY COST SYSTEM (PROMQACS)	QUALITY PERFORMANCE TRACKING SYSTEM (QPTS)	QUALITY PERFORMANCE MANAGEMENT SYSTEM (QPMS)	AUTOMATED PROCESSING OF CONSTRUCTION SPECIFICATIONS	CONSTRUCTION QUALITY INTEGRATION SYSTEM (CQIS)	QUALITY MANAGEMENT INFORMATION SYSTEM (QMIS)	QUALICON	QUALITY INFRASTRUCTURE SYSTEM
TOTAL SCORE	17	10	11	1	3	1	24	6	1	3	2	1	1	1	2	2	1	3	1	1	2	3	3	2	1	2	2	2
RATIO	15,60%	9,17%	10,09%	0,92%	2,75%	0,92%	22,02%	5,50%	0,92%	2,75%	1,83%	0,92%	0,92%	0,92%	1,83%	1,83%	0,92%	2,75%	0,92%	0,92%	1,83%	2,75%	2,75%	1,83%	0,92%	1,83%	1,83%	1,83%
GROUP RATIO	15,60%	45,87%						12,84%						25,69%														

The frequency distribution of in the scanned literature as in the ***Table 2.27***.

Among these systems, Quality or Performance included Earned Value Methods and CONQUAS are the 2 outstanding systematical and international systems that can be easily adapted and applied on construction assessment.

Table 2.27 The distribution of quality evaluation systems in literature studies

QUALITY TRACKING SYSTEMS (See Appendix C for Numbered Studies)																														
	Q-EVM	WIDELY ACCEPTED GENERIC SYSTEMS						SYSTEMS BASED ON STANDARDS						SPECIFICALLY DEVELOPED SYSTEMS																
SEQUENCE # OF STUDY	QUALITY / PERFORMANCE INCLUDED EVM	QUALITY FUNCTION DEPLOYMENT / QUALITY MATRICES	TOTAL QUALITY MANAGEMENT	LEAN PRODUCTION	SIX SIGMA	BEST VALUE	SOFTWARE / CAD / BIM BASED SYSTEMS	ISO QUALITY STANDARDS (ISO 9000,14000)	EFQM	MALCOLM BALRIDGE AWARD	CONQUAS	PASS	QLASSIC	FUZZY AHP BASED CONSTRUCTION ENGINEERING PROJECT QUALITY	SERVQUAL	QUALITY GATES	CRITICAL INCIDENT TECHNIQUE	QUALITY INSPECTION AND DEFECT MANAGEMENT SYSTEM (QIDMS)	PROJECT PERFORMANCE MONITORING SYSTEM (PPMS)	WEB BASED SYSTEM FOR WORK PERFORMANCE ANALYSIS (WPAS)	PROJECT MANAGEMENT QUALITY COST SYSTEM (PROMQACS)	QUALITY PERFORMANCE TRACKING SYSTEM (QPTS)	QUALITY PERFORMANCE MANAGEMENT SYSTEM (QPMS)	AUTOMATED PROCESSING OF CONSTRUCTION SPECIFICATIONS	CONSTRUCTION QUALITY INTEGRATION SYSTEM (CQIS)	QUALITY MANAGEMENT INFORMATION SYSTEM (QMIS)	QUALICON	QUALITY INFRASTRUCTURE SYSTEM
1	1																													
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5	1																													
7	1																													
8	1																													
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13		1						1							1															
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25		1	1							1																				
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47			1	1	1	1										1														
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156	1																													
157	1						1																							
158									1																					
TOTAL SCORE	17	10	11	1	3	1	24	6	1	3	2	1	1	1	2	2	1	3	1	1	2	3	3	2	1	2	2	2		
RATIO	15,60%	9,17%	10,09%	0,92%	2,75%	0,92%	22,02%	5,50%	0,92%	2,75%	1,83%	0,92%	0,92%	0,92%	1,83%	1,83%	0,92%	2,75%	0,92%	0,92%	1,83%	2,75%	2,75%	1,83%	0,92%	1,83%	1,83%	1,83%		
GROUP RATIO	15,60%	45,87%						12,84%						25,69%																

2.5.1. CONQUAS: The BCA (Building and Construction Authority of Singapore) Construction Quality Assessment System

According to CONQUAS manual (the BCA, 9th Ed., 2017); CONQUAS is a standardized construction quality assessment system being a part of Building and Construction Authority of Singapore since 1989. This system operates by keeping the expectation of end users on workmanship quality. Except Singapore, CONQUAS is a registered trademark in Malaysia, China, Hong Kong SAR, United Kingdom, Australia, South Africa and India. In other words, it is a widely used quality assessment system.

CONQUAS scores constructions in the three main categories namely; Structural, Architectural, and Mechanical & Electrical Works. These categories are further divided into sub-components for assessment. The sum of scoring of these 3 components gives the CONQUAS overall score for the project.

The labor quality is assessed through site inspection of licensed CONQUAS experts throughout construction stage for Structural and M&E works and after completion for Architectural works. Material tests and functionality test for some selected services or installations are also done to support the site inspections. Some underground works such as; excavation, piling, leaning are not tracked in this system.

CONQUAS scores the numerous selected samples with respect to size of building, since the scoring to all building is considered as impractical. Scoring is done once, reworks after first assessment are not rescored due to the objective of this system which is "doing things right the first time".

The weightage system is compromised of the cost proportions of work components in the different buildings and aesthetic consideration. The scores for components may be seen in ***Table 2.28***. Further information related to sub-component scores and details of method of scoring etc. may be seen in CONQUAS manual.

Table 2.28 The CONQUAS weighting system (arranged from CONQUAS manual)

Number	Type of Work	Residential Building (%)	Cat. A Commercial Building (%)
1.0	**Architectural work**	**85,00**	**75,00**
1.1	Floor	13,60	12,00
1.2	Internal wall	8,50	12,00
1.3	Ceiling	8,50	4,50
1.4	Door	5,95	4,50
1.5	Window	5,95	4,50
1.6	Component	5,10	4,50
1.7	Roof	3,40	3,00
1.8	Design, Material & Functional tests (water tightness test, pull-off test for internal walls, external façade, internal wall partition)	18,70	16,50
1.9	External wall (including façade)	10,20	9,00
1.10	External work (such as walkway, car park,fencing,etc)	5,10	4,50
2.0	**Structural work**	**10,00**	**10,00**
2.1	NDT - UPV test for concrete uniformity	3,50	3,50
2.2	NDT - electro covermeter test for concrete cover	3,50	3,50
2.3	Concrete quality	1,00	1,00
2.4	Steel reinforcement quality	1,00	1,00
2.5	Steel welding test	1,00	1,00
3.0	**M&E work**	**5,00**	**15,00**
3.1	Electrical	1,00	3,00
3.2	ACMV	1,33	4,00
3.3	Fire protection	0,67	2,00
3.4	Plumbing and sanitary	1,00	3,00
3.5	Basic fittings	1,00	3,00

The components of the framework that is planned to be developed within this study and the related information captured within CONQUAS are presented in the ***Table 2.29***.

Table 2.29 The components of CONQUAS

The components of the Framework to be Developed	The information captured within CONQUAS
KPI	Building (End Product) Quality Factor
Benchmark / Metric	Standard & Subjective Satisfaction
Data Source / Collection Method	Visual & Tech. Inspection & Material Testing
Data Analysis Methods	Mathematical Methods
Evaluation System	CONQUAS itself
Data Scoring Method	0&1 (pass or fail)
Data Representation Method	Numerical & Tabular

2.5.2. Quality Function Deployment

Quality Function Deployment (QFD) was explained as ‘‘a method to develop a design quality to satisfy customer needs and to translate the customer’s demands into design targets and to define major quality assurance points to be used throughout the production phase’’ by its developer Yoji Akao (1992). Moreover, Mallon J.C. and Mulligan D.E. (1993) stated that another reason for developing QFD is to use at initial stages of a project to produce more exact decisions by considering project budgets in terms of requirements of client and quality. Dikmen I., Birgönül M.T. and Kızıltaş S. (2004) proposed to use QFD also as a decision-making tool at later stages.

Building Quality Factors	Normalized Importance Weights		Building Performance Factors			Actual Level of Performance (Actual LP_j)
			Technical	Functional	Technical	
			0.375	0.279	0.346	
		Max Status	3	5	4	
Performance	0.125	3	**0.584**	**0.659**	**0.533**	1.776
Usability	0.127	4	**0.581**	**0.724**	**0.610**	1.915
Dependability	0.134	4	**0.576**	**0.632**	**0.480**	1.688
Conformance	0.108	5	**0.535**	**0.548**	**0.444**	1.527
Safety	0.137	3	**0.559**	**0.627**	**0.509**	1.695
Economic	0.123	4	**0.556**	**0.523**	**0.401**	1.480
Aesthetics	0.125	5	**0.554**	**0.561**	**0.653**	1.768
Perceived quality	0.121	4	**0.537**	**0.610**	**0.540**	1.687
Actual Level of Performance (Actual LP_j)			4.482	4.884	4.170	13.536

Figure 2.11 A QFD final result example from Lee et.al. (2006)

QFD may include any kind of one or more various Key Performance Indicators as its components together since, it is a very suitable system to modify easily. Therefore, one may easily add or drop any kind of KPIs from highest levels to lower levels shown in ***Figure 2.2*** and ***Table 2.3***. For example; in ***Figure 2.11***, a result illustration for an example for Building Quality Factor KPI is shown. Thus, for each activity type, this modification may easily be done from related standards, client needs etc. For the examples of application of QFD on some cases, studies of Dikmen et.al. (2004), Lee et.al. (2009), Yang et.al. (2003), Woldesenbet et.al. (2014), Yasamis-Speroni et.al. (2012) and Lee et.al. (2006) may be analyzed.

2.5.3. Quality Integrated Earned Value Methods

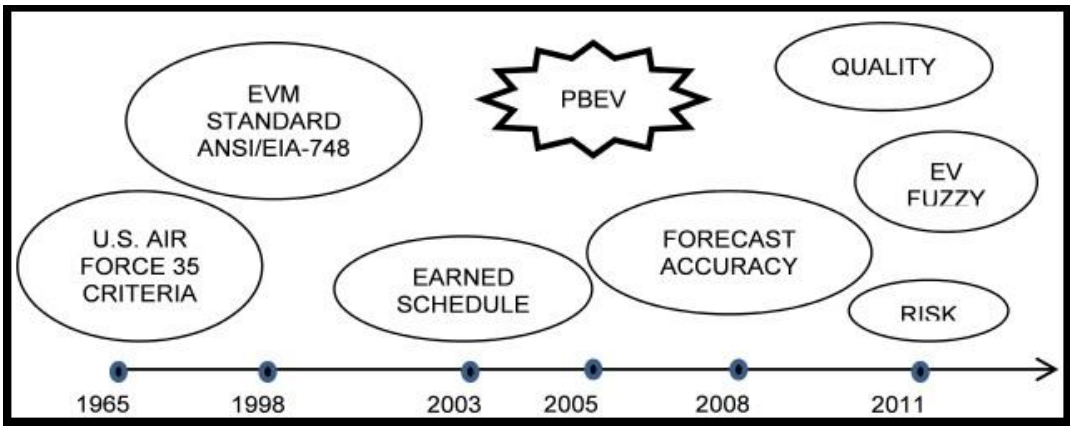


Figure 2.12 EVM evolution and research lines (p.4, 2013, Hernandez & Gomez)

The evolution of EVM for different areas can be seen in the ***Figure 2.12***. The history of new trends for EVM is recent, in other words, there are still more details to be developed in those areas. This study focuses on the quality and EVM relation and on related studies in this area, as stated before. Therefore, the details of quality integrated EVM studies were analyzed after introducing the findings related with other components of system from literature. Thus, data collected by the help of data collection methods according to metrics are analyzed with data analysis methods to measure KPIs and an output is given by a quality tracking system namely quality integrated earned value management.

In this part, the quality included EVM systems studied in literature are extracted in terms of sectors, KPIs (according to EVM type), metrics, data collection methods, data analysis methods and scoring methods. The relation between those components were analyzed in a binary pattern and the findings are illustrated as in the ***Tables 2.30, 2.31, 2.32, 2.33 & 2.34***.

Table 2.30 Sectors vs.KPIs (w.r.t.EVM type) frequency in Q-EVM literature

KPIs (EVM TYPE) \ SECTORS	AGRICULTURE		CONSTRUCTION		ANY PROJECT		PROCUREMENT OF GOODS		SYSTEM ENGINEERING		IT-SOFTWARE	
	FREQ	RATIO	FREQ	RATIO	FREQ	RATIO	FREQ	RATIO	FREQ	RATIO	FREQ	RATIO
FINANCIAL DATA (QUALITY COST INCLUDED EVM)	0	0,0%	2	33,3%	1	16,7%	0	0,0%	0	0,0%	3	50,0%
END PRODUCT QUALITY (QUALITY INCLUDED EVM)	1	11,1%	3	33,3%	2	22,2%	0	0,0%	0	0,0%	3	33,3%
END PRODUCT QUALITY (PERFORMANCE INCLUDED EVM)	0	0,0%	0	0,0%	2	40,0%	1	20,0%	1	20,0%	1	20,0%

Table 2.31 KPIs vs. metrics frequency in Q-EVM literature

METRICS \ KPIs (EVM TYPE)	FINANCIAL DATA (QUALITY COST INCLUDED EVM)		END PRODUCT QUALITY (QUALITY INCLUDED EVM)		END PRODUCT QUALITY (PERFORMANCE INCLUDED EVM)	
	FREQ	RATIO	FREQ	RATIO	FREQ	RATIO
STANDARDS / SEPC.S/ CODES / REQ.S	1	11,1%	5	55,6%	3	33,3%
FINANCIAL DATA (QUALITY COST)	6	75,0%	2	25,0%	0	0,0%
EXPERT SATISFACTION	0	0,0%	4	100,0%	0	0,0%
CLIENT SATISFACTION	0	0,0%	4	57,1%	3	42,9%

Table 2.32 Metrics vs. data sources frequency in Q-EVM literature

DATA SOURCES / COLLECTION METHODS \ METRICS	STANDARDS / SEPC.S/ CODES / REQ.S		FINANCIAL DATA (QUALITY COST)		EXPERT SATISFACTION		CLIENT SATISFACTION	
	FREQ	RATIO	FREQ	RATIO	FREQ	RATIO	FREQ	RATIO
TESTING & INSPECTION	6	42,9%	1	7,1%	3	21,4%	4	28,6%
ADMINISTRACTIVE CORPORATE DATA	1	50,0%	1	50,0%	0	0,0%	0	0,0%
FINANCIAL DATA	1	14,3%	6	85,7%	0	0,0%	0	0,0%
OTHER DATA OF PROJECT	2	33,3%	3	50,0%	1	16,7%	0	0,0%
EXPERT OPINION	5	38,5%	0	0,0%	4	30,8%	4	30,8%
CLIENT / OWNER OPINION	4	36,4%	0	0,0%	2	18,2%	5	45,5%

Table 2.33 Data sources vs. data analysis methods freq. in Q-EVM literature

DATA SOURCES / COLLECTION METHODS / DATA ANALYSIS METHODS	TESTING & INSPECTION		ADMINISTRACTIVE CORPORATE DATA		FINANCIAL DATA		OTHER DATA OF PROJECT		EXPERT OPINION		CLIENT OPINION	
	FREQ	RATIO	FREQ	RATIO	FREQ	RATIO	FREQ	RATIO	FREQ	RATIO	FREQ	RATIO
QUESTIONNARIE / DELPHI / SURVEY	4	33,3%	1	8,3%	0	0,0%	2	16,7%	4	33,3%	1	8,3%
CHECKLISTS / DATA SHEETS	0	0,0%	0	0,0%	0	0,0%	0	0,0%	0	0,0%	0	0,0%
SOFTWARE-BASED	1	20,0%	0	0,0%	1	20,0%	1	20,0%	2	40,0%	0	0,0%
CONCEPTUAL	3	33,3%	0	0,0%	2	22,2%	0	0,0%	3	33,3%	1	11,1%
MATHEMATICAL & STATISTICAL	7	24,1%	1	3,4%	6	20,7%	4	13,8%	6	20,7%	5	17,2%

Table 2.34 Data sources vs. data scoring methods freq. in Q-EVM literature

DATA ANALYSIS METHODS / DATA SCORING METHODS	QUESTIONNARIE / DELPHI / SURVEY		SOFTWARE-BASED		CONCEPTUAL		MATHEMATICAL & STATISTICAL	
	FREQ	RATIO	FREQ	RATIO	FREQ	RATIO	FREQ	RATIO
LINGUISTIC FUZZY	2	25,0%	0	0,0%	3	37,5%	3	37,5%
IN BETWEEN A RANGE	4	23,5%	1	5,9%	4	23,5%	8	47,1%
PASS OR FAIL (0 & 1)	1	25,0%	1	25,0%	0	0,0%	2	50,0%
QUALITY COST	0	0,0%	1	11,1%	2	22,2%	6	66,7%

It is observed that for the construction sector, quality included EVM and quality cost included EVM are preferred over Performance based EVM. IT-software sector studies are in the same trend with construction sector.

Quality included EVM studies mostly utilized standards, expert and client satisfactions; however, financial data is not that commonly preferred. Regarding performance based EVM, although standards and client satisfactions are referred, expert satisfaction and financial data were not included. Quality cost EVM studies mostly used financial data as the main metric. Expert and client satisfactions were not included in those studies.

For standards/codes metrics, testing & inspection results, expert and client opinions were used mostly as data sources. For financial data metric, financial data source and other data sources were used mostly. For expert satisfaction metrics, testing results, expert and client opinion sources were used mostly. For client satisfaction, testing results, expert and client opinion sources were used mostly.

For testing and inspection results data sources, mathematical and statistics, questionnaire and conceptual methods used as data analysis methods, mostly. Software based one was preferred weakly. For administrative data source, mathematical and questionnaire were used in one study for each. The others were not used. For financial data source, mathematical, conceptual and software-based data analysis methods were used. Others were not preferred. For other data sources, mathematical, questionnaire and software-based analysis methods were used. For expert opinion sources, mathematical, questionnaire, conceptual and software-based analysis methods were used. For client opinion sources, mathematical, questionnaire and conceptual analysis methods were used.

To the best of our knowledge, none of these studies proposed or suggested checklists and data sheets that could streamline the application of Q-EVM.

For questionnaire analysis method, in between range scoring, linguistic fuzzy transformation and pass or fail scoring methods were preferred. Quality cost was not used. For software-based methods, in between range, pass or fail and quality cost is used. For conceptual analysis method, in between range scoring, linguistic fuzzy transformation and quality cost scoring methods were preferred. Pass or fail was not preferred. For mathematical methods, all scoring methods were used.

When the founded results of relations between those components are represented by graphs, the following illustration occurs as shown in ***Figure 2.13***. The thickness of the lines represents the strength of the relation.

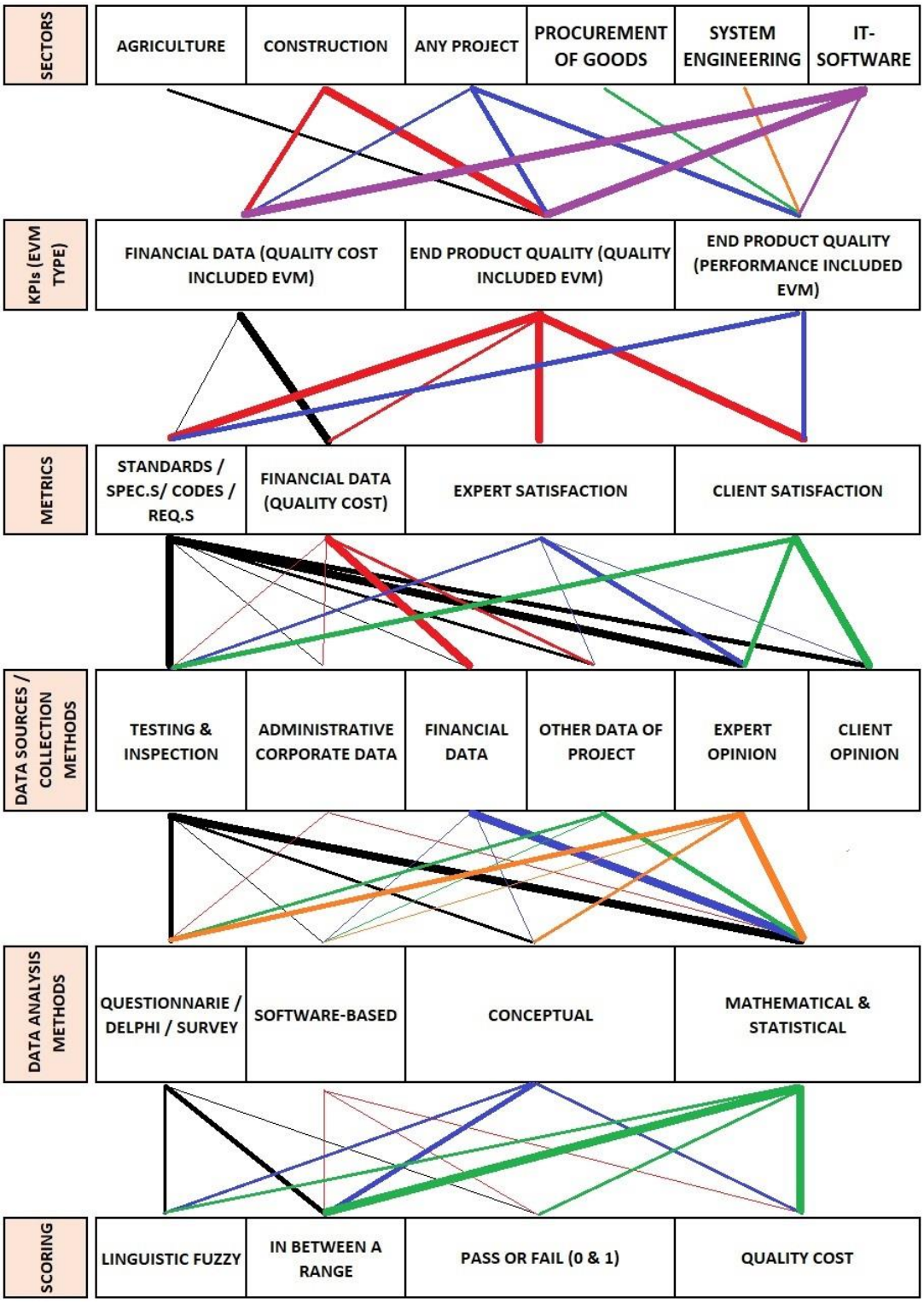


Figure 2.13 Relations between system components of Q-EVM in literature

The frequency distribution of the scanned literature is illustrated in the final ***Table 2.35*** located in next page. According to this table; studies related with Quality included EVM were based mostly in construction, IT-software and project-based **sectors** as ratio of **26%**, each. **Quality included EVM** is the mostly studied with a ratio of **47%**, (Only, end product (building quality) factor and financial data (quality cost) KPIs were preferred in EVM system studies. Corporate or service KPIs were not preferred.)

Standards were used **35%** as objective **metrics** and subjective satisfaction (expert and client) was preferred **42%** as soft metrics. Testing & inspection results, data base and perceptive **data sources / collection methods** were preferred in close frequency**, 29%, 39%, 32%,** respectively.

Mathematical and statistical **data analysis methods** were used popularly**. In any study checklists or data sheets were not presented.** 'In between a range' scoring was used mostly with **40%** as a **scoring method**. Afterwards quality cost was preferred with **30%** ratio.

Table 2.35 The distribution of system components of Q-EVM in literature studies

QUALITY / PERFORMANCE INCLUDED EARNED VALUE MANAGEMENT STUDIES (See Appendix C for Numbered Studies)																					
SEQUENCE # OF STUDY :			1	2	5	7	8	14	109	110	113	122	130	131	135	150	151	156	157	TOTAL	RATIO
SECTORS		AGRICULTURE	1																	1	5,3%
		CONSTRUCTION			1	1	1						1			1				5	26,3%
		ANY PROJECT						1		1	1							1	1	5	26,3%
		PROCUREMENT OF GOODS		1																1	5,3%
		SYSTEM ENGINEERING													1					1	5,3%
		IT-SOFTWARE							1	1		1		1			1			5	26,3%
KPIs (EVM TYPE)		FINANCIAL DATA (QUALITY COST INCLUDED EVM)			1	1			1			1		1					1	6	31,6%
		END PRODUCT QUALITY (QUALITY INCLUDED EVM)	1				1	1	1				1	1		1	1	1		9	47,4%
		END PRODUCT QUALITY (PERFORMANCE BASED EVM)		1						1	1				1					4	21,1%
METRICS		STANDARDS / SPECIFICATIONS / CODES ...	1	1			1	1		1		1	1		1			1		9	34,6%
		FINANCIAL DATA (QUALITY COST)			1	1			1			1		1					1	6	23,1%
		EXPERT SATISFACTION	1				1	1					1							4	15,4%
		CLIENT SATISFACTION	1	1				1		1	1						1	1		7	26,9%
DATA SOURCES	TEST & INSP.	MATERIAL (/SOFTWARE) TESTING RESULTS	1	1			1		1	1			1		1		1			8	23,5%
		VISUAL INSPECTION											1							1	2,9%
		HIGH- TECHNOLOGY INCLUDED INSPECTION											1							1	2,9%
		CORPORATE ADMINISTRATIVE / MANAGERIAL DATA												1	1					2	5,9%
		FINANCIAL DATA			1	1			1			1		1					1	6	17,6%
		STATISTICAL PAST DATA				1	1							1	1				1	5	14,7%
		EXPERT OPINION	1				1	1					1				1	1		6	17,6%
		CLIENT / CUSTOMER OPINION	1	1				1		1	1									5	14,7%
DATA ANALYSIS METHODS		QUESTIONNARIE / DELPHI / SURVEY					1	1					1		1		1			5	9,4%
		CHECKLISTS / DATA SHEETS																		0	0,0%
	SOFTW	SOFTWARE / CAD / ...											1					1	1	3	5,7%
		SPSS 24																	1	1	1,9%
	CONCEPTUAL	FUZZY					1		1								1			3	5,7%
		MULTI - ATTRIBUTE UTILITY THEORY (MAUT)						1												1	1,9%
		AHP / ANP					1										1			2	3,8%
		PAIRWISE COMPARISON						1												1	1,9%
		CORRELATION COEFFICIENT METHOD															1			1	1,9%
		ADDITIVE UTILITY MODEL						1												1	1,9%
		VALUE FUNCTIONS						1												1	1,9%
		PARTITIONING METHOD			1															1	1,9%
	MATH & STAT.	DESCRIPTIVE ANALYSIS											1				1		1	3	5,7%
		BIVARIATE ANALYSIS											1						1	2	3,8%
		BASIC MATHEMATICAL METHODS	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	16	30,2%
		OTHER STATISTICAL METHODS	1		1		1	1	1	1	1	1	1	1				1	1	12	22,6%
DATA SCORING		QUALITATIVE (OR LINGUISTIC) &/ TRANSFORMED BY FUZZY					1		1								1			3	15,0%
		IN BETWEEN A RANGE SCORING		1			1	1	1	1	1		1				1			8	40,0%
		0 & 1 (PASS OR FAIL) (YES OR NO)	1												1			1		3	15,0%
		QUALITY COST			1	1			1			1		1					1	6	30,0%

Another very important issue related with QEVM is ***the conversion or transition method from classical earned value to quality earned value***. Firstly, Performance Based Earned Value Method (PBEV) is based on penalty logic for the transition of Performance Earned Value (Solomon, 2006; Hernandez et.al, 2013; Yerabolu, 2010; Carson et.al, 2008) and the calculations for classical EVM are incorporated. Technical requirements are measured and scored with respect to negotiated terms before. Then, a penalty for the amount of lack of quality is simply applied on calculated earned value and this final value is called as "Performance Based Earned Value". For example; if the expected efficiency value is 100% for a procured engine and it is negotiated in contract that any loss in efficiency will be penalized as 40%, then in tests, if the efficiency is calculated as 80%, then, final EV is multiplied by 0,40 and this result is called as PBEV.

Thus, PBEV (Performance Based Earned Value) = EV (Classical Earned Value) * Penalty

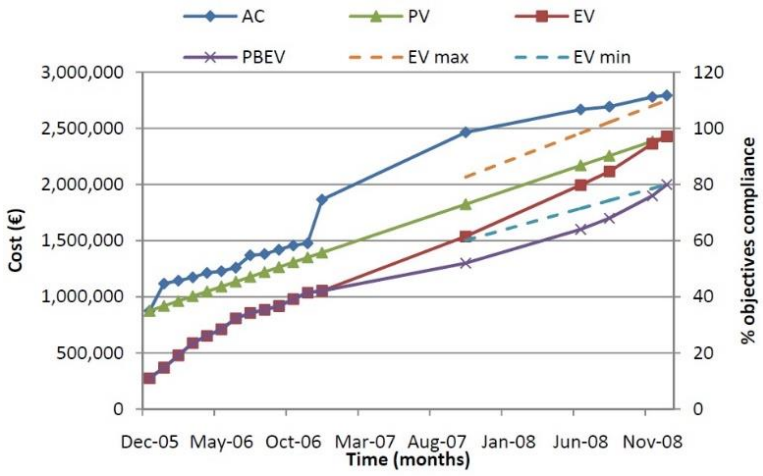


Figure 2.14 An example of result of PBEV from Hernandez et.al. (2013)

Another group of studies used Quality Cost included Earned Value Methods that are based on the general logic of multiplication of the classical earned value with a factor derived from quality cost. This multiplication approach resembles the penalty logic of

PBEV. Khesal et.al. (2018) derived a QPI (Quality performance index) by dividing Budgeted Quality Cost to Actual Quality Cost. Ma et.al. (2012) derived QPI as proportion of the Actual Quality Cost to Actual Total Cost and tracked these trends variations. Gao et.al. (2011) planned Budgeted Quality Cost Work Scheduled during scheduling and tracked the quality cost variety trend by comparing it with Actual Quality Cost Work Performed. Efe (2015) tried to estimate the final Earned Value by inserting unforeseen effects to classical concept by using a multiplication factor derived from Quality Cost data. This study converges with inverse manner; that is instead of altering the final Earned Value like other studies do, estimation of EV is altered. Khalid et.al. (2015) defined QPI (Quality Performance Index) as "1-cost of rework ratio" and tracked the quality concept over this index, similarly. For example; if a work costs $ 1.2million, quality cost is calculated as $ 400k, and EV=$1million, then the proportion of QC/AC= 0,4 m / 1,2 m= 0,25. (1-0,25=0,75 is success ratio). Then, QCEV (Quality Cost Earned Value) is $1 million (EV)*0,75= $750k, in this manner.

Thus, QCEV (Quality Cost Earned Value) = EV (Classical Earned Value) * (factor derived from a ratio of Actual with Earned or Planned Quality Cost)

In aforementioned studies, a ratio that is calculated from a definite penalty or quality cost is used to enable the translation of the EV into QEV. Another group of studies for transitioning into QEV uses a quantitative scoring for quality assessment. It should be emphasized that the following studies do not use Quality Cost concept, at all. One approach is the multiplication of classical earned value with a factor derived from quality score percentage. For instance, Dodson et.al. (2015) proposes that EV is equal to the multiplication of success ratio of test results and Actual Cost and the study gives equal weights to each component. Xu et.al. (2010) proposes that QEV = EV * a Factor of Past Data (unexplained how to derive) * Q_e where Q_e=AQ/BQ; and AQ (actual quality) comes from the ratio of test results to BQ (budgeted quality), and the means of assessment is undefined. Souza et.al. (2014) studied the prediction of final cost of rework and the total cost at the end of the project using the predicted cost of rework

by comparing the historical data of defects to current defect data. Huang et.al. (2018) proposed an expert opinion scoring altered with fuzzy, where QEV = EV*QI and QI (quality index) = Actual Quality / Planned Quality. Ying (2016) proposed Earned Quality = EV * Q_e, where Q_e=AQ/BQ, but the study does not state how to determine Actual Quality or Budgeted Quality, weight of Work Breakdown Structure and Quality Breakdown Structure. Miguel et.al. (2019) proposes QEV (Quality Earned Value) = EV (Earned Value) * QIN (Quality Index Number coming from Project Manager's rating) but the weights of Work Breakdown Structure or Quality Breakdown Structure is not stated. On the other hand, Ong et.al. (2018) implemented the CONQUAS method into QEVM by modifying the weights of the components in their study, and they proposed the calculation of Quality Performance Index (QPI) by QPI=AQ/PQ (where AQ is Actual Quality & PQ is Planned Quality) and, PQV=AC*(%Q target=80/100 for all) (PQV is Planned Quality Value, AC is Actual Cost & Q is quality). For example; if Earned Value of a project is $1 million, and actual quality is 80/100, then QEV is calculated by $1 m * 80%= $800k.

Thus, QEV (Quality Earned Value) = EV (Classical Earned Value) * (factor derived from a ratio of Actual with Earned or Planned Quality Score)

Another approach for quantitative scoring for quality assessment is to calculate Earned Value in terms of quality without transforming it into monetary value. Paquin et.al. (2000) proposed that instead of cost, quality scoring is introduced into classical EVM directly and calculations are performed. However, they did not calculate Earned Value for cost component, and did not compare cost and quality results so there was no relation commented among those components, there is no graphical representation and comment on results, as well. They offered Quality Breakdown Structure over Work Breakdown Structure as weightage system. QPI (Quality Performance Index) = (Earned Quality / Planned Quality) *100%.

Thus, QEV (Quality Earned Value) = EV (Classical Earned Value) (in terms of quality instead of cost)

2.6. Data Communication Methods

2.6.1. Data Scoring Methods

In the related literature studies, different types of scoring methods were utilized. According to summary ***Table 2.36***, **Linguistic scoring** transformed by Fuzzy is preferred about **24%**. '**In between a range' scoring** is ~ **49%**, while **pass or fail scoring** is ~ **13%**. Finally, **quality cost data** preferred as scoring is ~ **14%**. These scorings are used in transforming linguistic data or subjective opinion and also different scale results in a uniformly usable scoring.

Table 2.36 The distribution of quality scoring methods in literature studies

QUALITY SCORING METHODS IN RELATED STUDIES (See Appendix C for Numbered Studies)												
SEQUENCE # OF STUDY	QUALITATIVE (OR LINGUISTIC) &/ TRANSFORMED BY FUZZY	IN BETWEEN A RANGE SCORING									0 & 1 (PASS OR FAIL) (YES OR NO)	QUALITY COST
		0-1 SCORING	0-5 SCORING	1-7 SCORING	0-10 SCORING	1-9 SCORING (SAATY'S PAIRWISE / LIKERT)	1-10 SCORING	0-100 SCORING (%)	1-3-5-7-9 SCALE	0-1-3-9 SCALE		
1											1	
2								1				
5												1
7												1
8	1				1							
12	1	1										
13								1				
14		1										
15	1	1										
18								1				
25							1					
31	1		1									
38	1											
40		1				1						
41												
44	1							1				
51												1
53												1
55											1	
60	1				1							
63	1					1						
65	1		1									
66											1	
73											1	
77								1				
82	1	1						1				
87	1	1										
89											1	
93				1								
95												1
97	1									1		
98								1				
109	1	1										1
110								1				
113								1				
122												1
127											1	
130					1							
133												1
135											1	
136	1								1			
137						1						
143					1							
151	1		1		1							
156											1	
157												1
TOTAL SCORE	15	7	3	1	5	3	1	9	1	1	8	9
RATIO	23,8%	11,1%	4,8%	1,6%	7,9%	4,8%	1,6%	14,3%	1,6%	1,6%	12,7%	14,3%
GROUP RATIO	23,8%	49,2%									12,7%	14,3%

2.6.2. Result Representation Methods

In the literature studies, the mostly used data representation methods are **numerical, tabular or graphical** representation methods.

For *numerical* representation the following scoring may be given as an example as seen in ***Table 2.37***.

Table 2.37 An example of numerical representation from Xu et.al, 2010

Construction quality score	*AQ*	8.276
	BQ	7.000

For *tabular* representation the scoring may be given as an example in ***Table 2.38***.

Table 2.38 Table 2.29: An example of tabular representation from Dodson et.al, 2015

Table 4. Soybean harvesting quality requirements.

Description	Impurities (%)	Grain moisture (%)	Worked hours (hours)	Grain loss (Bags/ha)	Quality Performance Index
Lower Specification Limit	0	10	6.5	0.0	**1.0**
Target	2	13	7.0	1.0	**1.0**
Upper Specification Limit	3	14	7.5	1.5	**1.0**
Out of specification	>3	>14	>7.5	>1.5	**0.0**

For *graphical* representation the graph in ***Figure 2.15*** may be given as an example:

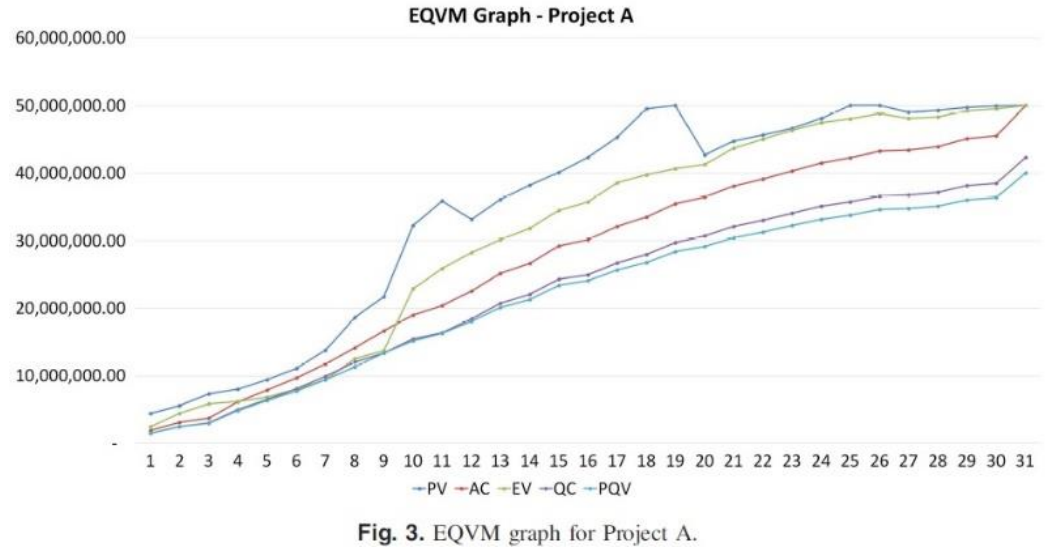


Fig. 3. EQVM graph for Project A.

Figure 2.15 An example of graphical representation from Ong et.al, 2018

Therefore, the final illustration of relations of all components of whole system as in the ***Figure 2.16***:

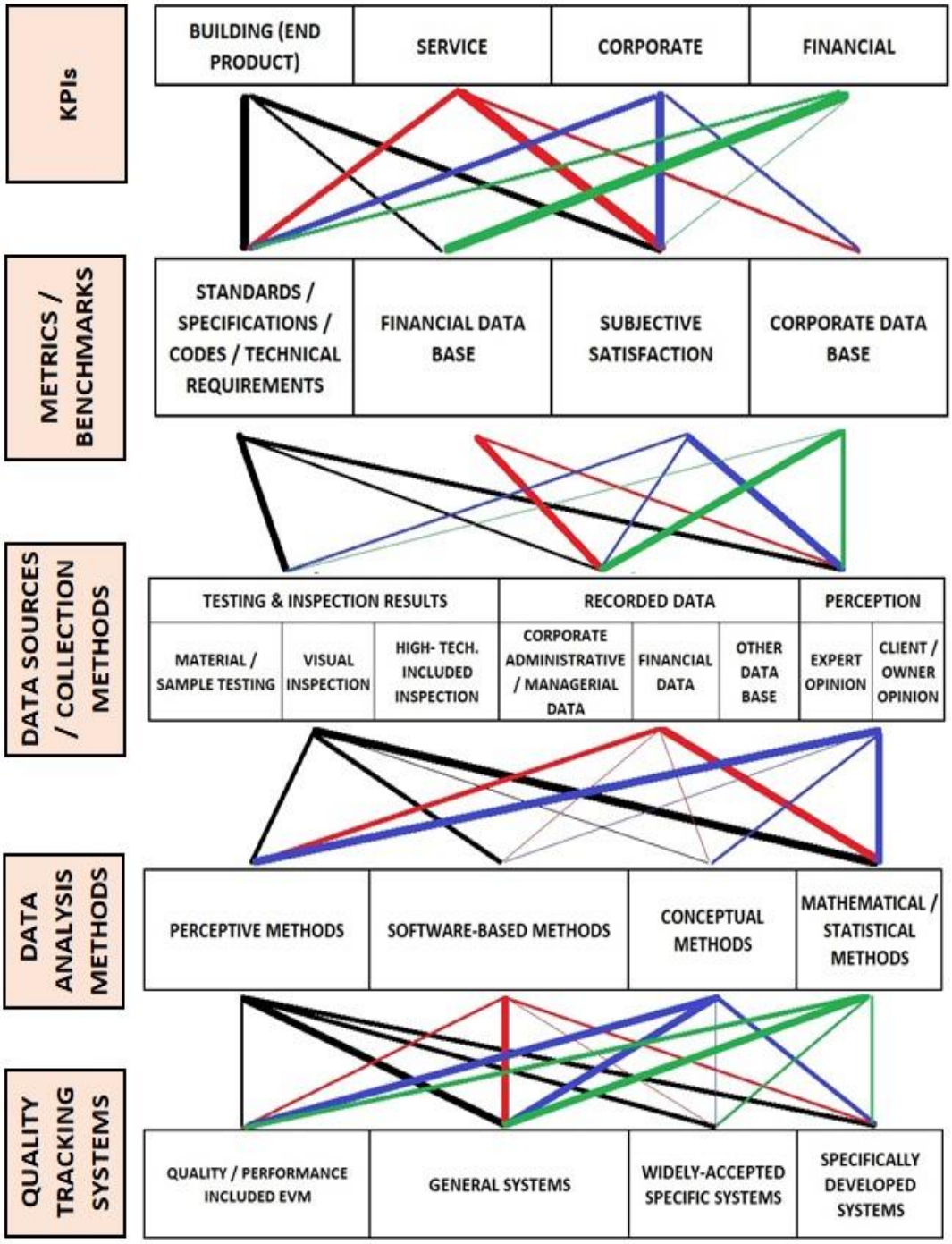


Figure 2.16 Relations between system components in literature

2.7. Literature Review Discussion

There are various **project-based quality tracking systems** developed in the literature. In order to check the quality progress systematically and to make it easily applicable in every project phase, Earned Value Management seems to a more suitable model to adapt the quality tracking system. The advantages of EVM has been explained in the previous parts. Moreover, some other quality assessment systems such CONQUAS may also be embedded into this integrated system. When the related studies were examined, some findings stand out:

Firstly, related studies use some regional or international norms. Due to the fact that some varieties exist among those norms used in different countries or locations; the norms and some details used in certain studies are required to be altered according to conditions of current regions (specifically Turkey for this study) in order to be used coherently.

Secondly, the commonalities and differences used in different studies need to be integrated into each other in order to propose a QEVM system that builds up on the strength of the existing studies. For instance, synthesized literature demonstrates that to measure the building quality factor KPI, standards / codes and/or subjective (expert and/ or client) satisfaction are considered as the most suitable metrics. Further explorations are required to identify the major components required to perform QEVM and their strengths.

Thirdly, the literature reveals that the most suitable data sources or data collection methods for those referred metrics are the testing and inspection results (visual / high-technology included inspection and material testing) and subjective perception (expert and / or client opinion). Although there are lots of data analysis methods in literature; questionnaire / Delphi /survey, creating / using checklists / data sheets, using fuzzy, AHP, descriptive analysis, statistical & basic mathematical methods and software supported solutions may be used coherently to extract those data acquired from the related data collection methods. As scoring method, between 0-10 scoring, fuzzy

conversion and 0 or 1 (pass or fail) scorings are the mostly used methods. However, the effects of applying different methods on the output of QEVM is still not known.

Fourthly, the perception of quality through various perspectives are stated in literature; however, there is not a tangible result illustrating the differences between them. A study is needed to be done to highlight the differences or similarities between different perspectives to construction quality, quantitatively.

Fifthly, it is observed that the output and the results of the developed system are generally represented in detailed tables or one cumulative trend graph. There is a need to explore alternative representations that can reflect the stakeholder/task specific trends of quality. Finally, any parts or the total of the developed or modified system shall be easily comparable and verifiable by some methods such case study in order to verify the suitability of modifications.

Sixthly, in the studies that quality is scored individually independent of the cost, the relation of quality and corresponding cost values is indefinite. Some studies states about this issue such client or expert target; however, even if a client asks for a target quality, its corresponding budgeted cost shall be identified, explicitly.

Seventhly, there are widely-used quality tracking system such CONQUAS; however, these systems also have some deficiencies. For example, CONQUAS does not track or integrate cost and schedule components. Some underground works are not tracked in this system. Inspection is done on samples to represent all building; however, this creates an approximate result not accurate. Scoring is done once, if there is rework which increases cost, the corresponding quality increment is not taken into account which is leading deviation in result. Weightage system is very architectural perspective oriented; less importance is given in structural and M&E works. In another study namely Ong et.al. (2018) suggests a scoring like that if the score is over 8, it is accepted; however, if the score is under 8, then a second scoring is done and 70% of first scoring and 30% is second scoring is accepted as final result. This approach also does not reflect final quality accurately.

Eighthly, in transition from classical EVM to Q-EVM, there is a gap in literature studies as stated in the following sentences. 17 directly-related studies with Quality EVM issue were analyzed stated in literature part. Generally, these transitions were done in 3 main concepts. PBEV (4 out of 17 studies) logic gives penalty to classical EVM for performance losses which is a very practical method; however, it is an approximation approach. Quality Cost studies (5 out of 17 studies) multiply the classical EVM with a factor derived somehow from Quality Cost and defends the reflection of these results' directly quality concept. However; for example; if two projects having overall quality levels 60 and 90, and having actual quality cost ratio to the budgeted quality cost (or to the overall budget) is 10% for both, then one may not defend the quality deviation is 10% for these two projects. Thus, quality cost ratio to some variables is also not a good illustrator for quality concept, directly. In third logic, Quality Scoring studies (8 out of 17 studies) multiply the classical EVM with a factor derived from somehow quality scoring results. 4 studies use a final quality score ratio to multiply the classical EVM result with this ratio in order to transform quality result into some monetary terms. This approach also gives approximate results, not exact ones as the logic of Quality Cost included studies. The other 4 studies developed some other criteria. Among those studies, Paquin et.al. (2000) suggests inserting quality component into classical EVM directly instead of cost. This approach offers a more accurate result; however, the cost component is excluded completely in this study. Work Breakdown Structure and Quality Breakdown Structures were created. However, instead of a weightage system, they proposed value functions to develop progress which deviates the results far away from exact ones, a little bit. Xu et.al. (2010) proposes Actual Quality from ratio of test results and Budgeted Quality and weightage used unknown how to assess and they propose a factor of past data called as $f(Q_e)$ and they said that it is not a well-established development, Souza et.al. (2014) tries to predict final cost of rework and depending on this the total cost at the end of the project by comparing the historical data of defects to current defect data. In construction works, number of defects usage does not make sense, this approach is more appropriate for industrial or software-based sectors. Moreover, as Khalid et.al.

(2015, p.276) stated, using past data so much in project-based works is not a correct approach, since every project has its own character and cannot be resembled to the others. Ong et.al. (2018) inserted the CONQUAS into QEVM by modifying the weights in their study. They also transformed quality into monetary terms which makes results approximation and used a average quality representation for cumulative progress that is result is always shown around the 80 point quality. Finally, these 8 studies do not used quality cost concept to analyze the effect of quality cost on quality. On the other hand, 5 quality cost related studies did not use quality scoring concept, as well. Therefore, since there are gaps to develop, issue of transition to QEVM is also needed to be studied on.

Finally, there are studies integrating Quality Cost into EVM; however, there is a need to go into details in terms of the sources and effects of quality cost. Some concerns such as; why Quality Cost (cost of rework etc.) occurs, what is the source of reworks, what is the relation of quality cost with productivity, how they affect each other are needed to be studied on. These concerns shall be inserted into Quality EVM concept, as well; since they are also a part of this issue.

CHAPTER 3

METHODOLOGY

The objective of this study is to develop an easily customizable, extendible, elaborate and practical way to support the project managers to track the quality component of construction projects. In order to achieve this, firstly, articles, papers and specifically developed systems like CONQUAS were reviewed in literature. Various differences were observed in the components and mechanics of these systems. After identification of such differences, the following research questions (RQ) are raised and answered to propose a QEVM framework for construction projects:

RQ1: What are the components of a practical and extendible QEVM framework that can be used for construction projects and what is the suitable transition to Quality EVM and how quality and cost may be related?

While some studies focus on only the financial data, some studies use the end product related KPIs to assess the performance of a product/process. Hence, the initial objective of this study is to identify the components of QEVM that can be customized and practically used. Moreover, proposed system shall have a smooth transition to QEVM in order to give accurate results and shall reflect quality and cost relation, correctly. Quality and cost relation shall be reflected, as well. When the framework is created, the developed system shall be extendible and practical.

RQ2: What is the effect of different quality scoring methods on the outcomes of QEVM framework?

Different scoring methods were utilized to quantify the quality of products/processes. While some studies used a scale (e.g., likert scale), some studies only focused on the fact that whether the requirements were met or not (pass-fail). Hence, the second

objective of this study is to compare the outcomes of the QEVM framework with the utilization of different scoring methods.

RQ3: How is the performance of the QEVM framework in terms of reflecting the client/ end user satisfaction levels?

Another issue was to test the framework for different perspectives. In different literature studies, different perspectives were stated such as; client/ end user, expert, contractor, designer, etc. Client, owner and expert perspectives were compared in this study. The reason behind that, the mostly interacted sides considered as owners, experts and clients during construction and after construction, respectively. Thus, looking through the quality concept through various perspectives was decided as the 3rd objective.

RQ4: How can the QEVM framework be improved with the integration of financial data and productivity and customizing the outputs according to different stakeholders/ tasks?

Quality shall be easily illustrated for different levels of details (e.g., components of quality: quality cost and quality productivity). In this study, the effect of the use of the following alternatives were tested to explore their value for the QEVM framework: (i) representing the quality contribution coming from general works and reworks separately, and their separated corresponding costs, (ii) developing separated illustration for each individual activities' data beside cumulative results, (iii) developing separated illustration for works completed by different crews and their separated contribution for productivity of quality.

In order to answer these research questions, the methodology of this study is demonstrated in ***Figure 3.1***.

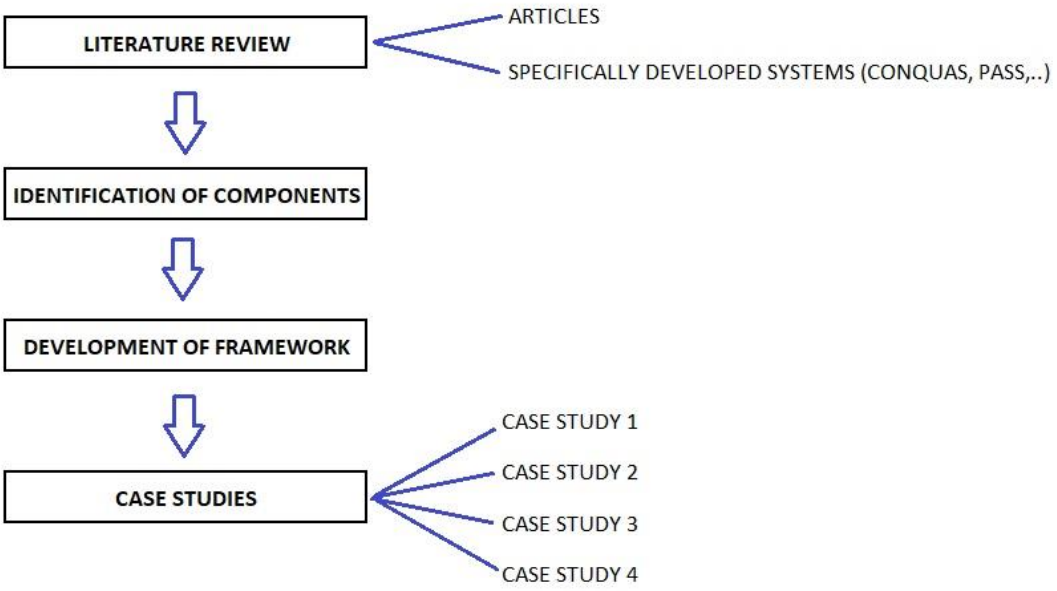


Figure 3.1 The methodology flow of this study

Careful investigation of the related studies in literature led to the identification of the components of the QEVM framework. With the realization that how the framework components are pieced together result in different outputs, four case studies were performed to develop the final configuration of the framework. During the case studies (see ***Table 3.1***), most of the components were chosen in accordance with the ones that were most commonly used in literature. For instance, it can be seen that the building (end product) quality factors were utilized as KPIs. In each case study, one or more variables were changed to see the effect on the final output. For instance, in the last case study, financial data was also used as a KPI. In summary, new trends or least-utilized alternatives in the literature were incorporated to the framework. The preferences in case studies can be seen in the ***Table 3.1***.

Table 3.1 The preferences for components in different case studies

COMPONENTS / CASES	KPIs	METRICS / BENCHMARKS	DATA COLLECTION METHODS	DATA ANALYSIS METHODS	QUALITY EVALUATION METHOD	DATA SCORING METHOD
CASE 1	BUILDING (END PRODUCT) QUALITY FACTOR	STANDARDS + EXPERT SATISFACTION + OTHER DATA	TESTING RESULTS + INSPECTION RESULTS + EXPERT OPINION + OTHER DATA BASE + CHECKLISTS	CHECKLISTS + SOFTWARE - BASED METHODS + MATHEMATICAL & STATISTICAL METHODS	WEIGHTS OF ONG ET.AL.(2018) + SUB-WEIGHTS OF CONQUAS + DERIVED Q-C VALUE FUNCTIONS+ Q-EVM	0-10 LIKERT SCALE
CASE 2	BUILDING (END PRODUCT) QUALITY FACTOR	STANDARDS + EXPERT SATISFACTION + OTHER DATA	TESTING RESULTS + INSPECTION RESULTS + EXPERT OPINION + OTHER DATA BASE + CHECKLISTS	CHECKLISTS + SOFTWARE - BASED METHODS + MATHEMATICAL & STATISTICAL METHODS	WEIGHTS OF CONQUAS & ONG ET.AL.(2018) + SUB-WEIGHTS OF CONQUAS + DERIVED Q-C VALUE FUNCTIONS+ Q-EVM	PASS OR FAIL (0&1) FOR WHOLE FLAT FOR AN ACIVITY
CASE 3	BUILDING (END PRODUCT) QUALITY FACTOR	STANDARDS + EXPERT SATISFACTION + OTHER DATA + CLIENT+OWNER SATISFACTION	INSPECTION RESULTS + EXPERT OPINION + OTHER DATA BASE + CHECKLISTS + CLIENT OPINION + OWNER OPINION	CHECKLISTS + SOFTWARE - BASED METHODS + MATHEMATICAL & STATISTICAL METHODS	WEIGHTS OF ONG ET.AL.(2018) + SUB-WEIGHTS OF CONQUAS + DERIVED Q-C VALUE FUNCTIONS+ Q-EVM	PASS OR FAIL (0&1) FOR DEFECTIVE AREA FOR AN ACIVITY
CASE 4	BUILDING (END PRODUCT) QUALITY FACTOR + FINANCIAL DATA (QUALITY COST)	STANDARDS + EXPERT SATISFACTION + OTHER DATA + FINANCIAL DATA	TESTING RESULTS + INSPECTION RESULTS + EXPERT OPINION + OTHER DATA BASE + CHECKLISTS + FINANCIAL DATA BASE	CHECKLISTS + SOFTWARE - BASED METHODS + MATHEMATICAL & STATISTICAL METHODS	WEIGHTS OF ONG ET.AL.(2018) + SUB-WEIGHTS OF CONQUAS + DERIVED Q-C VALUE FUNCTIONS+ Q-EVM	0-10 LIKERT SCALE

The last step of this study is to finalize the QEVM framework. According to whole findings, that framework explained in **Chapter 4** was developed.

CHAPTER 4

QEVM FRAMEWORK / MODEL

The QEVM framework can be seen in ***Figure 4.1***. Firstly, KPIs are determined that are aligned with the client requirements and strategic expectations of the companies. Afterwards, the metrics/ benchmarks are determined with respect to related KPIs. In this stage, by combining KPIs and benchmarks, **checklists allowing practical site investigation are developed** in accordance with certain location or region. Regional quality control checklists (for Turkey) were developed for this study as can be seen in Appendix A. Then, by following the instructions of related data collection methods, necessary data are collected. The collected data are analyzed with the help of data scoring methods and data analysis methods. Finally, all the related findings are processed by quality evaluation method including assignment of weights to relative contribution of different quality issues in order to obtain output for quality component. The final result is represented with the help of data communication methods. Afterwards, the quality output obtained from this system is integrated with cost and schedule components of project by Quality included Earned Value Method. By the way, **the value functions for the relation of quality and cost components are derived** in order to determine the targeted quality values. Final result is represented by data communication methods. The **results are analyzed in different level of details** for individual activities, quality cost (especially cost of rework), quality productivity and for different crews. Although some preferences are explained, there are different alternatives ways to integrate these components. In order to identify which combinations of preferences can yield the most effective output, 4 case studies were performed. The case studies are discussed in the following subsection.

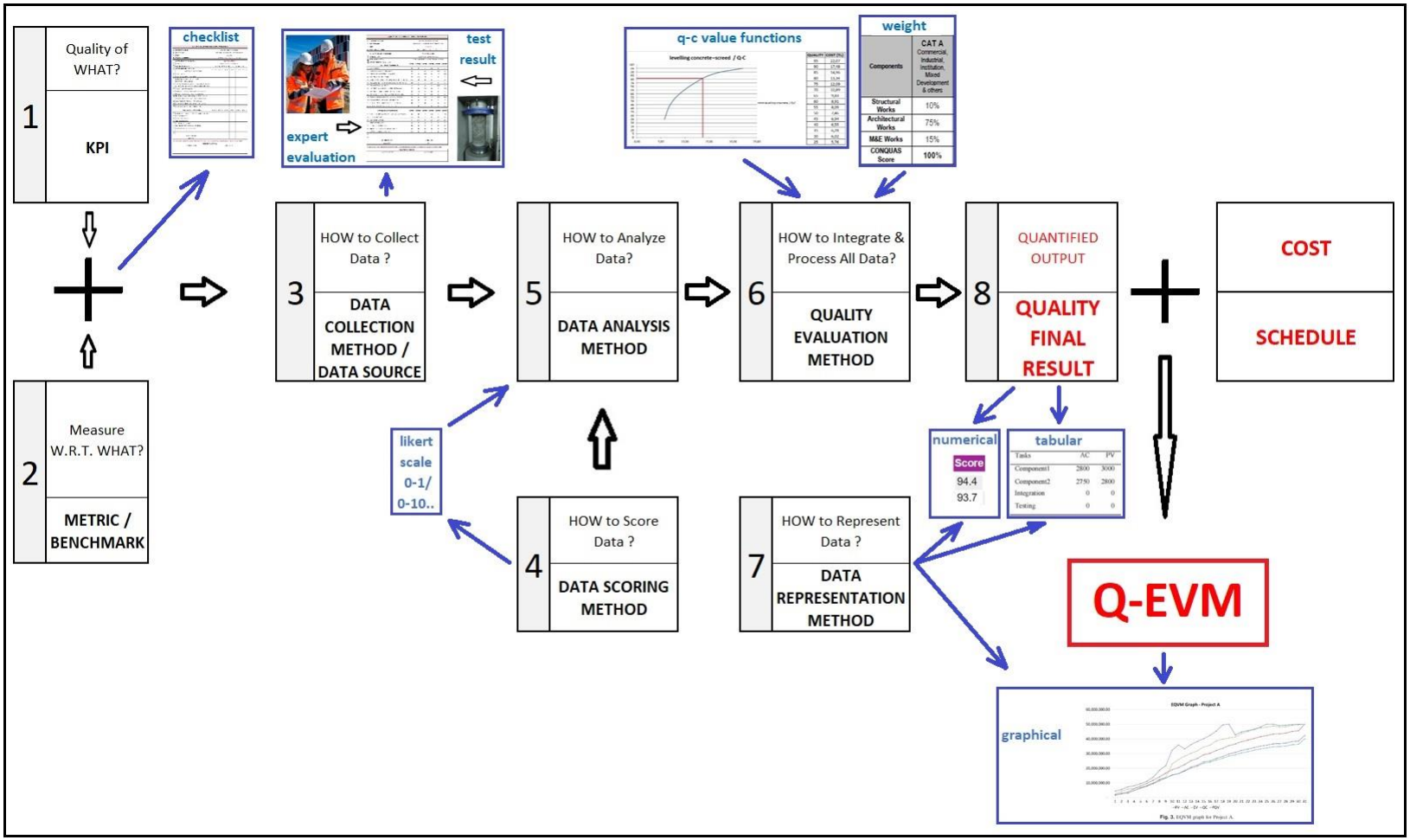


Figure 4.1 Developed system framework

The philosophy of certain **preferences for components** are explained in this section.

KPIs:

As stated in literature review part, there is a great number of supporters of the idea that the definition of quality is the fulfillment of the client needs. In construction works, the clients care about the quality of end products in terms of functional, behavioral and technical norms, more than other factors. Neither corporate quality nor service quality factors are recollected for a long time, but end product stays remedially with the client in construction. For this reason, **building (end product) quality factor** was considered a suitable KPI for construction works. Moreover, the literature reveals that half of the related studies have preferred this factor as KPI.

On the other hand, there are also studies related with **financial data KPI (quality cost)**. This factor is also needed to be analyzed in detailed, since quality cost is widely-accepted as a direct measure for quality and cost in literature. From the rework cost and rework amount of work, the productivity of quality was developed in this study.

Benchmarks / Metrics:

In this study, **standards, expert satisfaction, project data and financial data** were used as metrics. Moreover, **in one case, client satisfaction** was also used in order to check whether it is suitable to use or not. If ***Table 2.9*** (Metrics frequency with respect to KPIs in literature) is analyzed, it is clearly seen that using standards with end product KPI was preferred frequently. Afterwards, subjective satisfaction was the mostly used metric. Except this information, the mostly used combination in literature was the standards and subjective satisfaction metrics. Thus, these two components work with in compliance.

Actually, the subjective satisfaction (also called “soft” measures by Lee et.al, 2006) is a subjective measure as expected. Various studies already state the fact that quality is

perceived as a subjective component. Moreover, the literature results have shown that expert opinions are very crucial in inspection of construction works. Therefore, instead of trying to eliminate subjective methods in assessment of quality, it is strongly advised that subjective perspectives should be integrated into assessment system by trying to make them more objective by using them with objective measures such as standards.

Checklists:

One of the most prominent components of the framework is the development of checklists with respect to KPIs and Benchmarks. As stated in the methodology part, KPIs and metrics were determined as building quality factor and standards, expert satisfaction and other data, respectively. Afterwards, the checklists to collect data were derived from governmental and regional private specifications with respect to those determined components. Those checklists were derived specifically for structural and architectural works as seen in the ***Figure 4.2*** as an example.

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	ABC CONSTRUCTION COMPANY
B.	**PROJECT NAME:**	ABC RESIDENTIAL & COMMERCIAL PRESTIGE PROJECT
C.	**DATE :**	3.01.2017
D.	**WEATHER CONDITIONS :**	TEMPERATURE : -2 / 5 C' / CLOUDY

SEQUENCE #		RELATED SPECIFICATION **									
	ACTIVITY NAME / ID / EXPLANATION :		**FORMWORK WORKS**								
	MAIN LOCATION :		PARCEL #1 / NORTHEAST PART OF SITE / NEIGHBOUR OF WAY#1								
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION : FOUNDATION OF BLOCK C		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CORRECT ALTITUDE / ELEVATION OF FORMWORK	(1)									
2	CORRECT SHAFTS / SPACINGS	(1) (4.A8)									
3	VERY CLEAR / OILED SURFACE	(1) (4.A8)									
4	2MM REVERSE DISPLACEMENT / 1M OF BEAM	(1)									
5	CHECK FOR COORDINATINS (+-3MM)	(1)									
6	HORIZONTAL LEVEL / SMOOTHNESS (+-3MM)	(1)									
7	CROSS-SECTIONAL DIMENSIONS (+10 MM / -5 MM)	(2)									
8	PENETRATION / OPENING FOR SERVICES (+10 MM FOR SIZE & +-25 MM FOR LOCATION)	(2)									
9	TOLERANCE FOR LENGTH OF PRECAST MEMBERS (MAJOR DIMENSION) (UP TO 3M:+-6MM), (3M TO 4,5M: +-9MM), (4,5M TO 6 M: +-12MM), ADDITIONAL DEVIATION FOR EVERY SUBSEQUYENT 6M.: +-6MM)	(2)									
10	TOLERANCE FOR DEPARTURE OF ANY POINT FROM ITS POSTITION: 10MM	(2)									
11	BEING PLUMB / PERPENDICULAR (+-3MM)	(1)									
12	TOLERANCE FOR PLUMB: 3MM/M, MAX 20MM	(2)									
13	MAX DEVIATION OF MEAN LEVEL OF STAIRCASE THREAD TO TEMPORARY BENCH MARK: +-5MM	(2)									
14	FOR CAST IN-SITU ELEMENTS, THE DEVIATION OF LEVEL OF ANY POINT FROM THE INTENDED LEVEL : +-10MM	(2)									
15	BEFORE CONCRETING, THE INTERIOR MUST BE FREE FROM DEBRIS	(2)									
16	ALL FORMWORK JOINTS MUST NOT HAVE GAPS TO PREVENT LEAKAGE	(1) (2) (4.A8)									
17	THERE MUST BE ADEQUATE SUPPORT, BRACING AND TIE-BACK FOR THE FORMWORK / SCAFFOLDING TO PREVENT BULGING OR DISPLACEMENT OF STRUCTURAL ELEMENTS	(1) (2) (4.64) (4.A8)									
18	CONSTRUCTION JOINT / EDGE CLEARANCE	(4.103)									
19	FORMWORK POSITION / DIMENSION/ SHAPE / SUPPORT SUITABILITY	(4.103) (4.A8)									
20	EMBEDDING ITEM PLACEMENT AND POSITION	(4.103)									
21	FOUNDATION WORKS FOR ELECTRICITY	(4.103)									
22	MECHANICAL ADVANCE WORK COMPLETION	(4.103)									
23	SETTING OUT	(4.A8)									
24	TOP OF CONCRETE LEVEL READY FOR CASTING	(4.A8)									
25	CHAMFERS	(1) (4.A8)									
26	SCREW JACKS	(4.A8)									
27	SPLICES OF VERTICAL MEMBERS	(4.A8)									
28	WORKING PLATFORMS AND WALKWAYS	(4.A8)									
29	SHUTTERING DIMENSIONS & PLUMB	(4.A13.328)									
30											

	MATERIAL QUALITY INDICATORS	**R.S. ****	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	NON-DEFECTED FORMWORKS	(1) (2)									
2	NON-DEFECTED BELTS / SUPPORTERS	(1)									
3	HIGH-QUALITY FORMWORK OIL USE	(1)									
4											
	SCHEDULED DATE :										
	QUANTITY :										

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

Figure 4.2 An example of developed checklist for conventional formwork works

Data Sources & Collection Methods:

Testing and inspection results, expert opinion, project database, financial database and client opinion were used in this study as data sources. At this point, the project data is collected to populate the checklists. If ***Table 2.14*** (Data sources frequency with respect to metrics in literature) is analyzed, it is seen that testing & inspection results and subjective perception are the two powerful metrics used with standards.

Data Analysis Methods:

Checklists, software-based methods and **mathematical & statistical** methods were used in this study as data analysis methods. In this study, regionally developed checklists were used, different from the literature studies. The reason for that distinction is that standards and norms are variable with respect to different regions.

Quality Tracking System:

Various weightage and quality evaluation systems can be used to measure the contribution of different construction components to the total quality of the end product. CONQUAS and Ong et.al (2018) have developed strong weights for work components by widely-accepted methodologies. The proposed weights by Ong et.al, 2018, the quality evaluation system of CONQUAS (quality assessment system of Singapore Building and Construction Authority) and Quality Included Earned Value Method were used in this study.

Table 2. Weightage system for Quality Performed Assessment Method

Number	Type of work	Weightages	
		Residential building (%)	Commercial building (%)
1.0	Architectural work	50	45
1.1	Floor	7	7
1.2	Internal wall	8	6
1.3	Ceiling	5	4
1.4	Door	5	5
1.5	Window	5	5
1.6	Component	3	4
1.7	Roof	5	4
1.8	Waterproofing	4	3
1.9	External wall (including façade)	5	4
1.10	External work (such as walkway, car park, fencing, etc.)	3	3
2.0	Structural work	40	40
2.1	Formwork	7	7
2.2	Rebar	8	8
2.3	Finished concrete	8	8
2.4	Concrete quality	6	6
2.5	Steel reinforcement quality	5	5
2.6	Testing	6	6
3.0	M&E work	10	15
3.1	Electrical	2	3
3.2	ACMV	2	3
3.3	Fire protection	3	4
3.4	Plumbing and sanitary	1	2
3.5	Basic fittings	2	3

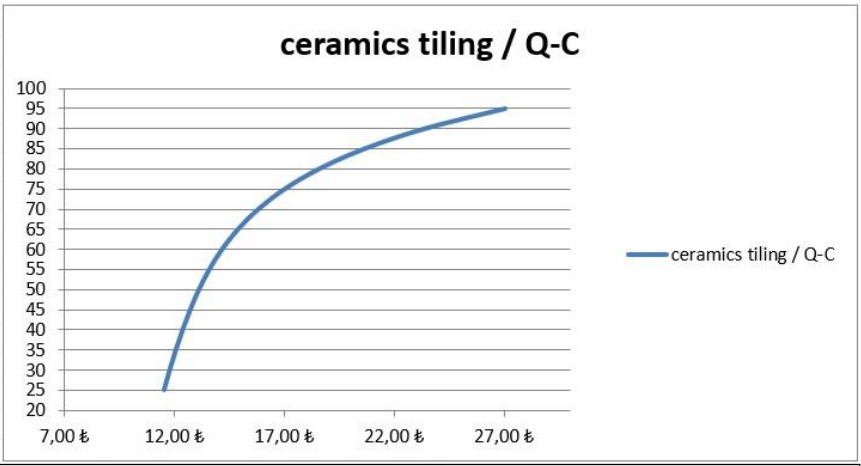
Figure 4.3 Weightage system used in study of Ong et.al, 2018

Derivation of Quality vs. Cost Value Functions:

The quality of a work produced by a worker may vary according to how much care and time the worker allocates to that amount of work. Hence, knowing the sectorial and regional norms, standards, conditions can help identification of target quality values for different work items. In the determination of target quality values, during scheduling stage, the targeted quality values were defined according to derived value functions for certain unit prices or vice versa. That is, according to a decided targeted quality level, corresponding unit price shall be selected from value functions. For each quality level, there is another corresponding unit price as expected since the unit labor cost of consumables increases by increment of the quality.

It shall be noted that, if budget limits have the priority than quality, then the procedure told in upper paragraph shall be applied, in sequence. For example; for ***Figure 4.4***, expecting a quality level of 90/100, while having a cost quota as 12 TL/m^2 for ceramics works is far from reality. That is, if unit price is defined firstly, then quality must be selected with respect to that cost value, given that the quality value will be within acceptable range. However, if client's or owner's quality need has a priority against budget, then firstly quality level can be defined and then corresponding unit cost value can be selected from value functions. If the case is like the second one, i.e., if quality has the priority, then Quality Function Deployment told in part 2.5.2. shall be used to assess target quality as a coherent method. Such target quality values can be assigned according to standards, codes and detailed requirements. Since the budget has the priority in the first three cases and since the targeted quality level is assigned by owner, directly, in the fourth case, QFD could not applied on this study.

QUALITY	COST (TL/m²)
95	27,07
90	23,41
85	20,67
80	18,60
75	17,04
70	15,84
65	14,91
60	14,18
55	13,60
50	13,13
45	12,73
40	12,39
35	12,07
30	11,79
25	11,54



Prices valid for the second half of year 2017

Figure 4.4 Example value function for ceramics tiling works

On the other hand, it must also be noted that, the quality-cost value functions were not derived for a part or complete of project budget; on the contrary, these functions were derived for UNIT PRICES for each lowest-level components of project namely;

individual activities such as, plastering, painting. That is, this part does not imply that a project with $ 100 million shall have more overall quality than one with budget of $ 1 million as can be seen from q-c value functions in Appendix B. On the contrary, for example; let's assume the subcontract unit price of gypsum plastering work of project with $ 1 million budgets (Project A) is 45 TL/ m^2 and it is 12 TL/m^2 for project with $ 100 million budget (Project B). The quality assessment is done for all activities one by one and then these quality values are added to each other with their corresponding project weights coming from CONQUAS & Ong et.al. (2018). Assume that for each activity. Project A has higher unit prices than Project B, the crews with correct work quality capacity were preferred for both of the projects, and there is no extra ordinary conditions. Then, *the overall quality of project* having smaller total budget *(Project A) is expected to be higher than* the one having higher total budget *(Project B)*.

Finally, it is also an important concern that these value functions shall be very dynamic especially in countries having high-rate inflation rates or high fluctuations in prices. Thus, these graphs may be updated in certain periods in order not to mislead the results. Moreover, since each project has its own characteristic and dynamics, these functions may be checked and updated for each project, as well. Inflation effect should be cared and the effects of fluctuation on results shall be excluded if it occurs.

Assessment of the Grade or Level of Quality:

These functions were derived according to integration of interviews with experts, crews and corporate owners and by the help of past data for related works and data from specifications, requirements, codes and standards.

As grade concept, for example; (in the first case) a gypsum plastering work in an unseen place such as in ventilation shaft where a coating on the surface of wall is necessary to be done to just protect the wall with no quality concern (with no quality criteria from specifications such as; vertical or horizontal alignments, setsquare, thick layer etc.) may be done with the lowest price in lowest acceptable level quality, or (as a second case) a gypsum plastering work for a limited-budgeted multi housing project

aiming to complete numerous units with the lowest price in the shortest duration with less quality requirement may allow flexible quality conditions in its specifications (for example, a limit for vertical and horizontal alignments, roughness and setsquare up to 10mm etc.) may be done with a medium-level quality consideration. On the other hand, as a third case, a gypsum plastering work done in a prestige project requiring very high-level quality criteria (such as, at most 1 mm deviation in any direction or alignment for at most a 1m radius of work area) to satisfy the customer shall be done in high-level quality.

Therefore, according to 3 example cases given in previous paragraph, the opinions of all sides (experts, crews and corporate owners etc.) on the expected quality levels and related cost values were taken and, unit price analyses were done according to those opinions for each case one by one. For instance, for the quality of gypsum plastering for ventilation shaft, the sides had discussions and identified a quality value of 25. For that 25-quality value, the subcontractor unit price (included main materials and supplies, labor, machinery, equipment, taxes, general expenses, insurance, financial expenditures, social security, food & beverages, sheltering and subcontractor profit as %15) calculated and the cost is found as 7,95 TL/m². Then these values were face validated by all other sides one more time and verifies as final values. Final corresponding unit cost values and quality levels or grades were calculated as *7,95TL, 11,08 TL, 19,25 TL* per m^2 and *25, 60, 95 quality levels*, respectively.

At the end of this determination, these final calculated results were asked again to related sides to verify them and when every sides considered the related values were logical, then those values were accepted as determined correct results. Then this pricing procedure was performed for various quality requirements of various activities as well. When the corresponding unit cost values were acquired for 7-9 different quality levels for the same work, the other missing values were obtained by interpolation and those graphs were finalized. This procedure was done for 18 different structural and architectural activities seen in Appendix B and Case Study 1. Thus, the grade perception is based on different level of technical characteristics for

different aims of various project types. In this study, the quality (the degree of meeting the requirements) is evaluated within the technical characteristics/ grade level of the project.

Moreover, it is noted that the all derived unit prices for subcontractors (in ***Tables 4.7 & 4.8***) include the labor costs, general expenses, indirect costs and "consumables or supplies" costs as material costs, etc. However; these prices exclude the "main material" prices namely; ceramics, marble, parquet, wallpaper, formwork, rebar, concrete. The reason for this exclusion is that the prices of those main materials ranges a very wide spectrum with respect to their luxury. **Since, luxury is a different concept from quality, those exclusions were decided to be done**.

For example; let's consider two different ceramics produced by the same materials and same inclusions having differences through design and aesthetics perspective leading a price gap among them. Then this difference is sourced from the luxury concept. However; if those ceramics have same design but have different clay and coating materials and different sintering heats, then the price difference sourced by durability difference among them is due to quality difference. Since the difference among quality and luxury concepts is a great topic on its own, it was not gone into details in this study in order not to deviate from the main concept. That difference issue may be another focus for another study.

QEVM Formulation:

Transition to QEVM

As explained in section "2.5.3.Quality Integrated Earned Value Methods" quality component is converted into monetary terms by applying some factors such as; penalty (Solomon P.,J.,2006), a factor coming from quality cost ratio (Gao et.al.,2011) or a factor coming from quality score ratio (Ong et.al.,2018)) such in the first three "transition to QEVM" cases explained in *"the conversion or transition method from classical earned value to quality earned value"* part. Differing from those, Paquin et.al. (2000) calculates quality by directly scoring without transforming into monetary

term explained as in the fourth “transition to QEVM” case. However; cost is also calculated and, targeted quality values were derived by quality-cost relation value functions by interrelating those two components different from that study. The stated literature studies proposed altering QPIs as stated in part 2.5.3. In this study, QPI (Quality Performance Index) = AQWP (Actual Quality Work Performed) / BQWP (Earned Quality – Budgeted Quality Work Performed) was derived different from all other studies.

Classical Terms

Earned Value (EV or BCWP-Budgeted Cost Work Performed) = % complete of work * BCWS (Budgeted Cost Work Scheduled)

Classical Variances

CV (Cost Variance) = EV (Earned Value) – ACWP (Actual Cost Work Performed)

SV (Schedule Variance) = EV (Earned Value) – BCWS (Budgeted Cost Work Scheduled)

Classical Indices

CPI (Cost Performance Index) = EV (Earned Value) / ACWP (Actual Cost Work Performed)

If CPI is less than 1 (< 1), project is over budget. If CPI is greater than 1 (> 1), project is under budget.

SPI (Schedule Performance Index) = EV (Earned Value) / BCWS (Budgeted Cost Work Scheduled)

If SPI is greater than 1(> 1), project is ahead of schedule. If SPI is less than 1(< 1), project is behind schedule.

Derived Term

Earned Quality Value (EQV or BQWP-Budgeted Quality Work Performed) = % complete of work * BQWS (Budgeted Quality Work Scheduled)

$$BQWS = \sum_{i=1}^{I} w_i * TQS_i$$

where w_i is the weight of the i^{th} item and TQS_i is the target quality score of the i^{th} item which is calculated using the Q-C value function.

$$AQWP = \sum_{i=1}^{I} w_i * QS_i$$

Where AQWP is Actual Quality Work Performed, and QS_i is the quality score given by the experts.

Derived Variance

QV (Quality Variance) = EQV (Earned Quality Value or BQWP) – AQWP (Actual Quality Work Performed)

Derived Index

QPI (Quality Performance Index) = EQV (Earned Quality Value or BQWP) / AQWP (Actual Quality Work Performed)

If QPI is less than 1 (<1), project is over quality. If QPI is greater than 1(>1), project is under quality.

Data Communication Methods:

0-10 Likert scale, pass & fail (0&1) scoring methods were used in this study as data scoring methods. **Numerical, tabular & graphical methods** were used in this study as data representation methods.

The use of the framework is detailed in the following case studies.

4.1. Case Study 1

The first case study project is a residential prestige project for a medium-level construction company registered in Ankara, Turkey. The project is located in north-west in Ankara where the typical weather conditions of 4 seasons are observed. The project has started on midyear of 2015 and was going on during the course of this study. The overall estimated cost for construction works (excluded indirect costs and land value) was 60 million TL, having 480 units. By the date of 01.03.2017, the works which were postponed due to harsh winter conditions were started again. The case study was applied on these "after winter works". The complete list of these works can be found in Appendix A. The cost of these works was about 400.000 TL. The related activities for this case study may be seen in ***Table 4.1***.

Table 4.1 The activities list for 1st case study

Category #	Work Category & Type
A	**Structural Works of Roof Flat (Columns and Slab)**
A1	Conventional Formwork
A2	Reinforcement Bar Instalment
A3	Concrete Pouring
B	**Architectural Works**
B.A.	**Floor**
B.A.1	Screed
B.A.2	Ceramics Tiling
B.A.3	Wood Parquet
B.A.4	Marble Slab Covering
B.B.	**Ceiling**
B.B.1	Gypsum Plastering
B.B.2	Painting
B.C.	**Interior Wall**
B.C.1	Gypsum Plastering
B.C.2	Cement Plastering
B.C.3	Ceramics Tiling
B.C.4	Wallpapering
B.D.	**Interior Pumice Wall**
B.E.	**Marble Slab and Stair Covering**

Due to the privacy conditions, the name of the company and project are not declared. The scheduled date for related works was in between 01.03/23.04.2017.

For the site inspections of structural and architectural works, a team was formed consisting of a 14-year experienced civil engineer, a 10-year experienced civil engineer and a 12-year experienced architecture. These 3 quality control members assigned the scorings of related construction activities. Except those 3 experts, a 2-year and a 3-year experienced 2 civil engineers helped the members by inserting the needed tools etc.to inspection lot and taking notes (see ***Figures 4.5 & 4.6***), filling checklists according to experts' ideas. In addition to the expert opinion, numerous test results (see ***Figure 4.7*** and ***Figure 4.8***) were collected.

Figure 4.5 Photos from site inspections

Figure 4.6 Photos from site inspections

BETON BASINÇ DENEY RAPORU

NUMUNE BİLGİLERİ			
ÜRETİCİ FİRMA	. BETON	ALINIŞ TARİHİ	
NUMUNE ŞEKLİ - BOYUTU	150x150x150 mm küp	DÖKÜLEN BETON MİKTARI	450m³
BETON SINIFI	C 35/45	NUMUNEYİ ALAN	
ALINDIĞI YER			

DENEY SONUÇLARI

Sıra	Alınış Saati	Sıcaklık (°C)		Slump (cm)	Beton Yaşı	Deney Tarihi	Kırılma Yükü (N)	Basınç Day. (N/mm²)
		Ortam	Beton					
1	11:35	27,0	24,0	15	7	26.07.2016	845.100	37,60
2	12:00			14	7	26.07.2016	859.800	38,20
3	12:31			15	7	26.07.2016	864.200	38,40
4	12:44			15	7	26.07.2016	825.500	36,70
5	13:00			14	7	26.07.2016	774.000	34,40
6	13:17			15	7	26.07.2016	755.800	33,60

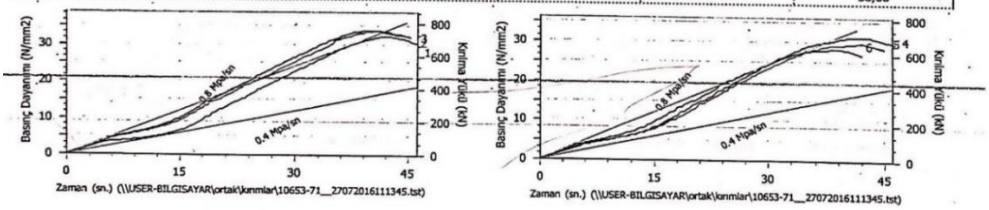


Figure 4.7 Example of results for concrete strength tests

BETON ÇELİK ÇUBUK DENEY RAPORU

NUMUNEYİ ALAN											
İLİŞİYE BİLGİLERİ											
ANMA ÇAPI (mm)	8	12	14	16							
İHRAZAT MİKTARI (ton)											
SAYISI	3	3	3	3							
BOYU (cm)	100	100	100	100							

YAPILAN DENEYLER (TS 708, TS EN ISO 15630-1, TS EN 6892-1' e göre)

DENEY SONUCU BULUNAN DEĞERLER									STANDARDDA İSTENİLEN DEĞERLER						
No	Anma Çapı (mm)	Tipi	Akma Day. (N/mm²)	Çekme Day. (N/mm²)	Çekme Akma Oranı	Re,act / Re,nor	Kopma Uz. (%)	Kütle (Kg/m)	Akma Day. (N/mm²) min.	Çekme Day. (N/mm²) min.	Çekme Akma Oranı min.	Re,act / Re,nor max.	Kopma Uz. (%) min.	Anma Kütlesi (Kg/m)	
														min.	max.
1	8	S420	462	705	1,53	1,10	21,88	0,395	420	500	1,15	1,3	10	0,371	0,418
2	8	S420	455	573	1,26	1,08	22,38	0,402	420	500	1,15	1,3	10	0,371	0,418
3	8	S420	491	599	1,22	1,17	23,62	0,406	420	500	1,15	1,3	10	0,371	0,418
4	12	S420	525	808	1,54	1,25	21,25	0,878	420	500	1,15	1,3	10	0,848	0,927
5	12	S420	527	809	1,53	1,25	22,17	0,882	420	500	1,15	1,3	10	0,848	0,927
6	12	S420	491	809	1,65	1,17	23,08	0,884	420	500	1,15	1,3	10	0,848	0,927
7	14	S420	462	626	1,36	1,10	18,21	1,255	420	500	1,15	1,3	10	1,155	1,264
8	14	S420	459	622	1,35	1,09	19,06	1,250	420	500	1,15	1,3	10	1,155	1,264
9	14	S420	471	734	1,56	1,12	20,21	1,253	420	500	1,15	1,3	10	1,155	1,264
10	16	S420	517	634	1,23	1,23	22,19	1,595	420	500	1,15	1,3	10	1,508	1,651
11	16	S420	452	564	1,25	1,08	22,88	1,598	420	500	1,15	1,3	10	1,508	1,651
12	16	S420	464	601	1,29	1,11	20,81	1,603	420	500	1,15	1,3	10	1,508	1,651

Figure 4.8 Example of results for reinforcement steel strength tests

The related activities were inspected during two months, and the results were recorded into Excel to store and to analyze (see ***Figure 4.9***). When the works were completed and all inspection and testing results were collected, data analysis was performed. The 20-year experienced project manager checked the results and orientated the processes and finally verified results. When the data analysis was combined with quality evaluation weights taken from Ong et.al. (2018) and sub-weights from CONQUAS, the results were generated as shown in ***Table 4.2***.

Assignment of Schedule, Budget & Targeted Quality Concepts:

At initial part of the first three case studies, the budgeting and scheduling were assigned firstly like in the classical EVM procedures. The certain subcontract unit prices were introduced and target dates for all activity types were scheduled and then according to unit prices of subcontractors, the corresponding achievable quality targets were assigned as can be seen in ***Tables 4.2 & 4.3***:

After activity names were created in Column B; Quantity values located in Column C, Unit Prices from contracts of subcontractors in Column E were introduced. By multiplying the Column C (quantity) with Column E (unit prices), the Budgeted Total Cost in Column F were obtained. By adding all total costs for each activities in Column F, the overall Budgeted Total Cost of all project in Cell F8 was obtained as 390.006,23 TL. Then, the quality weights in Column G were calculated according to weights of Ong et.al. (2018) and sub-weights of CONQUAS with respect to quantity proportion. As seen in cell G8, the overall weight is 100% for quality, that is, when all sub weights for quality is added to each other, the result converges to 100.

Then, as can be seen in ***Table 4.3***, The Corresponding Target Quality for Certain Unit Price in Column H was assigned from quality-cost value functions according to Unit Prices located in Column E. Finally, by multiplication of Column G (Weights) with Column H (Individual quality target values for each activity over 100), the weighted quality expectation in Column I (Total Quality Expectation) values were founded. By summing up all the weighted quality contributions, the cumulative "Total Expected Quality" for whole project in cell I8 was calculated as 79,65 / 100.

To introduce the actual results into this Excel Schedule, the same procedure was repeated. Firstly, actual costs and actual dates were entered into the table and when quality assessment was done, the quality values for each activity of each flat were introduced. By the same weightage (since quantities are the same), the actual qualities were multiplied and overall Actual Total Quality of project was assigned as 74,10 as can be seen in ***Table 4.4 & Table 4.5***.

Table 4.2 The high level (Work Level of 1, 2, 3, 4, 5) Budgeting, Scheduling and Assessing Target Quality

WORK LEVEL	ACTIVITY / WORK NAME	QUANTITY	UNIT	UNIT PRICE	BUDGETED COST WORK SCHEDULED (BCWS)	QUALITY WEIGHT (Wi)	TARGET QUALITY SCORE (TQS)	BUDGETED QUALITY WORK SCHEDULED (BQWS)	START DATE	FINISH DATE	TOTAL DURATION
1	TOTAL PROJECT				390.006,23 ₺	100,00%		79,95	01.03.2017	23.04.2017	54
2	BLOCK A				390.006,23 ₺	100,00%		79,95	1.03.2017	23.04.2017	54
3	REINFORCEMENT CONCRETE WORKS				16.755,85 ₺	44,44%		35,86	1.03.2017	15.03.2017	15
3	ARCHITECTURAL WORKS				373.250,38 ₺	55,56%		44,09	4.03.2017	23.04.2017	51
4	FLOOR COVERING WORKS				32.689,46 ₺	11,10%		8,62	13.03.2017	08.04.2017	27
5	Screed Works				16.535,38 ₺	1,89%		1,54	13.03.2017	17.03.2017	5
5	Ceramics Tiling Works				14.653,68 ₺	6,88%		5,40	24.03.2017	07.04.2017	15
5	Wood Parquet Works				696,96 ₺	2,00%		1,44	31.03.2017	08.04.2017	9
5	Marble Slab Works				803,44 ₺	0,33%		0,24	16.03.2017	17.03.2017	2
4	CEILING COVERING WORKS				13.559,98 ₺	7,94%		5,82	4.03.2017	13.04.2017	41
5	Gypsum Plastering Works				11.851,18 ₺	3,97%		2,86	4.03.2017	11.03.2017	8
5	Painting Works				1.708,80 ₺	3,97%		2,96	8.04.2017	13.04.2017	6
4	WALL COVERING WORKS				62.493,56 ₺	12,70%		9,58	6.03.2017	30.03.2017	25
5	Gypsum Plastering Works				32.411,32 ₺	3,34%		2,38	6.03.2017	17.03.2017	12
5	Cement Plastering Works				8.802,32 ₺	3,34%		2,64	11.03.2017	14.03.2017	4
5	Ceramics Tiling Works				5.911,64 ₺	2,32%		1,84	26.03.2017	30.03.2017	5
5	Wallpapering Works				15.368,28 ₺	3,68%		2,72	16.04.2017	23.04.2017	8
4	19CM PUMICE MASONRY				50.309,56 ₺	7,94%		6,56	5.03.2017	16.04.2017	43
5	19CM PUMICE MASONRY				50.309,56 ₺	7,94%		6,56	27.03.2017	01.04.2017	6
4	MARBLE SLAB - CIRCULATION				43.270,26 ₺	7,94%		6,87	5.03.2017	16.04.2017	43
5	MARBLE SLAB - CIRCULATION				43.270,26 ₺	7,94%		6,87	27.03.2017	16.04.2017	21
4	MARBLE STAIR - CIRCULATION				170.927,56 ₺	7,94%		6,64	5.03.2017	16.03.2017	12
5	MARBLE STAIR - CIRCULATION				170.927,56 ₺	7,94%		6,64	5.03.2017	16.03.2017	12

Table 4.3 The Assignment and Creating of Cumulative Target Quality over 100 Point

	B	C	D	E	F	G	H	I
3 4 5	ACTIVITY / WORK NAME	QUANTITY	UNIT	UNIT PRICE	BUDGETED COST WORK SCHEDULED (BCWS)	QUALITY WEIGHT (Wi)	TARGET QUALITY SCORE (TQSi)	BUDGETED QUALITY WORK SCHEDULED (BQWS)
8	TOTAL PROJECT				390.006,23 ₺	100,00%		79,95
9	BLOCK A				390.006,23 ₺	100,00%		79,95
10	REINFORCEMENT CONCRETE WORKS				16.755,85 ₺	44,44%		35,86
19	ARCHITECTURAL WORKS				373.250,38 ₺	55,56%		44,09
20	FLOOR COVERING WORKS				32.689,46 ₺	11,10%		8,62
21	Screed Works				16.535,38 ₺	1,89%		1,54
22	Screed Works - 11th Floor East Flats	298,14	m²	13,91 ₺	4.147,13 ₺	0,47%	81,65	0,39
23	Screed Works - 11th Floor West Flats	296,23	m²	13,91 ₺	4.120,56 ₺	0,47%	81,65	0,38
24	Screed Works - 12th Floor EastFlats	298,14	m²	13,91 ₺	4.147,13 ₺	0,47%	81,65	0,39
25	Screed Works - 12th Floor West Flats	296,23	m²	13,91 ₺	4.120,56 ₺	0,47%	81,65	0,38
26	Ceramics Tiling Works				14.653,68 ₺	6,88%		5,40
31	Wood Parquet Works				696,96 ₺	2,00%		1,44
36	Marble Slab Works				803,44 ₺	0,33%		0,24
39	CEILING COVERING WORKS				13.559,98 ₺	7,94%		5,82
40	Gypsum Plastering Works				11.851,18 ₺	3,97%		2,86
45	Painting Works				1.708,80 ₺	3,97%		2,96
46	Ceiling Painting Works - 11th Floor Ea	142,40	m²	3,00 ₺	427,20 ₺	0,99%	74,91	0,74
47	Ceiling Painting Works - 11th Floor We	142,40	m²	3,00 ₺	427,20 ₺	0,99%	74,91	0,74
48	Ceiling Painting Works - 12th Floor Ea	142,40	m²	3,00 ₺	427,20 ₺	0,99%	74,91	0,74
49	Ceiling Painting Works - 12th Floor We	142,40	m²	3,00 ₺	427,20 ₺	0,99%	74,91	0,74
50	WALL COVERING WORKS				62.493,56 ₺	12,70%		9,58
51	Gypsum Plastering Works				32.411,32 ₺	3,34%		2,38

Table 4.4 The Actual Values and Calculations

WORK LEVEL	ACTIVITY / WORK NAME	QUANTITY	UNIT	ACTUAL AVERAGE UNIT PRICE	ACTUAL COST WORK PERFORMED (ACWP)	QUALITY WEIGHT (Wi)	QUALITY SCORE (QSi)	ACTUAL QUALITY WORK PERFORMED (AQWP)	START DATE	FINISH DATE	TOTAL DURATION
1	TOTAL PROJECT				400.427,61 ₺	100,00%		74,10	05.03.2017	29.04.2017	56
2	BLOCK A				400.427,61 ₺	100,00%		74,10	5.03.2017	15.04.2017	42
3	REINFORCEMENT CONCRETE WORKS				18.109,67 ₺	44,44%		32,60	5.03.2017	18.03.2017	14
3	ARCHITECTURAL WORKS				382.317,94 ₺	55,56%		41,50	6.03.2017	15.04.2017	41
4	FLOOR COVERING WORKS				37.538,64 ₺	11,10%		8,61	10.03.2017	15.04.2017	37
5	Screed Works				20.719,74 ₺	1,89%		1,24	10.03.2017	18.03.2017	9
5	Ceramics Tiling Works				15.442,72 ₺	6,88%		5,79	28.03.2017	11.04.2017	15
5	Wood Parquet Works				644,68 ₺	2,00%		1,31	5.04.2017	15.04.2017	11
5	Marble Slab Works				731,50 ₺	0,33%		0,27	20.03.2017	22.03.2017	3
4	CEILING COVERING WORKS				14.890,58 ₺	7,94%		4,82	6.03.2017	13.04.2017	39
5	Gypsum Plastering Works				12.982,42 ₺	3,97%		2,29	6.03.2017	13.03.2017	8
5	Painting Works				1.908,16 ₺	3,97%		2,53	6.04.2017	13.04.2017	8
4	WALL COVERING WORKS				65.618,32 ₺	12,70%		9,25	11.03.2017	06.04.2017	27
5	Gypsum Plastering Works				34.380,24 ₺	3,34%		2,34	11.03.2017	23.03.2017	13
5	Cement Plastering Works				9.121,44 ₺	3,34%		2,51	12.03.2017	19.03.2017	8
5	Ceramics Tiling Works				6.229,92 ₺	2,32%		1,90	27.03.2017	06.04.2017	11
5	Wallpapering Works				15.886,72 ₺	3,68%		2,50	13.04.2017	21.04.2017	9
4	19CM PUMICE MASONRY				54.120,56 ₺	7,94%		7,17	27.03.2017	29.04.2017	34
5	19CM PUMICE MASONRY				54.120,56 ₺	7,94%		7,17	2.04.2017	13.04.2017	12
4	MARBLE SLAB - CIRCULATION				49.066,84 ₺	7,94%		6,30	27.03.2017	29.04.2017	34
5	MARBLE SLAB - CIRCULATION				49.066,84 ₺	7,94%		6,30	10.04.2017	29.04.2017	20
4	MARBLE STAIR - CIRCULATION				161.083,00 ₺	7,94%		5,35	27.03.2017	14.04.2017	19
5	MARBLE STAIR - CIRCULATION				161.083,00 ₺	7,94%		5,35	27.03.2017	14.04.2017	19

Table 4.5 The Final Actual Values

WORK LEVEL	ACTIVITY / WORK NAME	QUANTITY	UNIT	ACTUAL AVERAGE UNIT PRICE	ACTUAL COST WORK PERFORMED (ACWP)	QUALITY WEIGHT (Wi)	QUALITY SCORE (QSi)	ACTUAL QUALITY WORK PERFORMED (AQWP)
1	TOTAL PROJECT				400.427,61 ₺	100,00%		74,10
2	BLOCK A				400.427,61 ₺	100,00%		74,10
3	REINFORCEMENT CONCRETE WORKS				18.109,67 ₺	44,44%		32,60
3	ARCHITECTURAL WORKS				382.317,94 ₺	55,56%		41,50
4	FLOOR COVERING WORKS				37.538,64 ₺	11,10%		8,61
5	Screed Works				20.719,74 ₺	1,89%		1,24
6	Screed Works - 11th Floor East Flats	298,14	m²	17,43 ₺	5.196,58 ₺	0,47%	65,48	0,31
6	Screed Works - 11th Floor West Flats	296,23	m²	17,43 ₺	5.163,29 ₺	0,47%	67,89	0,32
6	Screed Works - 12th Floor EastFlats	298,14	m²	17,43 ₺	5.196,58 ₺	0,47%	63,12	0,30
6	Screed Works - 12th Floor West Flats	296,23	m²	17,43 ₺	5.163,29 ₺	0,47%	66,45	0,31
5	Ceramics Tiling Works				15.442,72 ₺	6,88%		5,79
5	Wood Parquet Works				644,68 ₺	2,00%		1,31
5	Marble Slab Works				731,50 ₺	0,33%		0,27
4	CEILING COVERING WORKS				14.890,58 ₺	7,94%		4,82
5	Gypsum Plastering Works				12.982,42 ₺	3,97%		2,29
5	Painting Works				1.908,16 ₺	3,97%		2,53
6	Ceiling Painting Works - 11th Floor East Flats	142,40	m²	3,35 ₺	477,04 ₺	0,99%	65,29	0,65
5	Ceiling Painting Works - 11th Floor West Flats	142,40	m²	3,35 ₺	477,04 ₺	0,99%	61,84	0,61
6	Ceiling Painting Works - 12th Floor East Flats	142,40	m²	3,35 ₺	477,04 ₺	0,99%	68,27	0,68
6	Ceiling Painting Works - 12th Floor West Flats	142,40	m²	3,35 ₺	477,04 ₺	0,99%	59,87	0,59
4	WALL COVERING WORKS				65.618,32 ₺	12,70%		9,25
5	Gypsum Plastering Works				34.380,24 ₺	3,34%		2,34

Table 4.6 Weekly and cumulatively derived results for 1st case

WEEKLY PROGRESS	WEEKS	BUDGETED COST WORK SHEDULED (BCWS)	BUDGETED QUALITY WORK SCHEDULED (BQWS)	ACTUAL COST WORK PERFORMED (ACWP)	ACTUAL QUALITY WORK PERFORMED (AQWP)	ACTUAL PROGRESS W.R.T. COST	ACTUAL PROGRESS W.R.T. QUALITY	EARNED VALUE FOR COST W.R.T. TIME (BCWP)	EARNED VALUE FOR QUALITY W.R.T. TIME (BQWP)
	1ST WEEK	80.961,13 ₺	17,32	10.281,04 ₺	7,97	2,57%	10,75%	10.023,16 ₺	8,59
	2nd WEEK	169.919,52 ₺	34,14	51.859,89 ₺	16,56	12,95%	22,35%	50.505,81 ₺	17,87
	3rd WEEK	7.821,20 ₺	0,92	33.904,09 ₺	16,72	8,47%	22,57%	33.033,53 ₺	18,04
	4th WEEK	67.657,37 ₺	12,10	46.995,02 ₺	3,55	11,74%	4,79%	45.786,73 ₺	3,83
	5th WEEK	30.513,22 ₺	7,91	128.633,34 ₺	13,34	32,12%	18,00%	125.270,00 ₺	14,39
	6th WEEK	19.686,54 ₺	5,18	88.917,44 ₺	10,60	22,21%	14,30%	86.620,38 ₺	11,43
	7th WEEK	13.447,25 ₺	2,38	25.116,75 ₺	3,48	6,27%	4,69%	24.453,39 ₺	3,75
	8th WEEK	0,00 ₺	0,00	14.720,05 ₺	1,89	3,67%	2,55%	14.313,23 ₺	2,04
	TOTAL	390.006,23 ₺	79,95	400.427,61 ₺	74,10	100,00%	100,00%	390.006,23 ₺	79,95

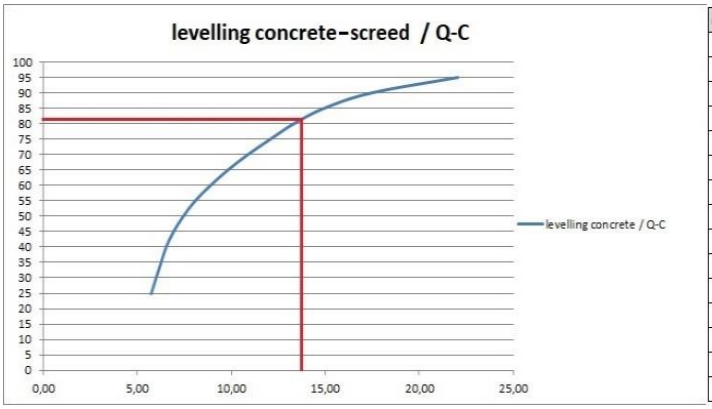
CUMULATIVE PROGRESS	WEEKS	BUDGETED COST WORK SHEDULED (BCWS)	BUDGETED QUALITY WORK SCHEDULED (BQWS)	ACTUAL COST WORK PERFORMED (ACWP)	ACTUAL QUALITY WORK PERFORMED (AQWP)	ACTUAL PROGRESS W.R.T. COST	ACTUAL PROGRESS W.R.T. QUALITY	EARNED VALUE FOR COST W.R.T. TIME (BCWP)	EARNED VALUE FOR QUALITY W.R.T. TIME (BQWP)
	1ST WEEK	80.961,13 ₺	17,32	10.281,04 ₺	7,97	2,57%	10,75%	10.023,16 ₺	8,59
	2nd WEEK	250.880,65 ₺	51,46	62.140,92 ₺	24,53	15,52%	33,10%	60.528,97 ₺	26,46
	3rd WEEK	258.701,85 ₺	52,39	96.045,01 ₺	41,25	23,99%	55,67%	93.562,49 ₺	44,51
	4th WEEK	326.359,22 ₺	64,49	143.040,03 ₺	44,80	35,73%	60,46%	139.349,23 ₺	48,34
	5th WEEK	356.872,44 ₺	72,39	271.673,37 ₺	58,14	67,85%	78,46%	264.619,23 ₺	62,73
	6th WEEK	376.558,99 ₺	77,57	360.590,80 ₺	68,74	90,06%	92,76%	351.239,61 ₺	74,16
	7th WEEK	390.006,23 ₺	79,95	385.707,56 ₺	72,21	96,33%	97,45%	375.693,00 ₺	77,91
	8th WEEK	390.006,23 ₺	79,95	400.427,61 ₺	74,10	100,00%	100,00%	390.006,23 ₺	79,95
	TOTAL	390.006,23 ₺	79,95	400.427,61 ₺	74,10	100,00%	100,00%	390.006,23 ₺	79,95

The yellow-highlighted results shown in ***Table 4.5*** were calculated according to classical EVM rules and schedule (BCWS, ACWP, progress, BCWP). The "quality" included columns which were not highlighted ones were generated with the same manner of cost calculations. That is, in EVM calculations, instead of cost component, quality component inserted and the same calculations were run. This approach -using quality instead of cost- was proposed by Paquin et.al (2000). Thus, earned value data for cost and quality were acquired. On the other hand, for actual quality scoring, Ong et al. (2018) gives 2 gradual scoring to works; if the scoring given during the initial inspection is under 8 point, a second measurement is done. The 70% of first measurement and 30% of second measurement are taken into account as final score. If the initial scoring is equal or more than 8, then that scoring is taken into account without second assessment. In this study, instead of this 2-gradual scoring approach, the last scoring for the last situation of any work is directly taken into account as what its value. For example; if work A costed 1.000 TL was scored as 6,2/10; however, after this scoring if there was a rework and new total cost for work A increased 1.200 TL, and a new scoring for final situation of work was scored as 7,8/10, then 1.200 TL

and 7,8/10 values were taken into account as actual cost and actual quality, respectively.

Identification of the Targeted Quality Values

Ong et.al, 2018 implies that the objective quality score is 8 (by scoring once if result is over8, scoring twice if result is under 8); however, in this study, value functions representing cost vs. quality pairs were derived -instead of taking directly 8 as the target quality- due to the fact that in different levels of cost, different quality levels are obtained. That is, by altering quality level, the unit cost is also differing or vice versa.



QUALITY	COST (TL)
95	22,07
90	17,48
85	14,96
80	13,34
75	12,09
70	10,89
65	9,83
60	8,91
55	8,09
50	7,46
45	6,94
40	6,55
35	6,28
30	6,02
25	5,76

Figure 4.9 Cost vs. quality graph to determine target quality score for screed works

For example, for screed works as shown in ***Figure 4.9***, for the unit price of **13,91 TL/m²** the corresponding targeted quality value is **81,65**.

Those quality vs. cost value functions were derived for numerous activities for Turkey, valid for year 2017 (as subcontractor price) as seen in the ***Tables 4.7 & 4.8***.

Those value functions were derived to use not only for the decision of targeted quality but also for illustration of the optimum quality level for works through cost perspective. In order to illustrate this optimal point, quality-cost increment trend was decided to be analyzed. Firstly, for all activities, the all corresponding unit costs for each quality levels were divided by quality values in order to have the unit cost/quality value for each level as seen in ***Table 4.9 & 4.10***.

Table 4.7 Derived unit costs for certain quality values – 1

QUALITY	UNIT COST (TL/1UNIT)								
	TUNNEL FORMWORK	POURING CONCRETE	REINFORCEMENT	CONVENT. FORMWORK	19CM PUMICE MASONRY	SCREED (LEVELLING CONCRETE)	MARBLE SLAB	MARBLE STAIRHEAD	MARBLE STAIR
95	37,22 TL	8,14 TL	413,46 TL	24,45 TL	23,27 TL	16,07 TL	28,10 TL	42,35 TL	21,04 TL
90	32,77 TL	7,06 TL	371,30 TL	21,99 TL	20,49 TL	14,54 TL	23,95 TL	36,30 TL	18,07 TL
85	29,37 TL	6,24 TL	339,48 TL	20,01 TL	18,68 TL	13,39 TL	20,87 TL	31,74 TL	15,90 TL
80	26,63 TL	5,58 TL	315,59 TL	18,38 TL	17,40 TL	12,46 TL	18,62 TL	28,20 TL	14,21 TL
75	24,34 TL	5,04 TL	297,91 TL	17,06 TL	16,37 TL	11,70 TL	16,98 TL	25,47 TL	12,88 TL
70	22,44 TL	4,61 TL	284,85 TL	15,99 TL	15,51 TL	11,05 TL	15,75 TL	23,41 TL	11,83 TL
65	20,86 TL	4,27 TL	275,22 TL	15,13 TL	14,78 TL	10,48 TL	14,79 TL	21,82 TL	11,00 TL
60	19,55 TL	3,99 TL	268,33 TL	14,45 TL	14,15 TL	9,96 TL	14,01 TL	20,62 TL	10,33 TL
55	18,47 TL	3,78 TL	262,60 TL	13,92 TL	13,59 TL	9,50 TL	13,34 TL	19,65 TL	9,80 TL
50	17,58 TL	3,61 TL	257,63 TL	13,50 TL	13,09 TL	9,08 TL	12,77 TL	18,83 TL	9,36 TL
45	16,84 TL	3,46 TL	253,18 TL	13,18 TL	12,64 TL	8,70 TL	12,27 TL	18,11 TL	8,99 TL
40	16,20 TL	3,34 TL	249,13 TL	12,92 TL	12,23 TL	8,36 TL	11,83 TL	17,46 TL	8,68 TL
35	15,65 TL	3,23 TL	245,37 TL	12,70 TL	11,86 TL	8,07 TL	11,43 TL	16,86 TL	8,39 TL
30	15,15 TL	3,14 TL	241,82 TL	12,51 TL	11,52 TL	7,82 TL	11,07 TL	16,30 TL	8,13 TL
25	14,70 TL	3,07 TL	238,42 TL	12,34 TL	11,20 TL	7,61 TL	10,74 TL	15,73 TL	7,90 TL

Table 4.8 Derived unit costs for certain quality values – 2

QUALITY	UNIT COST (TL/1UNIT)								
	BASEBOARD	CERAMICS TILE	WOOD PARQUET	CEILING PAINTING	WALL PAINTING	CEMENT PLASTER	GYPSUM PLASTER	CEILING GYP.PLAS.	WALL COVERING
95	8,31 TL	27,07 TL	4,88 TL	4,58 TL	5,52 TL	20,66 TL	19,25 TL	12,83 TL	6,79 TL
90	7,24 TL	23,41 TL	4,15 TL	3,95 TL	4,97 TL	17,99 TL	16,73 TL	11,36 TL	5,83 TL
85	6,42 TL	20,67 TL	3,71 TL	3,53 TL	4,60 TL	16,36 TL	15,20 TL	10,32 TL	5,12 TL
80	5,78 TL	18,60 TL	3,41 TL	3,23 TL	4,35 TL	15,22 TL	14,10 TL	9,50 TL	4,58 TL
75	5,27 TL	17,04 TL	3,16 TL	3,03 TL	4,16 TL	14,38 TL	13,20 TL	8,83 TL	4,16 TL
70	4,87 TL	15,84 TL	2,97 TL	2,89 TL	4,00 TL	13,60 TL	12,41 TL	8,29 TL	3,83 TL
65	4,55 TL	14,91 TL	2,80 TL	2,78 TL	3,88 TL	12,90 TL	11,72 TL	7,83 TL	3,56 TL
60	4,31 TL	14,18 TL	2,65 TL	2,69 TL	3,78 TL	12,25 TL	11,08 TL	7,45 TL	3,32 TL
55	4,12 TL	13,60 TL	2,52 TL	2,63 TL	3,70 TL	11,65 TL	10,50 TL	7,12 TL	3,12 TL
50	3,96 TL	13,13 TL	2,41 TL	2,57 TL	3,64 TL	11,10 TL	9,98 TL	6,84 TL	2,93 TL
45	3,84 TL	12,73 TL	2,32 TL	2,52 TL	3,59 TL	10,58 TL	9,49 TL	6,61 TL	2,76 TL
40	3,74 TL	12,39 TL	2,25 TL	2,46 TL	3,55 TL	10,09 TL	9,05 TL	6,41 TL	2,62 TL
35	3,66 TL	12,07 TL	2,19 TL	2,41 TL	3,52 TL	9,67 TL	8,65 TL	6,23 TL	2,48 TL
30	3,58 TL	11,79 TL	2,15 TL	2,37 TL	3,50 TL	9,28 TL	8,27 TL	6,07 TL	2,36 TL
25	3,52 TL	11,54 TL	2,12 TL	2,34 TL	3,48 TL	8,92 TL	7,95 TL	5,92 TL	2,25 TL

Table 4.9 Converted cost index values of unit prices – 1

QUALITY	UNIT COST / QUALITY								
	TUNNEL FORMWORK	POURING CONCRETE	REINFORCEMENT	CONVENT. FORMWORK	19CM PUMICE MASONRY	SCREED (LEVELLING CONCRETE)	MARBLE SLAB	MARBLE STAIRHEAD	MARBLE STAIR
95	0,39	0,09	4,35	0,26	0,24	0,17	0,30	0,45	0,22
90	0,36	0,08	4,13	0,24	0,23	0,16	0,27	0,40	0,20
85	0,35	0,07	3,99	0,24	0,22	0,16	0,25	0,37	0,19
80	0,33	0,07	3,94	0,23	0,22	0,16	0,23	0,35	0,18
75	0,32	0,07	3,97	0,23	0,22	0,16	0,23	0,34	0,17
70	0,32	0,07	4,07	0,23	0,22	0,16	0,23	0,33	0,17
65	0,32	0,07	4,23	0,23	0,23	0,16	0,23	0,34	0,17
60	0,33	0,07	4,47	0,24	0,24	0,17	0,23	0,34	0,17
55	0,34	0,07	4,77	0,25	0,25	0,17	0,24	0,36	0,18
50	0,35	0,07	5,15	0,27	0,26	0,18	0,26	0,38	0,19
45	0,37	0,08	5,63	0,29	0,28	0,19	0,27	0,40	0,20
40	0,41	0,08	6,23	0,32	0,31	0,21	0,30	0,44	0,22
35	0,45	0,09	7,01	0,36	0,34	0,23	0,33	0,48	0,24
30	0,51	0,10	8,06	0,42	0,38	0,26	0,37	0,54	0,27
25	0,59	0,12	9,54	0,49	0,45	0,30	0,43	0,63	0,32

Table 4.10 Converted cost index values of unit prices – 2

QUALITY	UNIT COST / QUALITY								
	BASEBOARD	CERAMICS TILE	WOOD PARQUET	CEILING PAINTING	WALL PAINTING	CEMENT PLASTER	GYPSUM PLASTER	CEILING GYP.PLAS.	WALL COVERING
95	0,09	0,28	0,05	0,05	0,06	0,22	0,20	0,14	0,07
90	0,08	0,26	0,05	0,04	0,06	0,20	0,19	0,13	0,06
85	0,08	0,24	0,04	0,04	0,05	0,19	0,18	0,12	0,06
80	0,07	0,23	0,04	0,04	0,05	0,19	0,18	0,12	0,06
75	0,07	0,23	0,04	0,04	0,06	0,19	0,18	0,12	0,06
70	0,07	0,23	0,04	0,04	0,06	0,19	0,18	0,12	0,05
65	0,07	0,23	0,04	0,04	0,06	0,20	0,18	0,12	0,05
60	0,07	0,24	0,04	0,04	0,06	0,20	0,18	0,12	0,06
55	0,07	0,25	0,05	0,05	0,07	0,21	0,19	0,13	0,06
50	0,08	0,26	0,05	0,05	0,07	0,22	0,20	0,14	0,06
45	0,09	0,28	0,05	0,06	0,08	0,24	0,21	0,15	0,06
40	0,09	0,31	0,06	0,06	0,09	0,25	0,23	0,16	0,07
35	0,10	0,34	0,06	0,07	0,10	0,28	0,25	0,18	0,07
30	0,12	0,39	0,07	0,08	0,12	0,31	0,28	0,20	0,08
25	0,14	0,46	0,08	0,09	0,14	0,36	0,32	0,24	0,09

Afterwards, the average of those values was taken and a trend graph was drawn as seen in ***Figure 4.10***.

QUALITY (Q)	AVERAGE UNIT COST / QUALITY
95	0,42
90	0,40
85	0,38
80	0,37
75	0,37
70	0,38
65	0,39
60	0,40
55	0,43
50	0,46
45	0,50
40	0,55
35	0,61
30	0,70
25	0,82

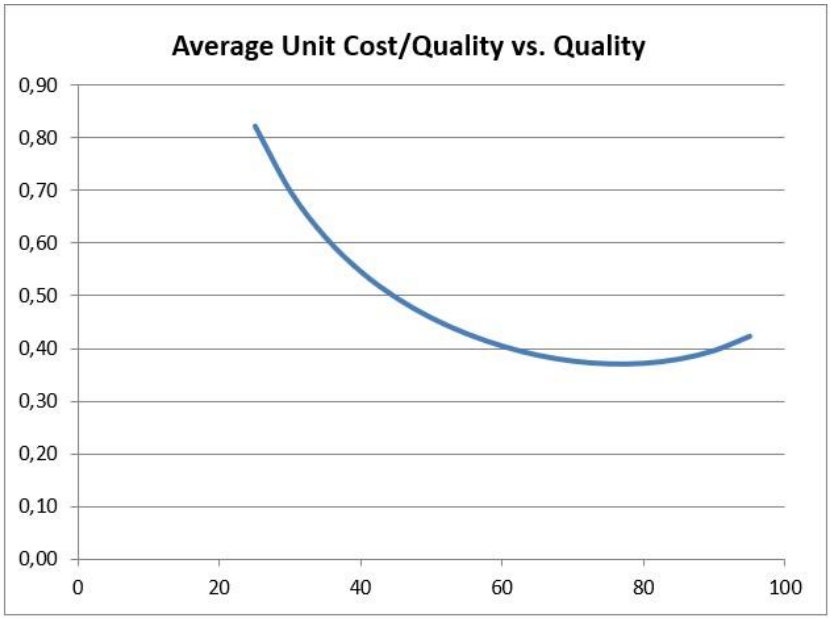


Figure 4.10 Average Unit Cost / Quality vs. Quality graph

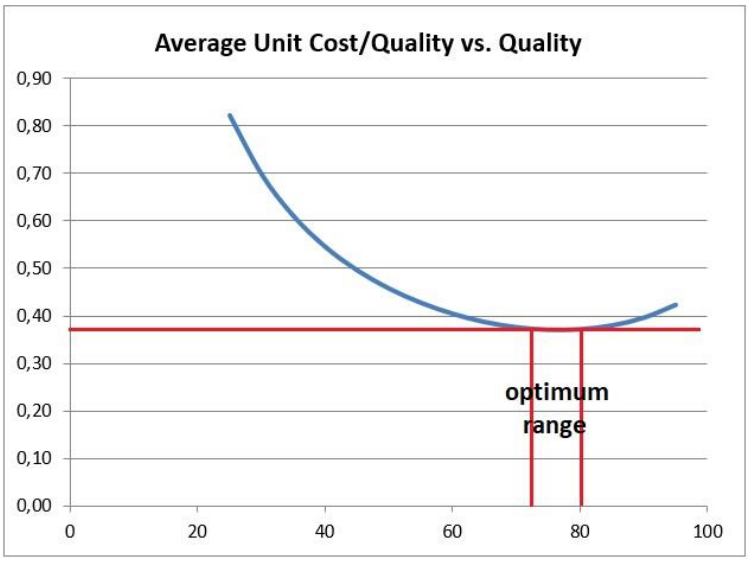


Figure 4.11 Optimum quality increment range through cost component

In ***Figure 4.11***, it is seen that in quality range from 25 to 70, unit quality cost is higher. Between 70-80 quality, the optimum unit quality cost is obtained in terms of quality. After 80 quality to 100, the unit quality cost is increased, as well.

Every owner desire to highest quality with the lowest price; thus, **it is logical to aim 80/100 quality (or 8/10 equivalently) for construction works through cost component.** Therefore, ***Figure 4.12*** verifies the 8/10 target quality of study 130 (Ong et.al, 2018), as well. However, as stated before, the corresponding unit cost value shall be calculated and used for 80/100 quality. If unit cost is defined firstly, then this approach may not be used, the corresponding quality level shall be used as target.

Communication of QEV

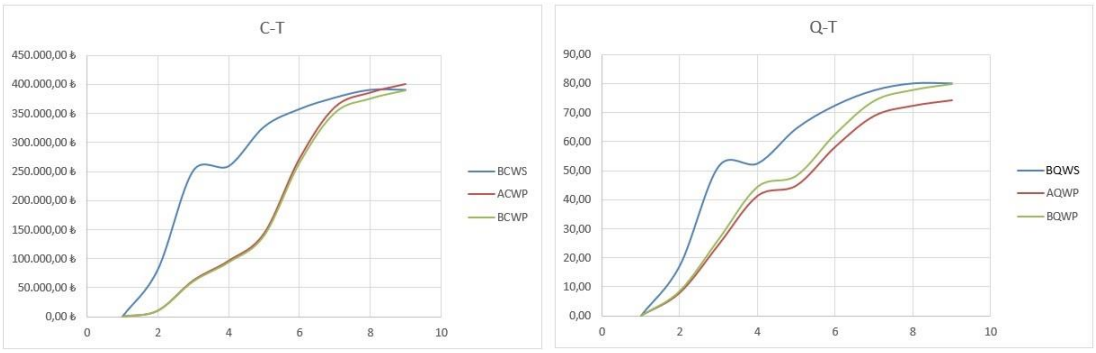


Figure 4.12 Final results for QEVM of Case Study 1

QPI=EQV/AQWP = 79,95/74,10=1,08>1, project is under quality.

Table 4.11 Scheduled and actual results for 1st case

SUMMARY	COST	SCHEDULE	QUALITY
SCHEDULED /BUDGETED	390.006,23 ₺	23.04.2017	79,95
ACTUAL	400.427,61 ₺	29.04.2017	74,10

According to final results in ***Table 4.11***, this project is behind schedule, over budget and under quality which means the **pessimistic** result.

In Figure 4.12, the Quality vs. Time graph also increasing cumulatively from 0 to 74,10. This cumulative increase does not mean the quality of initial works were less

and of the following ones were higher. This cumulative progress occurs since the system was created as quality weightages were distributed according to when whole system is summed the result is 100 as explained in detailed in the part of Assignment of Schedule, Budget & Targeted Quality Concepts in this case study.

This first case study was done in order to verify the first research question which investigates the components of a practical and extendible QEVM framework that can be used for construction projects.

As stated in literature review part, there is also CONQUAS weightage and different types of scoring methods. In first case study, Ong et.al. (2018)'s weightage and "in between 0-10 range" scoring was used. However, in parallel to second research question, different scoring methods shall be tested in order to see the different effects on the result and to decide which weightage and scoring method is more suitable for construction works. Therefore, the second case study was decided to be done.

4.2. Case Study 2

After, case study 1, a second case study was applied on the same Project with same conditions by some modifications on weightage and scoring method in order to check which scoring method gives more suitable result.

When the same scores for **CONQUAS weightage** is used, the actual overall quality is reduced to **69,05** from 74,10.

According to second part of this case, the works were **scored as 1&0 (pass or fail)** instead of 0-10 range scale. The following example can be given in order to explain the scoring logic; if the final score of plastering was 7,5/10 with respect to experts, and the targeted quality was 8/10 according to value functions, then that plastering work for that flat was scored as "0" or in vice versa case, it was scored as "1". According to this scoring, the results shown in ***Tables 4.12 & 4.13***, and ***Figure 4.13*** were obtained.

Table 4.12 According to new scoring method, new values (actual quality value has changed)

CUMULATIVE PROGRESS	WEEKS	BUDGETED COST WORK SCHEDULED (BCWS)	BUDGETED QUALITY WORK SCHEDULED (BQWS)	ACTUAL COST WORK PERFORMED (ACWP)	ACTUAL QUALITY WORK PERFORMED (AQWP)	ACTUAL PROGRESS W.R.T. COST	ACTUAL PROGRESS W.R.T. QUALITY	EARNED VALUE FOR COST (BCWP)	EARNED VALUE FOR QUALITY (BQWP)
	1ST WEEK	80.961,13 ₺	17,32	10.281,04 ₺	3,27	3,00%	8,04%	8.027,88 ₺	8,17
	2nd WEEK	250.880,65 ₺	51,46	62.140,92 ₺	7,16	16,00%	17,62%	51.202,63 ₺	22,98
	3rd WEEK	258.701,85 ₺	52,39	96.045,01 ₺	15,55	24,00%	38,25%	70.708,26 ₺	42,27
	4th WEEK	326.359,22 ₺	64,49	143.040,03 ₺	18,21	36,00%	44,78%	152.575,12 ₺	49,75
	5th WEEK	356.872,44 ₺	72,39	271.673,37 ₺	28,87	68,00%	71,02%	272.765,72 ₺	62,77
	6th WEEK	376.558,99 ₺	77,57	360.590,80 ₺	35,49	90,00%	87,30%	346.297,09 ₺	73,22
	7th WEEK	390.006,23 ₺	79,95	385.707,56 ₺	38,27	96,00%	94,14%	367.724,89 ₺	76,50
	8th WEEK	390.006,23 ₺	79,95	400.427,61 ₺	40,65	100,00%	100,00%	379.044,48 ₺	78,18
	TOTAL	**390.006,23 ₺**	**79,95**	**400.427,61 ₺**	**40,65**	**100,00%**	**100,00%**	**379.044,48 ₺**	**78,18**

Table 4.13 According to new scoring method, actual quality progress variation

SUMMARY	COST	SCHEDULE	QUALITY
SCHEDULED /BUDGETED	390.006,23 ₺	23.04.2017	79,95
ACTUAL	400.427,61 ₺	29.04.2017	40,65

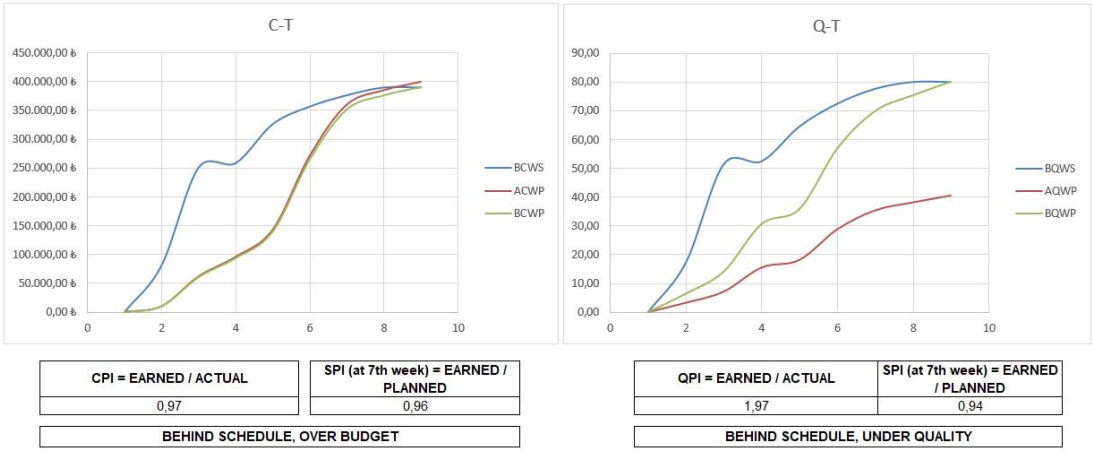


Figure 4.13 The final results according to 2nd case

After changing the scoring method, the final results were the same; this project is behind schedule, over budget and under quality which means the **pessimistic** result.

Comparison of Case Studies 1 and 2:

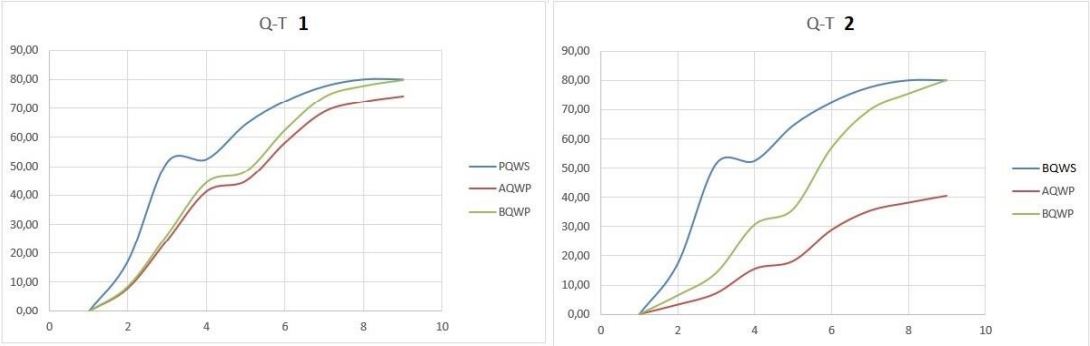


Figure 4.14 The Comparison of Final results for QEVM of Case Studies 1 & 2

Table 4.14 Comparison of scheduled and actual results for the cases 1 & 2

SUMMARY	COST	SCHEDULE	QUALITY
SCHEDULED / BUDGETED	390.006,23 ₺	23.04.2017	79,95
ACTUAL VALUES OF CASE 1	400.427,61 ₺	29.04.2017	**74,10**
ACTUAL VALUES OF CASE 2	400.427,61 ₺	29.04.2017	**40,65**

Table 4.14 reflects the great difference in the results of two case studies, when the quality scoring method is changed from 1-10 Likert Scale to Pass-Fail (0-1) grading. These results were discussed with the project team, according to their expertise; Likert is more suitable. Because they stated that the results acquired for Likert Scale (74) reflects the overall quality of the project better then Pass-Fail (41). Of course, there can be bias towards trying to present a higher scored building. However, during the meetings with the project team, they did not show any reluctance to accept low quality works; hence, the views of the project team has been regarded as a validation for the results.

Moreover, defining the final result by applying Pass-Fail score is very challenging. In this case, the value under the targeted value was considered as fail. However; there is a great range considered as 0 or 1. That is, if the threshold value was 70, then the score

5 and the score 69,9 were also considered as 0 quality, or it is considered as 100% quality even if it is 70,1 or 100. Thus, it did not make sense for experts. For example, in this project, results under 50 was reworked and results over 50 were accepted. Thus, if the threshold was taken as 50/100 then, the whole project would supposed to be a complete quality success as 1 (100/100). However, the actual quality value was 74,1/100 in the first case by scoring in between 0-10 range.

Therefore, according to "pass or fail" scoring method, the actual quality results were decreased dramatically. Both the results of first and second cases were evaluated by all the experts and the second result was considered far away from the reality, and the result of first case was taken into account as a satisfying result. Thus, according to these evaluations, this type of an overall 0&1 scoring for a flat is not appropriate scoring type.

Thus, after this unsatisfying result a third scoring type was needed to be tested and this leads to third case study. However, client and owner opinions were also inserted into the third case study in order to answer the third research question, as well.

4.3. Case Study 3

The change in the scoring method was tested in Case Study 2 and the expert opinions were used for the validation of the results. In this case study, the quality scores were checked against the feedbacks (***Figure 4.16***) that come from clients, experts & owner of the project. In this case, these feedbacks were converted into 0&1 scorings with the logic seen in the ***Figure 4.15***. According to this logic, if there was a complaint that needs rework, this defective area was counted as "0" and the rest quantity for this activity was scored as "1". In this way, activity will have an overall scoring between 0-1, that is, scoring was done as 0 & 1; however, the result was obtained "in between" 0 and 1.

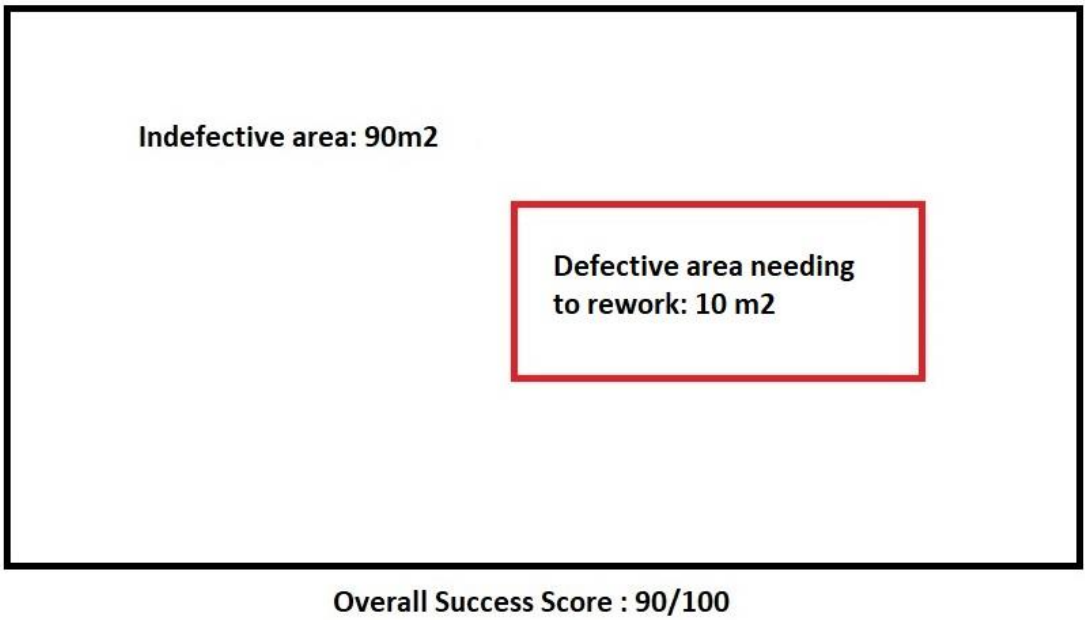
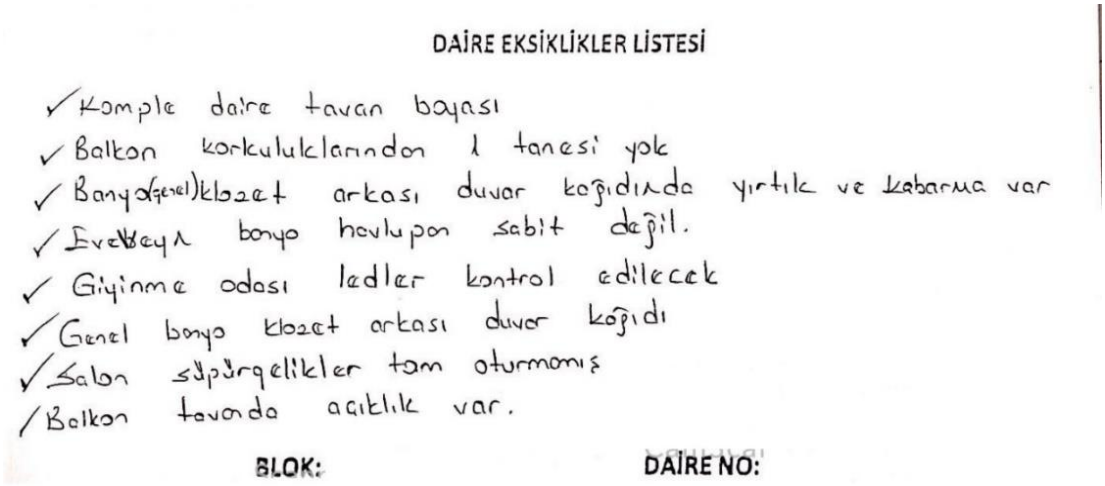


Figure 4.15 Scoring logic with respect to quantity


DAİRE EKSİKLİKLER LİSTESİ

✓ Komple daire tavan boyası
✓ Balkon korkuluklarından 1 tanesi yok
✓ Banyo(genel)kbzet arkası duvar kağıdında yırtık ve kabarma var
✓ Ev/beyaz boyo havlupan sabit değil.
✓ Giyinme odası ledler kontrol edilecek
✓ Genel boyo kbzet arkası duvar kağıdı
✓ Salon süpürgelikler tam oturmamış
✓ Balkon tavanda açıklık var.

BLOK: DAİRE NO:

Figure 4.16 A feedback example from client perspective

According to this scoring method, the results in ***Table 4.15*** were acquired. In this table, the scores according to different perspectives is seen. The results of first column come from owner (28 year-experienced engineer) and the general manager (40 year-experienced engineer) of the company. The second column's feedbacks come from the experts of case study 1. And, finally the feedbacks of third column was from clients.

Table 4.15 Average results for different perspectives

Number	Type of Work	OWNER	EXPERTS	CLIENTS
1.0	**Architectural work**	**80,31**	**80,66**	**85,32**
1.1	**Floor**	**14,71**	**16,11**	**16,85**
	Finishing	4,90	6,01	5,31
	Alignment & Evenness	1,85	1,90	2,45
	Crack & Damages	5,56	6,20	6,10
	Hollowness	1,34	1,37	1,90
	Jointing	1,06	0,64	1,10
1.2	**Internal wall**	**19,87**	**18,91**	**19,85**
	Finishing	3,17	3,83	3,98
	Alignment & Evenness	2,86	2,29	2,34
	Crack & Damages	10,36	9,41	10,24
	Hollowness	1,63	1,56	1,95
	Jointing	1,85	1,83	1,35
1.3	**Ceiling**	**9,74**	**11,17**	**11,87**
	Finishing	0,78	1,45	1,33
	Alignment & Evenness	1,92	2,41	2,84
	Crack & Damages	4,40	4,36	4,50
	Roughness	1,88	2,22	2,44
	Jointing	0,76	0,73	0,75
1.4	**Door**	**12,59**	**12,68**	**13,94**
	Joint & Gap	1,34	1,44	1,44
	Alignment & Evenness	1,39	1,42	1,48
	Material & Damages	3,28	2,56	2,94
	Functionality	3,03	3,47	4,32
	Accessories Defects	3,54	3,79	3,76
1.5	**Window**	**15,10**	**13,46**	**14,70**
	Joint & Gap	1,52	1,52	1,25
	Alignment & Evenness	1,52	1,35	1,52
	Material & Damages	3,73	2,75	3,60
	Functionality	6,06	5,91	6,06
	Accessories Defects	2,27	1,93	2,27
1.6	**Component**	**8,31**	**8,33**	**8,11**
	Joint & Gap	0,80	0,85	0,86
	Alignment & Evenness	1,64	1,71	1,68
	Material & Damages	3,39	3,23	3,07
	Functionality	1,18	1,25	1,24
	Accessories Defects	1,30	1,30	1,26

Six subcategories seen in ***Table 4.16*** for architectural works were used for scoring, since only those ones were commented in the feedbacks.

Table 4.16 Used work components for calculations coming from feedbacks

Table 2. Weightage system for Quality Performed Assessment Method

Number	Type of work	Weightages	
		Residential building (%)	Commercial building (%)
1.0	Architectural work	50	45
1.1	Floor	7	7
1.2	Internal wall	8	6
1.3	Ceiling	5	4
1.4	Door	5	5
1.5	Window	5	5
1.6	Component	3	4
1.7	Roof	5	4
1.8	Waterproofing	4	3
1.9	External wall (including façade)	5	4
1.10	External work (such as walkway, car park, fencing, etc.)	3	3
2.0	Structural work	40	40
2.1	Formwork	7	7
2.2	Rebar	8	8
2.3	Finished concrete	8	8
2.4	Concrete quality	6	6
2.5	Steel reinforcement quality	5	5
2.6	Testing	6	6
3.0	M&E work	10	15
3.1	Electrical	2	3
3.2	ACMV	2	3
3.3	Fire protection	3	4
3.4	Plumbing and sanitary	1	2
3.5	Basic fittings	2	3

The calculations were run as in the ***Table 4.17***. In third column (A), the section overall point (50), and sub-section (7) point is seen. In the fourth column (B), the overall score was converted into 100, and sub-scores were proportioned, as well.

Table 4.17 Details of calculations

Number	Type of Work	Residential Building (%)	Residential Building (%)	FLAT		
1.0	**Architectural work**	**A (50)**	**B (100)**	**C (defect %)**	**D (success %)**	**E (SCORE)**
1.1	Floor	7	21,21212121			**16,94**
	Finishing	2,1	6,363636364	7,00%	93,00%	5,92
	Alignment & Evenness	1,225	3,712121212	41,00%	59,00%	2,19
	Crack & Damages	2,1	6,363636364	18,00%	82,00%	5,22
	Hollowness	0,875	2,651515152	38,00%	62,00%	1,64
	Jointing	0,7	2,121212121	7,00%	93,00%	1,97

The feedbacks as in the ***Figure 4.16***, was converted into defect ratio by proportioning the quantity as defined in ***Figure 4.15***, in the 5th column (C). By subtracting the (C) values from "100%" in the 6th column (D), the success ratio was obtained. Finally, by multiplying (D) with sub-score weight (B), the final scores (E) for each row was calculated.

Table 4.18 Final results for each calculation

#	VALUES FROM	SCORE
1	**BUDGETED QUALITY WORK SCHEDULED (BQWS)**	**79,95**
2	**EXPERTS' ACTUAL QUALITY BY 0-10 RANGE SCORING - FIRST CASE STUDY**	**74,10**
3	**EXPERTS' ACTUAL QUALITY BY 0-10 RANGE SCORING (CONQUAS WEIGHTAGE) - FIRST CASE STUDY**	**69,05**
4	**EXPERTS' ACTUAL QUALITY BY 0 & 1 SCORING FOR WHOLE FLAT - SECOND CASE STUDY**	**40,65**
5	**EXPERTS' ACTUAL QUALITY BY 0 & 1 SCORING FOR LOCAL DEFECTIVE AREA - THIRD CASE STUDY**	**80,66**
	FIRST FLAT OF EXPERTS	81,88
	SECOND FLAT OF EXPERTS	80,35
	THIRD FLAT OF EXPERTS	80,57
	FOURTH FLAT OF EXPERTS	79,83
6	**OWNER & G.M.'S ACTUAL QUALITY BY 0 & 1 SCORING FOR LOCAL DEFECTIVE AREA - THIRD CASE STUDY**	**80,31**
	FIRST FLAT OF OWNER & GM	79,01
	SECOND FLAT OF OWNER & GM	81,53
	THIRD FLAT OF OWNER & GM	80,39
7	**CLIENTS' ACTUAL QUALITY BY 0 & 1 SCORING FOR LOCAL DEFECTIVE AREA - THIRD CASE STUDY**	**85,32**
	FIRST FLAT OF CLIENTS	86,12
	SECOND FLAT OF CLIENTS	86,87
	THIRD FLAT OF CLIENTS	83,15
	FOURTH FLAT OF CLIENTS	87,35
	FIFTH FLAT OF CLIENTS	82,93
	SIXTH FLAT OF CLIENTS	85,52

On the whole, the results which were illustrated as average in ***Table 4.15*** come from ***Table 4.18*** shows that there are differences on results with respect to various scoring type and different perspectives. The targeted quality was 79,95 and the overall actual quality score for case study 1 (for 0-10 Likert scoring) was 74,10. Converted results

from feedbacks by "0&1 for local defective area" scoring results for experts, owner and clients were 80,66, 80,31 and 85,32 in average, respectively. Since owner and general manager of company are also experienced engineers, it is seen that the results of owners and experts were compromised through the specialist window. However, it is also seen that, clients' views bring higher scores since they could not see details or philosophia of works as experts, in detailed.

In comparison, this type 0&1 scoring gave more reasonable result with respect to alternative of case study 2. However, it was the question in this point to prefer which scoring method, namely "0-10 Likert scoring" or "0&1 for local defective area" scoring type. In order to find the answer of this question; random 3 clients, experts, general manager and project manager were interviewed, and they were asked to give an overall score for related works in feedbacks. It is noted that none of the participants knew about those results were coming from calculations, in other words they responded the question as data-blind. Moreover, they did not give a certain score as result except PM, but they did in between some ranges. The answers of clients were about from 70 to 80. The experts thought near 70 – 75 is a good value. The general manager was unsatisfied due to some lack of quality and he gave a range in between 65 – 70. Finally, project manager answered as 75 as overall scoring as seen in ***Table 4.19***.

Table 4.19 Overall scores from interviews for different perspectives

	Clients	**Experts**	**GM**	**PM**
AQWP (Perception)	70-80	70-75	65-70	75

According to these results, simply the arithmetic average gives 75 as overall score. Moreover, all results were around the 75 individually, as well.

Thus, since the result of scoring method of 1st case, "in 0-10 between range" gave the nearest score (74,10), this scoring method was considered as more suitable for construction quality assessment.

Except the overall score, the sub-score average according to defect types may be analyzed by grouping as seen in the ***Table 4.20***. This analysis may also illustrate some defect trends about the related works and provides the owner to take precautions, as well.

According to these values, it is also seen that the roughness, finishing and hollowness were the main defect categories for this project. Jointing also seemed a little problematic. On the other hand, other defect types seemed well.

Table 4.20 Defect ratios

Defect Type	OWNER	EXPERTS	CLIENTS	AVERAGE
Finishing	51,67%	68,55%	64,33%	61,52%
Alignment & Evenness	82,17%	80,90%	88,28%	83,78%
Crack & Damages	93,00%	93,25%	96,22%	94,16%
Hollowness	59,00%	57,94%	75,92%	64,28%
Roughness	49,67%	58,50%	64,50%	57,56%
Jointing	81,78%	73,50%	73,50%	76,26%
Joint & Gap	92,22%	96,25%	90,83%	93,10%
Material & Damages	92,78%	76,25%	85,67%	84,90%
Functionality	84,44%	88,33%	95,28%	89,35%
Accessories Defects	96,11%	93,33%	97,06%	95,50%

4.4. Case Study 4

A final case study was applied in another project to verify the preferences for components of system whether suitable or not, and to develop the "quality productivity" concept.

The second project which this case study was applied on is a residential prestige project for a medium-level construction company registered in Ankara, Turkey, similar to the first company and project. The project is located on south part of Ankara experiencing the typical weather conditions of 4 seasons. The project has started at the beginning of 2017 and was going on during the time of data collection for this research study. The overall estimated cost for construction works (excluded indirect costs and

land value) was 90 million TL, having 390 units. By the date of 20.04.2018, the architectural works was started. The case study was applied on "masonry and gypsum plastering works" of a part of 70 units of project. The cost of these works was about 1,5 million TL. Due to the privacy conditions, the name of the company and project are not be declared. The scheduled date for related works was in between 01.03/23.04.2018.

For the site inspections of related masonry and gypsum plastering works, a team was created consisting of an 11-year experienced civil engineer (the same expert in CS1), a 13-year experienced architecture (the same expert in CS1) and a 14-year experienced construction technician (new member for this case). These 3 quality control members assigned the related scorings for related construction activities. Except those 3 experts, a 3-year and a 5-year experienced 2 civil engineers helped the members by inserting the needed tools etc.to inspection lot and taking notes, filling checklists according to experts' ideas.

New derived Checklists, weightage of Ong et.al (2018), expert opinions, between 0-10 scale scoring, 90/100 targeted quality (owner's preference) and corresponding budgeted costs for this quality target were used for this case.

After data collection and analysis, the findings in ***Tables 4.21, 4.22 & 4.23*** were acquired:

Table 4.21 Weekly progress summary for 4th case

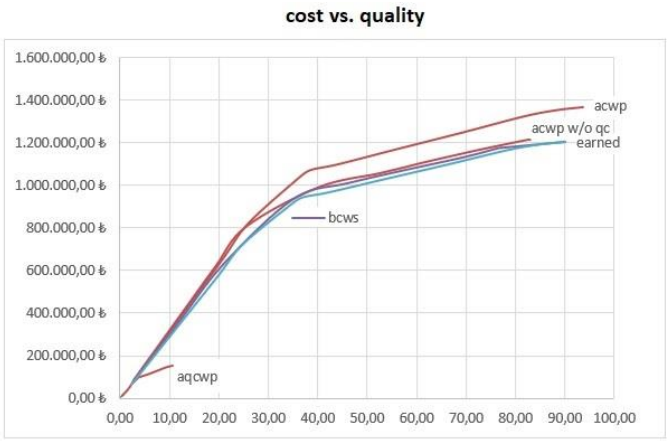
	SUMMARY	BCWS	BUDGETED QUALITY WORK SCHEDULED (BQWS)	PLANNED PROGRESS	ACWP	ACTUAL QUALITY WORK PERFORMED (AQWP)	EARNED VALUE (BCWP)	EARNED VALUE (BQWP)
WEEKLY PROGRESS	1ST WEEK	102.113,87 ₺	3,39	8,50%	75.381,04 ₺	2,40	66.211,51 ₺	2,31
	2nd WEEK	245.690,75 ₺	8,16	20,45%	138.245,62 ₺	4,38	187.699,43 ₺	6,52
	3rd WEEK	281.966,84 ₺	9,36	23,46%	156.275,26 ₺	4,92	325.049,27 ₺	11,24
	4th WEEK	305.882,06 ₺	14,23	25,45%	156.275,26 ₺	4,94	462.399,10 ₺	15,99
	5th WEEK	72.688,69 ₺	10,91	6,05%	140.647,73 ₺	4,42	585.929,84 ₺	20,24
	6th WEEK	60.261,11 ₺	11,35	5,01%	156.275,26 ₺	4,84	723.279,68 ₺	24,89
	7th WEEK	62.344,17 ₺	12,32	5,19%	199.681,53 ₺	9,54	898.722,16 ₺	34,05
	8th WEEK	41.550,47 ₺	6,83	3,46%	48.617,56 ₺	2,89	941.381,13 ₺	36,84
	9th WEEK	1.041,53 ₺	0,48	0,09%	26.659,64 ₺	5,45	964.813,51 ₺	42,08
	10th WEEK	9.373,80 ₺	4,33	0,78%	71.923,37 ₺	12,06	1.028.020,87 ₺	53,67
	11th WEEK	11.456,86 ₺	5,30	0,95%	77.813,52 ₺	13,25	1.096.395,38 ₺	66,40
	12th WEEK	7.290,73 ₺	3,37	0,61%	76.264,00 ₺	12,54	1.163.448,05 ₺	78,46
	13th WEEK	0,00 ₺	0,00	0,00%	29.758,68 ₺	6,68	1.189.644,26 ₺	84,88
	14th WEEK	0,00 ₺	0,00	0,00%	13.945,70 ₺	5,34	1.201.660,87 ₺	90,02
	TOTAL	1.201.660,87 ₺	90,02	100,00%	1.367.764,16 ₺	93,65	1.201.660,87 ₺	90,02

Table 4.22 Cumulative progress summary for 4th case

CUMULATIVE PROGRESS	SUMMARY	BCWS	PQWS	PLANNED PROGRESS	ACWP	AQWP	BCWP	BQWP
	1ST WEEK	102.113,87 ₺	3,39	8,50%	75.381,04 ₺	2,40	66.211,51 ₺	2,31
	2nd WEEK	347.804,61 ₺	11,54	20,45%	213.626,65 ₺	6,78	187.699,43 ₺	6,52
	3rd WEEK	629.771,45 ₺	20,90	23,46%	369.901,91 ₺	11,70	325.049,27 ₺	11,24
	4th WEEK	935.653,51 ₺	35,13	25,45%	526.177,17 ₺	16,64	462.399,10 ₺	15,99
	5th WEEK	1.008.342,20 ₺	46,04	6,05%	666.824,91 ₺	21,06	585.929,84 ₺	20,24
	6th WEEK	1.068.603,31 ₺	57,39	5,01%	823.100,17 ₺	25,90	723.279,68 ₺	24,89
	7th WEEK	1.130.947,48 ₺	69,71	5,19%	1.022.781,70 ₺	35,44	898.722,16 ₺	34,05
	8th WEEK	1.172.497,95 ₺	76,54	3,46%	1.071.399,26 ₺	38,33	941.381,13 ₺	36,84
	9th WEEK	1.173.539,48 ₺	77,02	0,09%	1.098.058,90 ₺	43,78	964.813,51 ₺	42,08
	10th WEEK	1.182.913,28 ₺	81,35	0,78%	1.169.982,27 ₺	55,84	1.028.020,87 ₺	53,67
	11th WEEK	1.194.370,14 ₺	86,65	0,95%	1.247.795,79 ₺	69,09	1.096.395,38 ₺	66,40
	12th WEEK	1.201.660,87 ₺	90,02	0,61%	1.324.059,78 ₺	81,63	1.163.448,05 ₺	78,46
	13th WEEK	1.201.660,87 ₺	90,02	0,00%	1.353.818,47 ₺	88,31	1.189.644,26 ₺	84,88
	14th WEEK	1.201.660,87 ₺	90,02	0,00%	1.367.764,16 ₺	93,65	1.201.660,87 ₺	90,02
	TOTAL	**1.201.660,87 ₺**	**90,02**	**100,00%**	**1.367.764,16 ₺**	**93,65**	**1.201.660,87 ₺**	**90,02**

Table 4.23 Quality cost and without quality cost actual progress values

AQCWP	ACTUAL QUALITY VARIATION WORK PERFORMED (AQVWP)	ACWP (WITHOUT QC)	ACTUAL QUALITY WORK PERFORMED (AQWP) WITHOUT QC
6.934,45 ₺	0,22	85.558,23 ₺	2,73
18.584,50 ₺	0,61	245.451,19 ₺	7,68
30.504,69 ₺	1,17	443.112,36 ₺	13,81
43.320,01 ₺	1,61	623.239,20 ₺	19,39
54.464,41 ₺	2,00	806.609,78 ₺	25,44
69.879,35 ₺	2,44	991.760,78 ₺	40,06
89.958,02 ₺	3,39	1.056.670,69 ₺	52,15
96.006,99 ₺	3,64	1.085.195,95 ₺	57,31
101.714,10 ₺	4,29	1.109.499,13 ₺	61,49
113.284,69 ₺	5,84	1.166.335,31 ₺	72,20
128.084,28 ₺	7,50	1.214.413,08 ₺	82,15
142.170,16 ₺	9,08	1.216.454,71 ₺	83,02
148.021,89 ₺	9,92	1.216.454,71 ₺	83,02
151.309,48 ₺	10,60	1.216.454,71 ₺	83,02
151.309,48 ₺	**10,60**	**1.216.454,71 ₺**	**83,02**

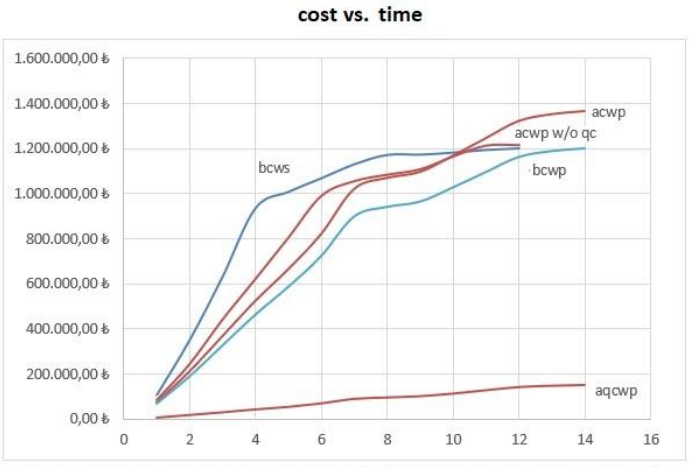


QPI = EARNED / ACTUAL (AT 14TH WEEK)	CPI = EARNED / ACTUAL (AT 14TH WEEK)
0,96	0,88

OVER QUALITY OVER BUDGET

Figure 4.17 CPI and QPI values for 4th case (C vs. Q)

In ***Figure 4.17***, cost vs. quality values are illustrated in graph. The "bcws", "earned" and "acwp" lines are classical representation of EVM; however, in this case, Actual Cost graphs were illustrated as its components; "aqcwp" represents the actual quality cost work performed and "acwp w/o qc" stands for actual cost work performed without quality cost. Thus, the effect of reworks may be tracked in this case.



CPI = EARNED / ACTUAL (AT 14TH WEEK)	SPI = EARNED / PLANNED (AT 12TH WEEK)
0,88	0,97

BEHIND SCHEDULE OVER BUDGET

Figure 4.18 CPI and SPI values for 4th case (C vs. T)

In ***Figure 4.18***, cost vs. time values are illustrated in graph. The "bcws", "bcwp (earned)" and "acwp" lines are classical representation of EVM; however, in this case, Actual Cost graphs were decomposed like in the ***Figure 4.17***. Thus, the effect of reworks in terms of cost and time may be tracked in this graph, as well.

QPI = EARNED / ACTUAL (AT 14TH WEEK)	SPI = EARNED / PLANNED (AT 12TH WEEK)
0,96	0,97

BEHIND SCHEDULE OVER QUALITY

Figure 4.19 QPI and SPI values for 4th case (Q vs. T)

In ***Figure 4.19***, quality vs. time values are illustrated in graph. Actual Qost graphs were decomposed like in the ***Figure 4.17*** as before and after reworks. Thus, the effect of reworks in terms of quality and time may be tracked in this graph, as well.

According to this case study, schedule is behind the planned value for 2 weeks. Quality is over the planned one about 4%, and cost was exceeded by 14%.

Table 4.24 Scheduled and actual results for 4th case

SUMMARY	COST	SCHEDULE	QUALITY
SCHEDULED /BUDGETED	1.201.660,87 ₺	14.07.2018	90,00
ACTUAL	1.367.764,16 ₺	30.07.2018	93,65

Therefore, according to results, the project is behind the schedule. Despite the fact that quality is over the expected value, cost exceeded the budgeted value.

The findings of quality values were asked to and verified by owner's experts who are a 10-year experienced civil engineer and 25-year experienced site technician.

The first part of the Case Study 4 was applied in order to verify the preferences. After this part, this case study was maintained as its second part in order to compare the Quality Cost Included EVM concept in the literature with the one in this case study. Afterwards the third part was maintained in order to improve *"quality productivity"* concept.

For second part of this case, quality cost included EVM concept in the literature with the offered concept of this study.

For the same case, the data in ***Tables 4.21 & 4.22*** were arranged and used as in the ***Tables 4.25 & 4.26***.

Table 4.25 Scheduled and actual results with Quality Cost

CUMULATIVE PROGRESS	SUMMARY	BCWS	BQWS	ACWP (WITH QC)	AQWP	BCWP WITH QC
	1ST WEEK	102.113,87 ₺	3,39	75.381,04 ₺	2,40	66.211,51 ₺
	2nd WEEK	347.804,61 ₺	11,54	213.626,65 ₺	6,78	187.699,43 ₺
	3rd WEEK	629.771,45 ₺	20,90	369.901,91 ₺	11,70	325.049,27 ₺
	4th WEEK	935.653,51 ₺	35,13	526.177,17 ₺	16,64	462.399,10 ₺
	5th WEEK	1.008.342,20 ₺	46,04	666.824,91 ₺	21,06	585.929,84 ₺
	6th WEEK	1.068.603,31 ₺	57,39	823.100,17 ₺	25,90	723.279,68 ₺
	7th WEEK	1.130.947,48 ₺	69,71	1.022.781,70 ₺	35,44	898.722,16 ₺
	8th WEEK	1.172.497,95 ₺	76,54	1.071.399,26 ₺	38,33	941.381,13 ₺
	9th WEEK	1.173.539,48 ₺	77,02	1.098.058,90 ₺	43,78	964.813,51 ₺
	10th WEEK	1.182.913,28 ₺	81,35	1.169.982,27 ₺	55,84	1.028.020,87 ₺
	11th WEEK	1.194.370,14 ₺	86,65	1.247.795,79 ₺	69,09	1.096.395,38 ₺
	12th WEEK	1.201.660,87 ₺	90,02	1.324.059,78 ₺	81,63	1.163.448,05 ₺
	13th WEEK	1.201.660,87 ₺	90,02	1.353.818,47 ₺	88,31	1.189.644,26 ₺
	14th WEEK	1.201.660,87 ₺	90,02	1.367.764,16 ₺	93,65	1.201.660,87 ₺
	TOTAL	**1.201.660,87 ₺**	**90,02**	**1.367.764,16 ₺**	**93,65**	**1.201.660,87 ₺**

Table 4.26 Scheduled and actual results without Quality Cost

CUMULATIVE PROGRESS	SUMMARY	BCWS (SCHEDULED)	BQWS	ACWP (WITHOUT QC)	ACTUAL QUALITY WORK PERFORMED (AQWP) WITHOUT QC	BCWP W/O QC	BCWP WITH QC IN LITERATURE
	1ST WEEK	102.113,87 ₺	3,39	85.558,23 ₺	2,73	84.517,72 ₺	73.875,50 ₺
	2nd WEEK	347.804,61 ₺	11,54	245.451,19 ₺	7,68	242.466,15 ₺	211.935,55 ₺
	3rd WEEK	629.771,45 ₺	20,90	443.112,36 ₺	13,81	437.723,48 ₺	382.606,67 ₺
	4th WEEK	935.653,51 ₺	35,13	623.239,20 ₺	19,39	615.659,71 ₺	538.137,71 ₺
	5th WEEK	1.008.342,20 ₺	46,04	806.609,78 ₺	25,44	796.800,24 ₺	696.469,58 ₺
	6th WEEK	1.068.603,31 ₺	57,39	991.760,78 ₺	40,06	979.699,54 ₺	856.338,75 ₺
	7th WEEK	1.130.947,48 ₺	69,71	1.056.670,69 ₺	52,15	1.043.820,05 ₺	912.385,41 ₺
	8th WEEK	1.172.497,95 ₺	76,54	1.085.195,95 ₺	57,31	1.071.998,41 ₺	937.015,63 ₺
	9th WEEK	1.173.539,48 ₺	77,02	1.109.499,13 ₺	61,49	1.096.006,02 ₺	958.000,28 ₺
	10th WEEK	1.182.913,28 ₺	81,35	1.166.335,31 ₺	72,20	1.152.150,99 ₺	1.007.075,64 ₺
	11th WEEK	1.194.370,14 ₺	86,65	1.214.413,08 ₺	82,15	1.199.644,07 ₺	1.048.588,54 ₺
	12th WEEK	1.201.660,87 ₺	90,02	1.216.454,71 ₺	83,02	1.201.660,87 ₺	1.050.351,39 ₺
	13th WEEK	1.201.660,87 ₺	90,02	1.216.454,71 ₺	83,02	1.201.660,87 ₺	1.050.351,39 ₺
	14th WEEK	1.201.660,87 ₺	90,02	1.216.454,71 ₺	83,02	1.201.660,87 ₺	1.050.351,39 ₺
	TOTAL	1.201.660,87 ₺	90,02	1.216.454,71 ₺	83,02	1.201.660,87 ₺	1.050.351,39 ₺

The actual quality cost 151.309,48 TL is divided by budgeted cost (1.201.660,87 TL) in order to find the ratio of quality cost to budgeted value as 12,59%. Afterwards 100%-12,59% = 87,41% value was founded and multiplied by the Earned Value (BCWP W/O QC column of ***Table 4.21***) in order to have the Earned Value including Quality Cost concept (BCWP WITH QC IN LITERATURE column of ***Table 4.21***) according to QPI definition of Khalid and Yeoh (2015, p.278) and also QEV definition of Miguel, Madria and Polancos (2019, p.624). After finding the Earned Value amounts according to approaches of this study and Khalid et.al. (2015) and Miguel et.al (2019), the graphs for them were drawn in order to compare the results, representatively as in the ***Figures 4.20 & 4.21.***

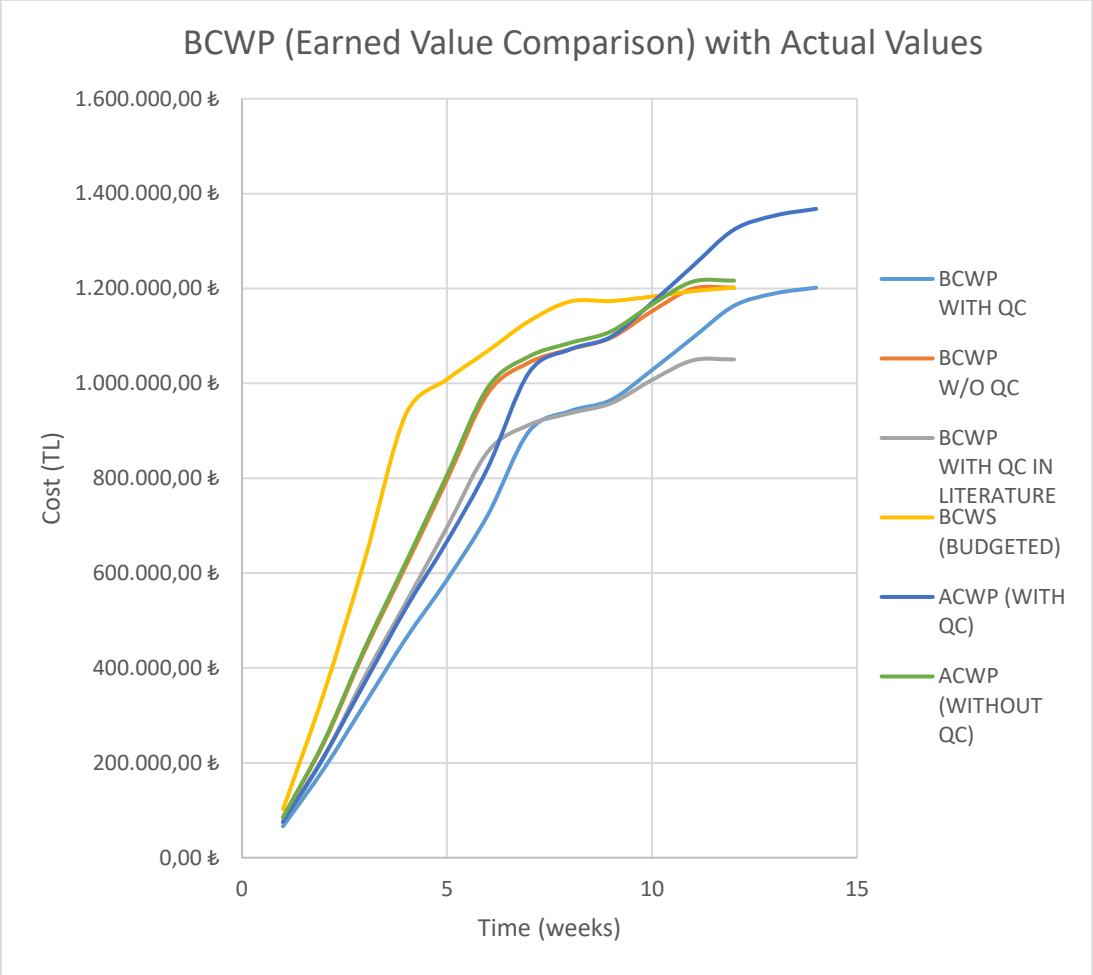


Figure 4.20 Actual, Budgeted and Earned Values

In ***Figure 4.20***; BCWS is the classical EVM approach for budgeted cost work scheduled, BCWP without QC represents the Earned Value before reworks, ACWP with QC shows the whole actual costs including reworks and ACWP with QC stands for the actual costs except reworks. Those values were inserted this graph in order to visualize the differences. The other two lines "BCWP with QC" and "BCWP with QC in literature" represents the two final Earned Value results for different approach. Let analyze them in ***Figure 4.21***, separately.

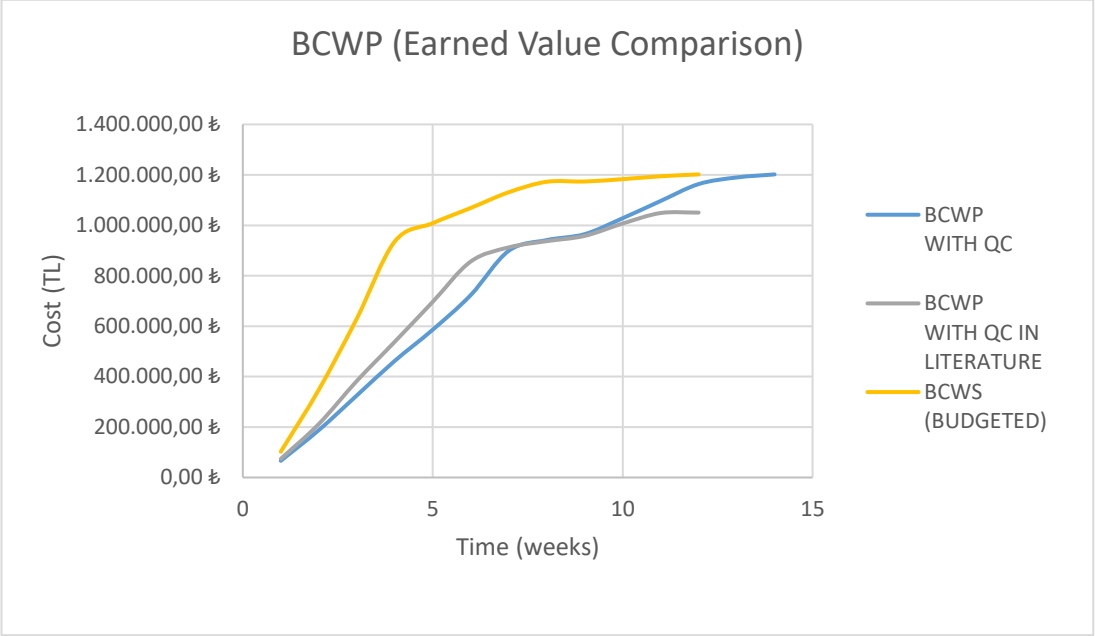


Figure 4.21 Earned Value Comparison of this study and literature

Consequently, as shown in ***Figure 4.21***, the "BCWP WITH QC" graph offered by this study was coming from the detailed tracked work and rework data week by week and reflecting the exact data, not approximate. However, BCWP WITH QC IN LITERATURE graph was created with the data coming from generalization approach (multiplied Earned Value with Quality Cost ratio). Multiplying the Quality Cost success ratio with Earned Value result is giving an approximate result, because there is a generalization approach in its philosophy. Thus, as also can be seen from the graph, there is a certain difference sourcing from this generalization and this study proposes a more accurate result in order to eliminate this deviation.

For third part of this case, cost of failure or cost of loss (component of quality cost) was calculated separately by keeping the data related with rework such as; manhours, daily wages and indirect costs. Afterwards, a new trend was tried to be created named as **"productivity of quality"**. This definition serves the unit quality per man-day. Moreover, **"cost of unit quality"** concept was also developed as cost / unit quality. This trend illustrates the "quality productivity of crews" and "the cost paid to crews

to improve the quality of work", and helps to owner as beneficial indicators in tracking crew's labor productivity.

The data related with work details of two different gypsum plastering crews were kept to analyze and to develop the concepts. The first crew worked on their first flat, and then moved on the second flat. At the end of the machinery plastering, and manual plastering of first flat, the expert team scored the related works and asked for improvement. While a part of first crew continued the initial works of second flat, several workers come back to first flat for reworks. Then, after improvements and reworks, expert team has scored again the first flat and accepted the gypsum plastering works. However, at this moment, since it was realized that the unit cost of work was exceeded with respect to contract value due to lack of labor quality capacity of first crew, a second crew was negotiated as precaution. While the first crew was finishing the second flat works, the second new crew started the work at their first floor in another block of project. When the first crew completed their second flat works, the expert team did not accept the work quality and reworks were done. At that moment, second crew also completed their first flat works and experts scored the work quality. The initial work quality of second crew was observed having higher value than the first crew's one. However, this work also needed less improvements for minor errors. While first crew completed their reworks for their second flat, the second crew also completed their reworks for first flat and experts scored the works, as well.

When the first crew's works for 2 flats were compared with second crew's results, it was seen that first crew's labor quality capacity was less than the second crew's one which was leading to cost overrun. Thus, the first crew's contract was cancelled.

Table 4.27 Daily and cumulative progress of 1st crew for 1st & 2nd flats

1st CREW - 1st FLAT	1st CREW - 1st FLAT (Daily Progress)							1st CREW - 1st FLAT (Cumulative Progress)						
		DAY	COST	QUALITY		DAY	COST	QUALITY		DAY	COST	QUALITY		DAY	COST	QUALITY
	INITIAL GYP.PLAST. WORK	1	2.120,00 ₺	14,69	REWORK	8	1.060,00 ₺	2,57	INITIAL GYP.PLAST. WORK	1	2.650,00 ₺	14,69	REWORK	8	15.900,00 ₺	78,3
		2	2.385,00 ₺	16,52		9	1.325,00 ₺	3,22		2	4.505,00 ₺	31,21		9	17.225,00 ₺	81,52
		3	2.385,00 ₺	16,52		10	1.325,00 ₺	3,22		3	6.890,00 ₺	47,73		10	18.550,00 ₺	84,74
		4	2.385,00 ₺	8,4		11	1.060,00 ₺	2,57		4	9.275,00 ₺	56,13		11	19.610,00 ₺	87,31
		5	2.385,00 ₺	8,4		12	530,00 ₺	1,29		5	11.660,00 ₺	64,53		12	20.140,00 ₺	88,6
		6	2.120,00 ₺	7,47						6	13.780,00 ₺	72				
		7	1.060,00 ₺	3,73						7	14.840,00 ₺	75,73				
		TOTAL	**14.840,00 ₺**	**75,73**		**TOTAL**	**5.300,00 ₺**	**12,87**		**TOTAL**	**14.840,00 ₺**	**75,73**		**TOTAL**	**20.140,00 ₺**	**88,6**
	COST / QUALITY			**195,96 ₺**	**COST / QUALITY**			**411,81 ₺**	**COST / QUALITY**			**195,96 ₺**	**COST / QUALITY**			**411,81 ₺**
	TOTAL COST			**20.140,00 ₺**	**TOTAL QUALITY**			**88,6**	**AVERAGE COST / QUALITY**							**227,31 ₺**

1st CREW - 2nd FLAT	1st CREW - 2nd FLAT (Daily Progress)							1st CREW - 2nd FLAT (Cumulative Progress)						
		DAY	COST	QUALITY		DAY	COST	QUALITY		DAY	COST	QUALITY		DAY	COST	QUALITY
	INITIAL GYP.PLAST. WORK	1	2.385,00 ₺	15,39	REWORK	8	1.325,00 ₺	3,86	INITIAL GYP.PLAST. WORK	1	2.650,00 ₺	15,39	REWORK	8	16.695,00 ₺	78,53
		2	2.385,00 ₺	15,39		9	1.060,00 ₺	3,09		2	4.770,00 ₺	30,78		9	17.755,00 ₺	81,62
		3	2.385,00 ₺	15,39		10	1.060,00 ₺	3,09		3	7.155,00 ₺	46,17		10	18.815,00 ₺	84,71
		4	2.385,00 ₺	8,27		11	795,00 ₺	2,32		4	9.540,00 ₺	54,44		11	19.610,00 ₺	87,03
		5	2.385,00 ₺	8,27		12	530,00 ₺	1,54		5	11.925,00 ₺	62,71		12	20.140,00 ₺	88,57
		6	1.855,00 ₺	6,44						6	13.780,00 ₺	69,15				
		7	1.590,00 ₺	5,52						7	15.370,00 ₺	74,67				
		TOTAL	**15.370,00 ₺**	**74,67**		**TOTAL**	**4.770,00 ₺**	**13,9**		**TOTAL**	**15.370,00 ₺**	**74,67**		**TOTAL**	**20.140,00 ₺**	**88,57**
	COST / QUALITY			**205,84 ₺**	**COST / QUALITY**			**343,17 ₺**	**COST / QUALITY**			**205,84 ₺**	**COST / QUALITY**			**343,17 ₺**
	TOTAL COST			**20.140,00 ₺**	**TOTAL QUALITY**			**88,57**	**AVERAGE COST / QUALITY**							**227,39 ₺**

Table 4.28 Daily and cumulative progress of 2nd crew for 1st & 2nd flats

2nd CREW - 1st FLAT	2nd CREW - 1st FLAT (Daily Progress)							2nd CREW - 1st FLAT (Cumulative Progress)						
		DAY	COST	QUALITY		DAY	COST	QUALITY		DAY	COST	QUALITY		DAY	COST	QUALITY
	INITIAL GYP.PLAST. WORK	1	2.650,00 ₺	14,52	REWORK	7	530,00 ₺	2,05	INITIAL GYP.PLAST. WORK	1	2.650,00 ₺	14,52	REWORK	7	14.840,00 ₺	87,13
		2	2.650,00 ₺	14,52		8	530,00 ₺	2,05		2	5.300,00 ₺	29,04		8	15.370,00 ₺	89,18
		3	2.650,00 ₺	14,52		9	530,00 ₺	2,05		3	7.950,00 ₺	43,56		9	15.900,00 ₺	91,23
		4	2.650,00 ₺	14,52						4	10.600,00 ₺	58,08				
		5	2.650,00 ₺	19,29						5	13.250,00 ₺	77,37				
		6	1.060,00 ₺	7,71						6	14.310,00 ₺	85,08				
		TOTAL	14.310,00 ₺	85,08		TOTAL	1.590,00 ₺	6,15		TOTAL	14.310,00 ₺	85,08		TOTAL	15.900,00 ₺	91,23
	COST / QUALITY			168,19 ₺		COST / QUALITY		258,54 ₺		COST / QUALITY		168,19 ₺		COST / QUALITY		258,54 ₺
	TOTAL COST			15.900,00 ₺		TOTAL QUALITY		91,23		AVERAGE COST / QUALITY					174,28 ₺	

2nd CREW - 2nd FLAT	2nd CREW - 2nd FLAT (Daily Progress)							2nd CREW - 2nd FLAT (Cumulative Progress)						
		DAY	COST	QUALITY		DAY	COST	QUALITY		DAY	COST	QUALITY		DAY	COST	QUALITY
	INITIAL GYP.PLAST. WORK	1	2.650,00 ₺	14,23	REWORK	7	795,00 ₺	2,81	INITIAL GYP.PLAST. WORK	1	2.650,00 ₺	14,23	REWORK	7	14.575,00 ₺	86,73
		2	2.650,00 ₺	14,23		8	795,00 ₺	2,81		2	5.300,00 ₺	28,46		8	15.370,00 ₺	89,54
		3	2.650,00 ₺	14,23		9	795,00 ₺	2,81		3	7.950,00 ₺	42,69		9	16.165,00 ₺	92,35
		4	2.650,00 ₺	14,23						4	10.600,00 ₺	56,92				
		5	2.385,00 ₺	20,25						5	12.985,00 ₺	77,17				
		6	795,00 ₺	6,75						6	13.780,00 ₺	83,92				
		TOTAL	13.780,00 ₺	83,92		TOTAL	2.385,00 ₺	8,43		TOTAL	13.780,00 ₺	83,92		TOTAL	16.165,00 ₺	92,35
	COST / QUALITY			164,20 ₺		COST / QUALITY		282,92 ₺		COST / QUALITY		164,20 ₺		COST / QUALITY		282,92 ₺
	TOTAL COST			16.165,00 ₺		TOTAL QUALITY		92,35		AVERAGE COST / QUALITY					175,04 ₺	

Table 4.29 Average progress of crews for 2 flats and related data of capacity

1st CREW - AVERAGE

1st CREW - AVERAGE (Cumulative Progress)

	DAY	COST	QUALITY		DAY	COST	QUALITY
MACHINERY(c1)	1	2.650,00 ₺	15,04	REWORK(c1)	8	16.297,50 ₺	78,415
	2	4.637,50 ₺	31		9	17.490,00 ₺	81,57
	3	7.022,50 ₺	46,95		10	18.682,50 ₺	84,725
MANUAL(c1)	4	9.407,50 ₺	55,29		11	19.610,00 ₺	87,17
	5	11.792,50 ₺	63,62		12	20.140,00 ₺	88,585
	6	13.780,00 ₺	70,58				
	7	15.105,00 ₺	75,2				
	TOTAL	**15.105,00 ₺**	**75,2**		**TOTAL**	**20.140,00 ₺**	**88,585**
COST / QUALITY			**200,86 ₺**	**COST / QUALITY**			**377,49 ₺**
TOTAL COST			**20.140,00 ₺**	**TOTAL QUALITY**			**88,585**
AVERAGE COST / QUALITY (quality productivity)						**227,35 ₺**	

work productivity = 1.100 m² / 76 worker-day = 14,47 m²/manday
unit work cost = 20.140 TL / 1.100 m² = 18,31 TL/m²
quality productivity = 88,59 quality / 76 worker-day = 1,17 q/manday
unit quality cost = 20.140 TL / 88,59 quality = 227,35 TL/quality

2nd CREW - AVERAGE

2nd CREW - AVERAGE (Cumulative Progress)

	DAY	COST	QUALITY		DAY	COST	QUALITY
MACHINERY(c2)	1	2.650,00 ₺	14,38	REWORK(c2)	7	14.707,50 ₺	86,93
	2	5.300,00 ₺	28,75		8	15.370,00 ₺	89,36
	3	7.950,00 ₺	43,13		9	16.032,50 ₺	91,79
	4	10.600,00 ₺	57,5				
MANUAL(c2)	5	13.117,50 ₺	77,27				
	6	14.045,00 ₺	84,5				
	TOTAL	**14.045,00 ₺**	**84,5**		**TOTAL**	**16.032,50 ₺**	**91,79**
COST / QUALITY			**166,21 ₺**	**COST / QUALITY**			**270,73 ₺**
TOTAL COST			**16.032,50 ₺**	**TOTAL QUALITY**			**91,79**
AVERAGE COST / QUALITY (quality productivity)						**174,66 ₺**	

work productivity = 1.100 m² / 60,5 worker-day = 18,18 m²/manday
unit work cost = 16.032,50 TL / 1.100 m² = 14,56 TL/m²
quality productivity = 91,78 quality / 60,5 worker-day = 1,52 q/manday
unit quality cost = 16.032,50 TL / 91,78 quality = 174,66 TL/quality

According to ***Table 4.29***, the overall capacity of quality productivity of first crew is less than the second's one. While, a worker of first crew produces 1,17-unit quality in a working day, a worker of second crew may produce 1,52-unit quality in a day.

Moreover, a unit quality produced by first crew costs 227,35 TL; however, the cost of unit quality is 174,66 TL, in average.

Thus, it is clearly seen that, the second crew is capable to produce more quality with less cost with respect to second crew, on total.

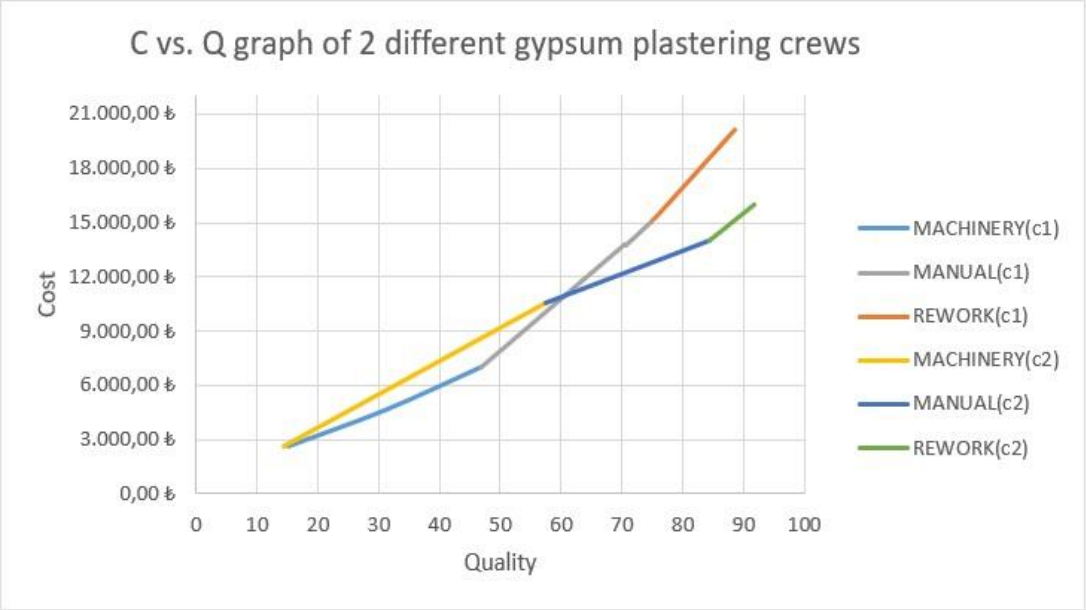


Figure 4.22 Cost vs. Quality graph of 1st & 2nd crews

A very important finding for this second part of the 4th case study is that this part proves that work productivity and quality productivity are not only different but also intimate concepts. That is, they are both dependent to each other. Work productivity shall not be analyzed without quality productivity concept. Actually, the work productivity is affected and shaped by quality productivity as can be seen from ***Figure 4.22***. The expected or targeted quality defines the need of the amount of how many man-days to consume for related work. The work productivity shall be defined for a

certain quality target. That is, for each targeted quality value, there is a corresponding work productivity value. Moreover, since quality concept affects the work productivity; quality capacity of workers is in the concern, yet. Thus, the dependency of quality productivity and work productivity to each other is the deduction from this part. For example; in 4th case, the first crew was decided as infeasible for higher quality works more than about 65 point; however, on the other hand, it is also correct that the second crew seems unfeasible for the gypsum plastering works needing under 65 quality scores such as; warehouses, industrial constructions where needing less quality more functionality. It is seen that, for works of such warehouses which does not need higher level quality of labor, crews such first one is more feasible with respect to second one. However, for prestige projects needing higher level of labor quality such as, residential, commercial, shopping malls, hotels or residences etc. the crews such second one having more capacity to produce more quality levels of labor with less cost is more feasible.

Finally, EVM values for each subcontractor / crew were illustrated, separately in this part. In literature, there is no separate illustration and it was considered the separate representation will be beneficial in order to analyze crews independent from each other. This separate analysis approach enables the owner to see the source of problems in terms of crew or subcontractor and to take precautions at early stages. The data seen in ***Tables 4.30, 4.31, 4.32 & 4.33*** were drawn as graph in ***Figures 4.23 & 4.24***.

Table 4.30 Data for masonry crew

CUMULATIVE PROGRESS FOR CREW OF MASONRY WORKS	WEEKS	BUDGETED COST WORK SCHEDULED (BCWS)	BUDGETED QUALITY WORK SCHEDULED (BQWS)	ACTUAL COST WORK PERFORMED (ACWP)	ACTUAL QUALITY WORK PERFORMED (AQWP)	ACTUAL PROGRESS W.R.T. COST	ACTUAL PROGRESS W.R.T. QUALITY	EARNED VALUE W.R.T. COST (BCWP)	EARNED VALUE W.R.T. QUALITY (BQWP)
	1ST WEEK	102.113,87 ₺	3,39	75.381,04 ₺	2,40	7,46%	7,59%	68.015,68 ₺	2,30
	2nd WEEK	347.804,61 ₺	11,54	213.626,65 ₺	6,78	21,14%	21,41%	192.741,47 ₺	6,48
	3rd WEEK	629.771,45 ₺	20,90	369.901,91 ₺	11,70	36,60%	36,94%	333.696,21 ₺	11,18
	4th WEEK	894.115,36 ₺	29,68	526.177,17 ₺	16,64	52,06%	52,53%	474.650,95 ₺	15,90
	5th WEEK	911.738,29 ₺	30,26	666.824,91 ₺	21,06	65,98%	66,48%	601.564,92 ₺	20,12
	6th WEEK	911.738,29 ₺	30,26	823.100,17 ₺	25,90	81,44%	81,75%	742.519,66 ₺	24,74
	7th WEEK	911.738,29 ₺	30,26	979.375,43 ₺	30,73	96,90%	96,97%	883.474,40 ₺	29,34
	8th WEEK	911.738,29 ₺	30,26	1.010.630,48 ₺	31,69	100,00%	100,00%	911.738,29 ₺	30,26
	TOTAL	**911.738,29 ₺**	**30,26**	**1.010.630,48 ₺**	**31,69**	**100,00%**	**100,00%**	**911.738,29 ₺**	**30,26**

Table 4.31 Data for first crew of gypsum plastering

CUMULATIVE PROGRESS FOR FIRST CREW OF GYPSUM PLASTERING	WEEKS	BUDGETED COST WORK SCHEDULED (BCWS)	BUDGETED QUALITY WORK SCHEDULED (BQWS)	ACTUAL COST WORK PERFORMED (ACWP)	ACTUAL QUALITY WORK PERFORMED (AQWP)	ACTUAL PROGRESS W.R.T. COST	ACTUAL PROGRESS W.R.T. QUALITY	EARNED VALUE W.R.T. COST (BCWP)	EARNED VALUE W.R.T. QUALITY (BQWP)
	1ST WEEK								
	2nd WEEK								
	3rd WEEK								
	4th WEEK	41.538,15 ₺	5,45	0,00 ₺	0,00	0,00%	0,00%	0,00 ₺	0,00
	5th WEEK	59.219,58 ₺	10,87	0,00 ₺	0,00	0,00%	0,00%	0,00 ₺	0,00
	6th WEEK	64.427,24 ₺	13,28	0,00 ₺	0,00	0,00%	0,00%	0,00 ₺	0,00
	7th WEEK	64.427,24 ₺	13,28	48.054,84 ₺	6,37	60,55%	48,00%	39.010,69 ₺	6,37
	8th WEEK	64.427,24 ₺	13,28	79.363,04 ₺	13,27	100,00%	100,00%	64.427,24 ₺	13,28
	TOTAL	**64.427,24 ₺**	**13,28**	**79.363,04 ₺**	**13,27**	**100,00%**	**100,00%**	**64.427,24 ₺**	**13,28**

Table 4.32 Data for second crew of gypsum plastering

CUMULATIVE PROGRESS FOR SECOND CREW OF GYPSUM PLASTERING	WEEKS	BUDGETED COST WORK SCHEDULED (BCWS)	BUDGETED QUALITY WORK SCHEDULED (BQWS)	ACTUAL COST WORK PERFORMED (ACWP)	ACTUAL QUALITY WORK PERFORMED (AQWP)	ACTUAL PROGRESS W.R.T. COST	ACTUAL PROGRESS W.R.T. QUALITY	EARNED VALUE W.R.T. COST (BCWP)	EARNED VALUE W.R.T. QUALITY (BQWP)
	5th WEEK	37.384,34 ₺	4,91	0,00 ₺	0,00	0,00%	0,00%	0,00 ₺	0,00
	6th WEEK	92.437,78 ₺	13,85	0,00 ₺	0,00	0,00%	0,00%	0,00 ₺	0,00
	7th WEEK	154.781,95 ₺	26,17	13.021,88 ₺	1,50	4,69%	3,09%	10.575,73 ₺	1,44
	8th WEEK	196.332,42 ₺	33,00	56.561,74 ₺	8,92	20,36%	18,33%	45.910,85 ₺	8,52
	9th WEEK	197.373,95 ₺	33,48	93.900,23 ₺	15,89	33,80%	32,63%	76.217,42 ₺	15,17
	10th WEEK	206.747,75 ₺	37,81	128.139,68 ₺	21,68	46,13%	44,54%	104.021,00 ₺	20,70
	11th WEEK	218.204,61 ₺	43,11	170.714,95 ₺	28,99	61,46%	59,54%	138.589,44 ₺	27,67
	12th WEEK	225.495,34 ₺	46,48	234.066,26 ₺	36,67	84,27%	75,32%	190.024,92 ₺	35,01
	13th WEEK	225.495,34 ₺	46,48	263.824,95 ₺	43,35	94,98%	89,04%	214.175,47 ₺	41,39
	14th WEEK	225.495,34 ₺	46,48	277.770,64 ₺	48,69	100,00%	100,00%	225.495,34 ₺	46,48
	TOTAL	**225.495,34 ₺**	**46,48**	**277.770,64 ₺**	**48,69**	**100,00%**	**100,00%**	**225.495,34 ₺**	**46,48**

Table 4.33 Data for the whole of works

CUMULATIVE PROGRESS FOR ALL WORKS	WEEKS	TOTAL BCWS	TOTAL BQWS	TOTAL ACWP	TOTAL AQWP	ACTUAL PROGRESS W.R.T. COST	ACTUAL PROGRESS W.R.T. QUALITY	TOTAL EARNED (BCWP)	TOTAL EARNED (BQWP)
	1st WEEK	102.113,87 ₺	3,39	75.381,04 ₺	2,40	5,51%	2,57%	66.211,51 ₺	2,31
	2nd WEEK	347.804,61 ₺	11,54	213.626,65 ₺	6,78	15,62%	7,24%	187.699,43 ₺	6,52
	3rd WEEK	629.771,45 ₺	20,90	369.901,91 ₺	11,70	27,05%	12,49%	325.049,27 ₺	11,24
	4th WEEK	935.653,51 ₺	35,13	526.177,17 ₺	16,64	38,48%	17,76%	462.399,10 ₺	15,99
	5th WEEK	1.008.342,20 ₺	46,04	666.824,91 ₺	21,06	48,76%	22,48%	585.929,84 ₺	20,24
	6th WEEK	1.068.603,31 ₺	57,39	823.100,17 ₺	25,90	60,19%	27,65%	723.279,68 ₺	24,89
	7th WEEK	1.130.947,48 ₺	69,71	1.022.781,70 ₺	35,44	74,79%	37,83%	898.722,16 ₺	34,05
	8th WEEK	1.172.497,95 ₺	76,54	1.071.399,26 ₺	38,33	78,34%	40,92%	941.381,13 ₺	36,84
	9th WEEK	1.173.539,48 ₺	77,02	1.098.058,90 ₺	43,78	80,29%	46,74%	964.813,51 ₺	42,08
	10th WEEK	1.182.913,28 ₺	81,35	1.169.982,27 ₺	55,84	85,55%	59,62%	1.028.020,87 ₺	53,67
	11th WEEK	1.194.370,14 ₺	86,65	1.247.795,79 ₺	69,09	91,24%	73,76%	1.096.395,38 ₺	66,40
	12th WEEK	1.201.660,87 ₺	90,02	1.324.059,78 ₺	81,63	96,82%	87,16%	1.163.448,05 ₺	78,46
	13th WEEK	1.201.660,87 ₺	90,02	1.353.818,47 ₺	88,31	99,00%	94,29%	1.189.644,26 ₺	84,88
	14th WEEK	1.201.660,87 ₺	90,02	1.367.764,16 ₺	93,65	100,00%	100,00%	1.201.660,87 ₺	90,02
	TOTAL	**1.201.660,87 ₺**	**90,02**	**1.367.764,16 ₺**	**93,65**	**100,00%**	**100,00%**	**1.201.660,87 ₺**	**90,02**

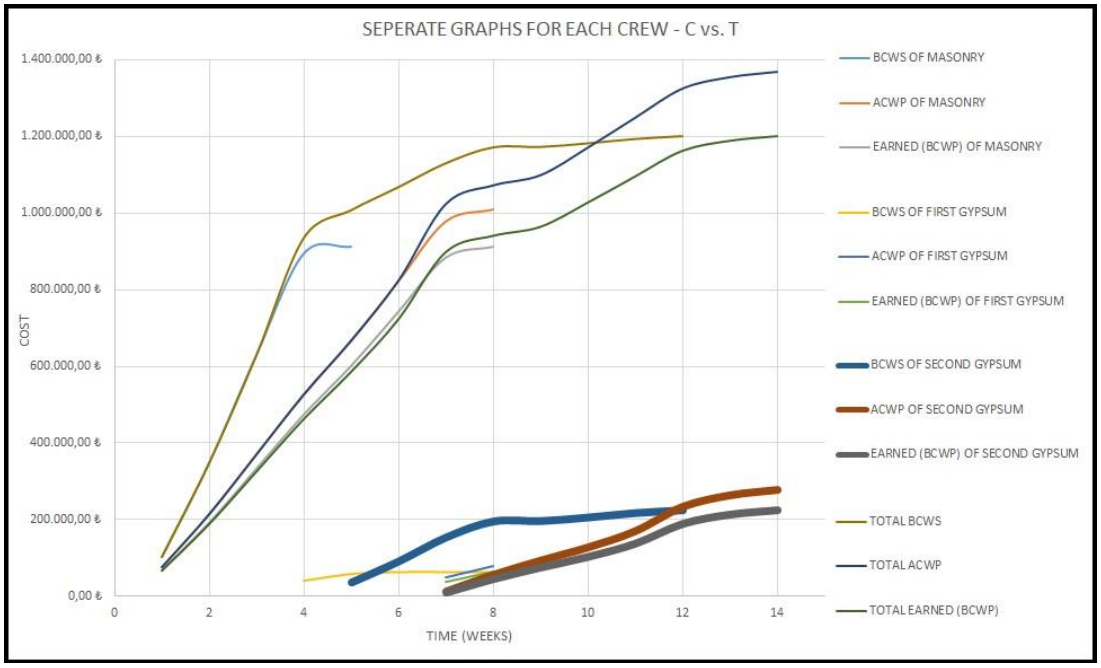


Figure 4.23 Cost vs. Time graph of EVM values

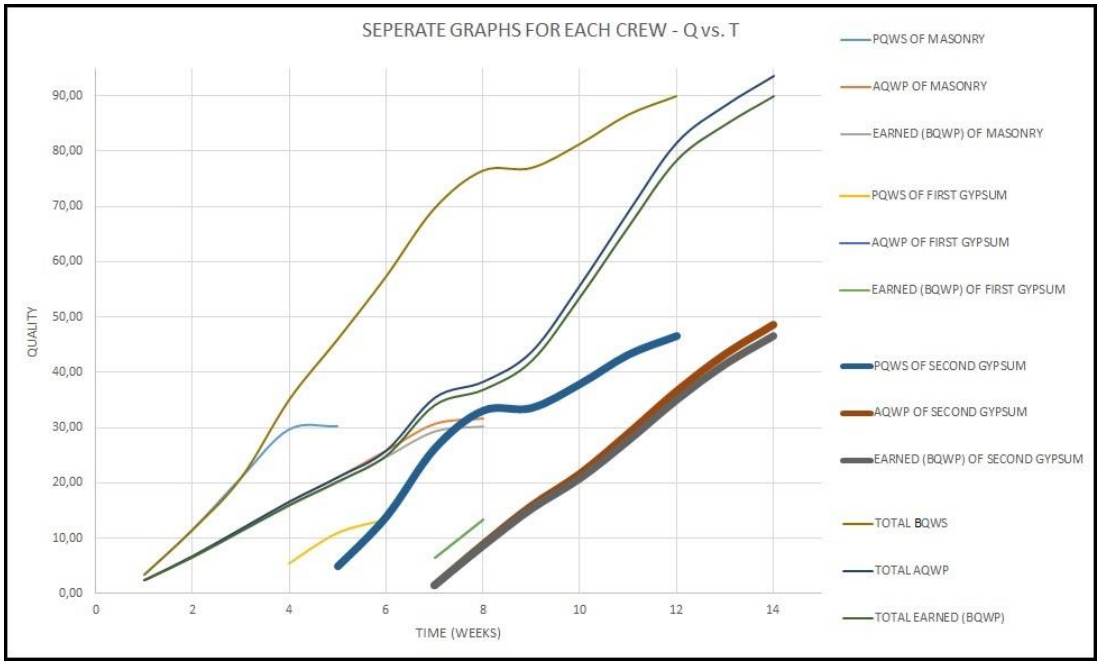


Figure 4.24 Quality vs. Time graph of EVM values

According to ***Figures 4.23 & 4.24***; all crews exceed the budgeted cost, they are behind the schedule and works of masonry and second gypsum crews are over quality, quality of work of first gypsum crew is overlapped in the graph, thus it is on the target.

For example; in cost-time graph, the second gypsum crew -seen with thick layers- is seen behind the schedule and over the budget. In quality-time graph, it is seen again behind the schedule and over the expected quality.

4.5. Discussions on the Findings of Case Studies

Within the scope of this research study, four case studies were performed. In these case studies, the quality of two different projects were assessed by using the developed QEVM framework. For both of these case studies, checklists were developed using the local and company specific requirements, benchmarks and KPIs. These checklists were populated with expert opinions and test results (strength tests for concrete and reinforcement bars) in first two cases. The client, owner and expert feedbacks were used as data sources in the 3rd case. Site inspection results of experts, financial data and quality productivity concepts were used as data collection method for the 4th case.

In parallel to ***first research question*** in terms of system components; when the overall expert and client scores are compared with the results obtained from QEVM framework, it is observed that the building (end product) quality factor is a suitable **KPI** for construction works. Financial data (quality cost) is also another KPI to be needed to track in order to keep project budget under control. Service or Corporate level KPIs are more suitable ones for other sectors than construction. Moreover, standards / codes, financial data and subjective satisfaction are suitable **benchmarks** or metrics to measure building quality factor KPI, with respect to them. Some **data sources** such as; expert and client opinions shall not be ignored just because they seem as subjective measures. On the contrary, it was clearly seen that *expert opinion is a very necessary data source for assessment of especially quality concept.* These kinds of measures shall be supported by objective ones such as; test results, high technology

included inspections in order to eliminate the subjectivity discussion. Moreover, means (questionnaire, checklists) are also very beneficial supporter tools to collect subjective measures. *Regional Checklists* (see Appendix A) were derived for this study. It is suggested to consulting more than 2 experts for expert opinions in order to reduce the subjectivity, as well. Perceptive, software-based, conceptual or mathematical & statistical data analysis methods are easily applicable **data analysis methods** to analyze the collected data. As **quality evaluation method**, Combining the Q-EVM, CONQUAS, and weights of Ong et.al (2018) created a framework for assessment of construction quality working in harmony. Moreover, *value functions* for quality versus cost were proposed and derived in order to define targeted quality values as can be seen in Appendix B. To sum up related parts with *transition to Q EVM from classical EVM*, instead of using an approximation method as in the 4 PBEV studies, 5 Quality Cost EVM studies and 7 Quality EVM studies, an exact method was proposed as Paquin et.al. (2000) by inserting and comparing cost component, as well. Final Q EVM value was not transformed into monetary terms and commented as in quality scoring terms. The clear weightages were proposed as Work Breakdown Structure and Quality Breakdown Structure; the high-level weightage was used of Ong et.al. (2018) and lower-level weightage was used of CONQUAS with the suggestion of their being modifiable. Past data usage was not preferred since the target works are project based. Quality-cost relations were derived as value functions for 18 activities in order to have accurate results, this part is solving this gap in literature. The final Cost and Quality representations were done separately in order to see the effects of them on to each other. Quality Cost concept was also introduced the quality scoring EVM system which were not used together in literature in order to analyze further steps. This step was done and stated also in 4th case study; however, it is placed also in transition to QEVM part as contribution of this part.

The effect of different kind of **scoring methods** were studied in Case Studies 1, 2 &3 to analyze the ***second research question*** and the "in between a range" Likert scoring is proposed as a more suitable scoring method for the scoring of quality of construction

works, the results of this type scoring were considered as more close to perception. A "0&1" scoring for an activity or defect type for a whole flat, room or area gave unrealistic result. A partial "0&1" scoring has given more realistic result according to previous method; however, the first one was evaluated as more applicable one.

The **quality perceptions of different sides** were also questioned as ***third RQ***. Client scorings gave higher quality results with respect to experts and owner. However, the results of experts were evaluated as more accurate. Thus, expert opinions were considered as more comprehensive in terms of behavioral, functional and technical perspectives with respect to clients, in assessment of construction quality.

Quality cost concept was inserted and **quality productivity** concept was proposed and analyzed in detailed in the 4th case study to respond ***fourth research question***. Quality cost concept in literature studies were generally offered with a generalization approach by multiplying quality cost ratio (to overall budget) with Earned Value; however, in this study, an exact approach was proposed by keeping all rework cost data, separately. Variety in results was illustrated. In addition to quality cost insertion, the quality productivity capacity of crews was tracked in order to increase efficiency and reduce the cost. It was shown that for different quality targets, different characterized crews may have optimum productivity.

CHAPTER 4

CONCLUSION & DISCUSSION

In the construction sector, cost, time and quality also known as iron triangle are considered as the most important three components out of nine project management knowledge areas, in practice. When seeking an objective, Earned Value Method come into prominence as a simple and powerful tool for tracking time, budget and scope. The general problem in construction sector is to track quality component less systematically, in practice. Thus, in this study a Quality included Earned Value Management (QEVM) Framework is developed as a progress measurement method including quality component. If it is needed to highlight one more time the reason behind quality integration into EVM, this integration creates a systematical and totalitarian way to track quality with respect to cost and time. Otherwise, companies already track quality component by the help of site employers, individually, or using systems like CONQUAS. However, tracking the quality component separately, and not correlating with cost and schedule is not a sustainable approach for understanding the performance of projects. Moreover, integrating the quality information into the EVM facilitates tracking quality in a systematic manner.

In order to develop the QEVM framework, firstly literature was reviewed in terms of system requirements namely; Key Performance Indicators, benchmarks or metrics, data sources or data collection methods, quality evaluation system, data communication systems and finally for Quality Earned Value Method. Valuable studies were founded related with this issue in literature; however, it was realized that there is a lack of an extendible, elaborate and practical QEVM system that can be used for construction projects. In order to address this gap, four research questions were raised.

In order to answer the RQ of "What are the components of a practical and extendible QEVM framework that can be used for construction projects?", an extensive literature review was performed and the components of the QEVM framework was identified as: Building (end product) quality factor & financial data (quality cost) as *KPI*, standards, financial data & subjective satisfaction as *benchmarks*, testing & inspection results, data base, perception & means as *data sources*, perceptive & mathematical methods as *data analysis methods*, systems based on standards (specifically CONQUAS) & Q-EVM as quality evaluation system and finally in between a range Likert Scale as *data scoring* methods. Some developed or new suggestions for problems in transition to QEVM part were introduced the system.

One of the important components of the framework is the development of checklists with integration of locational & regional needs such standards.

In order to answer the RQ of "What is the effect of different quality scoring methods on the outcomes of QEVM framework?" two case studies were performed on the same project using a "In-between a range" and a "Pass-Fail" scoring. The project used in these case studies is a prestige residential building complex project with 480 units. The case study was applied on after winter works on a block including structural works of roof flat and architectural works of eight flats. Using the checklists derived within the scope of this research study, the quality of the tasks/components of the project was evaluated with the help of three experts. The results of these case studies revealed that the more suitable scoring method for a building construction project is an in between a range Likert scale for this study.

In order to answer the RQ of "How is the performance of the QEVM framework in terms of reflecting the client/ end user satisfaction levels?", a total a total of six client feedbacks matching with the related tasks for eight units of the third case study was acquired and analyzed. The results of this case study revealed that experts are looking through a more comprehensive perspective with respect to clients for this study.

In order to answer the RQ of "How can the QEVM framework be improved with the integration of financial data and productivity and customizing the outputs according to different stakeholders/ tasks?" a different case study was performed. This case study is based on a different residential prestige building complex project with 390 units. For this work package, quality cost was separated from total cost (the contribution of cost of loss is separated from other costs to track quality efficiently), and unit quality cost per unit quality treatment was tracked to determine the "quality productivity" of crews. Value functions of cost vs quality were derived for many activities using experts' opinion and collecting the related cost data from companies doing related jobs. Moreover, optimum quality level through cost component was also decided by calculations of unit cost for each quality increment for different quality levels of activities. As expected, it was confirmed with the collected data that improving or treating a less quality work is much more expensive than the case of doing it for the first time with higher quality. Moreover, illustration of activities' separate contribution to Earned Value was analyzed to visualize more elaborate and detailed role of each activity.

One of the limitations of this study is the fact that "quality-cost" relation value functions for a limited number of activities were derived by collecting a wide-range of cost data from the sector and experts. Even if, it is seen as a suitable manner to solve the relation among these components, manual collection of temporary cost data for all kinds of construction project activities may not be a sustainable approach in the long run.

As future developments; firstly, the general problem of the index of SPI's (and similarly QPI's) always giving 1 as result at the end of project remains as the main problem of EVM independent from this study as stated in the page 401, Lipke et al. (2009). That related study also suggests a concept as Earned Schedule to solve this problem. In future studies Earned Schedule concept may be integrated with quality included EVM, as well. Secondly, the derived concept of "productivity of quality" is considered worthwhile to be improved in future studies to track the quality

contribution and the corresponding cost value of crews in order to having an end product with more quality and less cost. This improvement is considered to provide the companies saving cost of losses in remarkable amounts.

The checklists developed in this study provide a practical template to apply and adapt for each construction project. As a future research, these templates can be customized according to companies and can be incorporated into organizational culture of companies. In this way, project, activity and subcontractor-based quality comparisons can be performed to help strategize future quality investments. Furthermore, a central QEVM tool can be developed that integrates the nonconformance reports and external failure records to identify and track the reasons and trends of quality related problems and expenditures.

As stated in “Derivation of Quality vs. Cost Value Functions” part of Chapter 4, in this study, the targeted quality levels are assigned by either according to cost values or by owner. In further studies, the targeted quality value can be assigned by Quality Function Deployment. Moreover, as Dikmen et.al. (2004) proposed, QFD may also be used as a quality assessor tool at later stages by incorporating the weights and sub-weights and criteria of Ong.et.al. (2018) and CONQUAS.

REFERENCES

Ahmed, H. M. and Yusuff, R. M. (2016). *Factors affecting quality during the construction phase in Iraqi government companies.* International Journal of Applied Engineering Research, 11 (13). pp. 7974-7981.

Akao Y. Quality function deployment: integrating customer requirements into product design. Cambridge: Productivity Press;1992.

Akinci, B., Boukamp, F., Gordon, C., Huber, D., Lyons, C., & Park, K. (2006). A formalism for utilization of sensor systems and integrated project models for active construction quality control. *Automation in Construction, 15*(2), 124-138.

Almaian, R. Y., Needy, K. L., Walsh, K. D. and Alves, T. D. (2016). A Qualitative Data Analysis for Supplier Quality-Management Practices for Engineer-Procure-Construct Projects. *Journal of Construction Engineering and Management, 142*(2), 04015061.

Arditi, D. and Günaydin, H. M. (1997). Total Quality Management in the Construciton Process. International Journal of Project Management, 15(4), 235-243.

Arditi, D. and Lee D.E. (2003). Assessing the corporate service quality performance of design/build contractors using quality function deployment. Construction Management Economy, 21(2), 175-185.

Arditi, D. and Lee D.E. (2004). Service quality performance of design/build contractors using quality function deployment. Construction Management Economy, 22(1), 123-127.

Atasoy, G., Tang, P., and Akinci, B. (2009). "A comparative study on the use of laser scanners for construction quality control and progress monitoring purposes." CIB W078 26th Int. Conf.—Managing IT in Construction, CRC, Taylor & Francis Group, London.

Atkinson, R. (1999). Project management: Cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. *International Journal of Project Management, 17*(6), 337-342.

Baldrige National Quality Program. *The Malcolm Baldrige Criteria for Performance Excellence*. (n.d.). Retrieved from http://www.asq104.org/app/download/557659904/The+Malcolm+Baldrige+Criteria+for+Performance+Excellence+200910.pdf

Boukamp, F., and Akinci, B. (2007). Automated processing of construction specifications to support inspection and quality control. *Automation in Construction, 17*(1), 90-106.

Boydak, A. (2013). Differences of earned value management practices in construction. Paper presented at PMI® Global Congress 2013—EMEA, Istanbul, Turkey. Newtown Square, PA: Project Management Institute.

Bubshait, A. A. and Al-Atiq T. H., (1999). ISO 9000 Quality Standards in Construction. *Journal of Construction Engineering and Management*, 117(2), 341-359.

Building and Construction Authority of Singapore (2017). CONQUAS: Construction Quality Assessment System. Retrieved from https://www.bca.gov.sg/Professionals/IQUAS/others/CONQUAS8.pdf

Burati, J. L., Matthews, M.F., Kalidindi, S.N. (1991). Quality Management in Construction Industry. *Journal of Construction Engineering and Management*, 117(2), 341-359.

Burati, J. L., Matthews, M.F., Kalidindi, S.N. (1992). Quality Management Organizations and Techniques. *Journal of Management in Engineering*, 15(6), 41-46.

Carson, R. S., & Zlicaric, B. (2008). 1.3.2 Using Performance-Based Earned Value® for Measuring Systems Engineering Effectiveness. *INCOSE International Symposium*, *18*(1), 111-122.

Chan, A. P., & Chan, A. P. (2004). Key performance indicators for measuring construction success. *Benchmarking: An International Journal*, *11*(2), 203-221.

Chase, G. W. (1993). Effective Total Quality Management (TQM) Process for Construction. *Journal of Management in Engineering*, *9*(4), 433-443.

Chen, L., & Luo, H. (2014). A BIM-based construction quality management model and its applications. *Automation in Construction*, *46*, 64-73.

Chin, S., Kim, K., & Kim, Y. (2004). A process-based quality management information system. *Automation in Construction*, *13*(2), 241-259.

Chow, L. K., & Ng, S. T. (2007). A fuzzy gap analysis model for evaluating the performance of engineering consultants. *Automation in Construction*, *16*(4), 425-435.

Crosby, Philip B. (1979). “Quality is Free”, McGraw-Hill Book Company.

Czemplik, A. (2015). Inspection of Construction Works According to Polish Construction Law. *IOP Conference Series: Materials Science and Engineering*, *96*, 012057.

Daher, S., Zayed, T., Elmasry, M., & Hawari, A. (2018). Determining Relative Weights of Sewer Pipelines’ Components and Defects. *Journal of Pipeline Systems Engineering and Practice*, *9*(1), 04017026.

Davis, K., Ledbetter, W. B., & Burati, J. L. (1989). Measuring Design and Construction Quality Costs. *Journal of Construction Engineering and Management, 115*(3), 385-400.

Deffenbaugh, R. L. (1993). Total Quality Management at Construction Jobsites. *Journal of Management in Engineering, 9*(4), 382-389.

Dikmen, I., Birgonul, M. T., & Kiziltas, S. (2005). Strategic use of quality function deployment (QFD) in the construction industry. *Building and Environment, 40*(2), 245-255.

Dodson, M., Defavari, G., & Carvalho, V. D. (2015). Quality: The Third Element of Earned Value Management. *Procedia Computer Science, 64*, 932-939.

Efe, P. (2015). QEVM: Quality Integrated Earned Value Management (Unpublished doctorate's thesis). Middle East Technical University. Retrieved November 22, 2017, from https://tez.yok.gov.tr.

EFQM Excellence Model. (2012). Home. Retrieved from https://www.efqm.org/.

Federle, M. O., & Chase, G. W. (1993). Applying Total Quality Management to Design and Construction. *Journal of Management in Engineering, 9*(4), 357-364.

Fuming, L., Wang, F., & Song, Y. (2009). Improved Fuzzy Comprehensive Evaluation Model of Construction Engineering Quality. *2009 Second International Conference on Intelligent Computation Technology and Automation*.

Gao, X. K., & Ye, Z. M. (2011). The Application of Improved Earned Value Model in Engineering Quality and Progress Coordination Management. *Applied Mechanics and Materials, 71-78*, 4580-4584.

Golparvar-Fard, M., Bohn, J., Teizer, J., Savarese, S., & Peña-Mora, F. (2011). Evaluation of image-based modeling and laser scanning accuracy for emerging automated performance monitoring techniques. *Automation in Construction, 20*(8), 1143-1155.

Gordon, C., & Akinci, B. (2005). Technology and Process Assessment of Using LADAR and Embedded Sensing for Construction Quality Control. *Construction Research Congress 2005*.

Graves, R. (1993). Total Quality—Does It Work in Engineering Management? *Journal of Management in Engineering, 9*(4), 444-455.)

Hammad, D. B., Shafiq, N., and Nuruddin, M. F. (2014). Criticality Index of Building Systems Using Multi-Criteria Decision Analysis Technique. *MATEC Web of Conferences, 15*, 01018.

Hensey, M. (1993). Essential Tools of Total Quality Management. Journal of Management in Engineering, 9(4), 329-339.

Hernandez, J. I., Olaso, J. R., & Rubio, J. (2013). Technical Performance Based Earned Value as a Management Tool for Engineering Projects. *Engineering Management*.

Hoxley, M. (2000). Measuring UK construction professional service quality: The what, how, when and who. *International Journal of Quality & Reliability Management, 17*(4/5), 511-526.

Hu, Y. Z., Zhong, B., Luo, H., & Hu, H. M. (2013). The regulation constraint modeling and semantic inferring in construction quality checking. *Structural Survey, 31*(5), 387-400.

Huang, H., & Zheng, J. (2018). Quality earned value analysis based on IFPUG method in software project. *Proceedings of 2018 International Conference on Big Data Technologies - ICBDT 18*.

Huang, S., Kang, Y., Wang, Z., & Zhao, D. (2010). Track Integration Quality Index. *Icctp 2010*.

Hughes, S. W., Tippett, D. D., & Thomas, W. K. (2004). Measuring Project Success in the Construction Industry. *Engineering Management Journal, 16*(3), 31-37.

Jafari, A., & Love, P. E. (2013). Quality Costs in Construction: Case of Qom Monorail Project in Iran. *Journal of Construction Engineering and Management, 139*(9), 1244-1249.

Kalyan, T. S., Zadeh, P. A., Staub-French, S., & Froese, T. M. (2016). Construction Quality Assessment Using 3D as-built Models Generated with Project Tango. *Procedia Engineering, 145*, 1416-1423.

Khalid, T. A., & Yeoh, E. (2015). Controlling software cost using fuzzy Quality based EVM. *2015 International Conference on Computing, Control, Networking, Electronics and Embedded Systems Engineering (ICCNEEE)*.

Kim, Y. S., Oh, S. W., Cho, Y. K., & Seo, J. W. (2008). A PDA and wireless web-integrated system for quality inspection and defect management of apartment housing projects. *Automation in Construction, 17*(2), 163-179.

Koziołek, S., & Derlukiewicz, D. (2012). Method of assessing the quality of the design process of construction equipment with the use of DFSS (design for Six Sigma). *Automation in Construction,22*, 223-232.

Kwahk, K., Park, M., Kim, J., & Kim, J. (2011). Development of a Progress Management System Integrated with the Quality Inspection Process: Case of a nuclear power plant

construction project in Korea. *Journal of Asian Architecture and Building Engineering, 10*(2), 391-398.

Lam, K. C., & Ng, S. T. (2006). A cooperative Internet-facilitated quality management environment for construction. *Automation in Construction, 15*(1), 1-11.

Laofor, C., & Peansupap, V. (2012). Defect detection and quantification system to support subjective visual quality inspection via a digital image processing: A tiling work case study. *Automation in Construction, 24*, 160-174.

Ledbetter, W. B. (1994). Quality Performance on Successful Project. *Journal of Construction Engineering and Management, 120*(1), 34-46.

Lee, D., & Arditi, D. (2006). Total Quality Performance of Design/Build Firms Using Quality Function Deployment. *Journal of Construction Engineering and Management, 132*(1), 49-57. doi:10.1061/(asce)0733-9364(2006)132:1(49)

Lee, D., Lim, T., & Arditi, D. (2009). Automated stochastic quality function deployment system for measuring the quality performance of design/build contractors. *Automation in Construction, 18*(3), 348-356.

Lee, M., Chou, C., & Li, K. (2009). Automatic measurement of runway grooving construction for pavement skid evaluation. *Automation in Construction, 18*(6), 856-863.

Likins, G., Piscsalko, G., Rausche, F., & Hussein, M. (2004). Monitoring Quality Assurance for Deep Foundations. *Current Practices and Future Trends in Deep Foundations*.

Lim, C., Yu, J., & Kim, C. (2011). The development of work performance analysis system. *Automation in Construction, 20*(1), 28-36.

Lipke, W., Zwikael, O., Henderson K., & Anbari, F. (2009). Prediction of project outcome The application of statistical methods to earned value management and earned schedule performance indexes. *International Journal of Construction Management*, 27, 400-407.

Liu, J. (1997). Quality prediction for concrete manufacturing. *Automation in Construction, 5*(6), 491-499.

Liu, L., Chen, I., Kayacan, E., Tiong, L. K., & Maruvanchery, V. (2015). Automated construction quality assessment: A review. *2015 10th International Symposium on Mechatronics and Its Applications (ISMA)*.

Loushine, T. W., Hoonakker, P. L., Carayon, P., & Smith, M. J. (2006). Quality and Safety Management in Construction. *Total Quality Management & Business Excellence, 17*(9), 1171-1212.

Love, P. E., & Irani, Z. (2003). A project management quality cost information system for the construction industry. *Information & Management, 40*(7), 649-661.

Luo, H., & Gong, P. (2014). A BIM-based Code Compliance Checking Process of Deep Foundation Construction Plans. *Journal of Intelligent & Robotic Systems, 79*(3-4), 549-576.

Ma, X., & Yang, B. (2012). Optimization study of Earned Value Method in construction project management. *2012 International Conference on Information Management, Innovation Management and Industrial Engineering*.

Mallon JC, Mulligan DE. Quality function deployment—a system for meeting customers' needs. Journal of Construction Engineering and Management 1993;119(3):516–31.

Manap N., Goh Y. K. and Syahrom N. (2017). Compulsory of Malaysia's Quality Assessment System in Construction (QLASSIC). *The International Conference on Eco Engineering Development 2017 (ICEED 2017), IOP Conf. Ser.: Earth Environ. Sci. 109 012008*.

Miguel, A., Madria, W., & Polancos, R. (2019). Project Management Model: Integrating Earned Schedule, Quality, and Risk in Earned Value Management. *2019 IEEE 6th International Conference on Industrial Engineering and Applications (ICIEA)*.

Ministry of Environment & Urbanization, Turkey (2007). *Construction General Technical Specification*. Retrieved from https://yfk.csb.gov.tr/sartnameler-i-330

Montero, R., Victores, J., Martínez, S., Jardón, A., & Balaguer, C. (2015). Past, present and future of robotic tunnel inspection. *Automation in Construction, 59*, 99-112.

Navon, R. (2005). Automated project performance control of construction projects. *Automation in Construction, 14*(4), 467-476.

Omar, T., & Nehdi, M. L. (2016). Data acquisition technologies for construction progress tracking. *Automation in Construction, 70*, 143-155.

Ong, H. Y., Wang, C., & Zainon, N. (2018). Developing a Quality-Embedded EVM Tool to Facilitate the Iron Triangle in Architectural, Construction, and Engineering Practices. *Journal of Construction Engineering and Management, 144*(9), 04018079.

Paquin, J., Couillard, J., & Ferrand, D. (2000). Assessing and controlling the quality of a project end product: The earned quality method. *IEEE Transactions on Engineering Management, 47*(1), 88-97.

Pheng, L. S., & Wee, D. (2001). Impact of ISO 9000 on the Reduction of Building Defects. *Architectural Science Review, 44*(4), 367-377.

PMBOK® Guide. (2000). Retrieved September 17, 2018, from https://www.pmi.org/pmbok-guide-standards/foundational/pmbok

Pollack-Johnson, B., & Liberatore, M. (2006). Incorporating Quality Considerations Into Project Time/Cost Tradeoff Analysis and Decision Making. *IEEE Transactions on Engineering Management, 53*(4), 534-542.

Ravichandran, T., & Rai, A. (2000). Quality Management in Systems Development: An Organizational System Perspective. *MIS Quarterly, 24*(3), 381.

Rodríguez-Martín, M., Lagüela, S., González-Aguilera, D., & Martínez, J. (2016). Thermographic test for the geometric characterization of cracks in welding using IR image rectification. *Automation in Construction, 61*, 58-65.

Rounds, J.L.& Chi, N.Y. (1985). Total Quality Management For Construction. *Journal of Construction Engineering and Management,* 111(2), 117-128.

Rumane, A. R. (2018). *Quality management in construction projects*. Boca Raton, FL: CRC Press.

Samuels, A. F., & Young, J. D. (2013). Independent Data for Quality-Management Design. *Leadership and Management in Engineering, 13*(4), 265-274.

Saram, D. D., Ahmed, S. M., & Anson, M. (2004). Suitability of the Critical Incident Technique to Measure Quality of Construction Coordination. *Journal of Management in Engineering, 20*(3), 97-109.

Schubert, P., Guiver, T., Macdonald, R. & Yu, F. (2006). Using Quality Measures to Manage Statistical Risks in Business Surveys. *Proceedings of Q2006 European Conference on Quality in Survey Statistics 2006*.

Seymour, D. and Low, S.P. (1990). The quality debate. *Construction Management and Economics,* 8 (1), Spring E. & F.N. Spon Ltd.

Small, E. P., Bakry, I., & Ayyash, L. (2019). Evaluating the effect of TQM on MEP construction productivity and project delivery in Dubai. *International Journal of Construction Management,* 1-15.

Solomon, P., & Young, R. (2005). *Performance-based earned value*. Hoboken, NJ: Wiley.

Song S.H., Lee H.S. & Park M. Development of Quality Performance Indicators for Quality Management in Construction Projects (n.d.). Retrieved from http://www.irbnet.de/daten/iconda/CIB4419.pdf

Souza, A. D., Rocha, A. R., Cristina, D., & Constantino, B. A. (2014). A Proposal for the Improvement of Project's Cost Predictability Using Earned Value Management and Quality Data – An Empirical Study. *Communications in Computer and Information Science Systems, Software and Services Process Improvement,* 170-181.

Stevens, J. D., Glagola, C., & Ledbetter, W. B. (1994). Quality-Measurement Matrix. *Journal of Management in Engineering, 10*(6), 30-35.

Stukhart, G. (1989). Construction Materials Quality Management. *Journal of Performance of Constructed Facilities, 3*(2), 100-112.

Sullivan, K. T. (2011). Quality Management Programs in the Construction Industry: Best Value Compared with Other Methodologies. *Journal of Management in Engineering, 27*(4), 210-219.

Tam, C., Deng, Z., Zeng, S., & Ho, C. (2000). Performance assessment scoring system of public housing construction for quality improvement in Hong Kong. *International Journal of Quality & Reliability Management, 17*(4/5), 467-478.

Taneja, S., Akinci, B., Garrett, J. H., Soibelman, L., Ergen, E., Pradhan, A., . . . Anil, E. B. (2011). Sensing and Field Data Capture for Construction and Facility Operations. *Journal of Construction Engineering and Management, 137*(10), 870-881.

Wanberg, J., Harper, C., Hallowell, M. R., & Rajendran, S. (2013). Relationship between Construction Safety and Quality Performance. *Journal of Construction Engineering and Management, 139*(10), 04013003.

Wang, J., Sun, W., Shou, W., Wang, X., Wu, C., Chong, H., Sun, C. (2014). Integrating BIM and LiDAR for Real-Time Construction Quality Control. *Journal of Intelligent & Robotic Systems,79*(3-4), 417-432.

Wang, L. (2008). Enhancing construction quality inspection and management using RFID technology. *Automation in Construction, 17*(4), 467-479.

Wang, Q., Kim, M., Cheng, J. C., & Sohn, H. (2016). Automated quality assessment of precast concrete elements with geometry irregularities using terrestrial laser scanning. *Automation in Construction, 68,* 170-182.

Wardle T. and Duncan A. (2017). Branz: Prioritizing quality: Literature review of common residential housing defects. Retrieved from *https://www.branz.co.nz/cms_show_download.php?id=e89942dc9675615b4ad03e72c4d7ced70f47e77e*.

Willis, T. H., & Willis, W. D. (1996). A quality performance management system for industrial construction engineering projects. *International Journal of Quality & Reliability Management,13*(9), 38-48.

Woldesenbet, A., & Jeong, H. D. (2014). Highway Data Quality Report Card (HDQ RC): A Conceptual Framework of Pavement Management Data. *Construction Research Congress 2014*.

Wu, Y., Huang, Y., Zhang, S., & Zhang, Y. (2014). Quality Management Evaluation Based on Self-Control and Cosupervision Mechanism in PIP. *Journal of Management in Engineering, 30*(2), 180-184.

Xi, W. (2014). Construction engineering quality reflected in financial information and model establishment. *2014 11th International Conference on Service Systems and Service Management (ICSSSM)*.

Xu, J., Zhang, H., & Li, F. (2010). Project integrated management based on quality earned value. *The 2nd International Conference on Information Science and Engineering*.

Yan, Z. (2016). Estimating Quality of the Construction Engineering Project Using Fuzzy AHP Approach. *2016 International Conference on Smart Grid and Electrical Automation (ICSGEA)*.

Yang, Y. Q., Wang, S. Q., Dulaimi, M., & Low, S. P. (2003). A fuzzy quality function deployment system for buildable design decision-makings. *Automation in Construction, 12*(4), 381-393.

Yasamis-Speroni, F., Lee, D., & Arditi, D. (2012). Evaluating the Quality Performance of Pavement Contractors. *Journal of Construction Engineering and Management, 138*(10), 1114-1124.

Yerabolu, R. (2010). Quality, Risk Management, and Integration Management Disciplines into Earned Value Management (EVM) for Deriving Performance Based Earned Value (PBEV). Retrieved from Project Management Institute: http://www.pmi.org/Knowledge- Center/Knowledge-Shelf/~/media/Members/Knowledge%20Shelf/Yerabolu2_2010.ashx

Ying, H. (2016). The Highway Construction Cost Control Model Based on the Improved Earned Value Method Theory. *2016 International Conference on Smart City and Systems Engineering (ICSCSE)*.

Zavadskas, E. K., Liias, R., & Turskis, Z. (2008). Multi-attribute decision-making methods for assessment of quality in bridges and road construction: State-of-the-art surveys. *The Baltic Journal of Road and Bridge Engineering, 3*(3), 152-160.

Zhong, B., Ding, L., Luo, H., Zhou, Y., Hu, Y., & Hu, H. (2012). Ontology-based semantic modeling of regulation constraint for automated construction quality compliance checking. *Automation in Construction, 28*, 58-70.

APPENDICES

Appendix A

Developed checklists:

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS		
A.	CORPORATION NAME :	
B.	PROJECT NAME:	
C.	DATE :	
D.	WEATHER CONDITIONS :	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	ALUMINUM CEILING WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	FIXING TO CEILING SHALL BE MADE WITH A SPACING 1-1,25 M	(3)									
2	MAIN CARRIER FRAME SHALL BE CREATED WITH L, U, T PROFILES WITH 1,5-2 CM JOINTING GAP	(3)									
3	L PROFILES SHALL BE INSERTED AT BORDERS OF PANELS	(3)									
4	ALIGNMENT OF RAILS SHOULD BE VISUALLY STRAIGHT	(2)									
5	SURFACE SHOULD BE OVERALL LEVEL AND EVEN	(2)									
6	CHIPPED SURFACES OR CORNERS SHOULD NOT BE SEEN	(2)									
7											
8											
9											
10											
11											
12											
13											
14											
15											

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	DIAMETER OF LEG OF SUSPENSION SHALL BE 4 MM AT LEAST	(3)									
2	PANELS HAVING THICKNESS AT LEAST 0,5MM SHALL BE INSERTED OVER PROFILES	(3)									
3	L PROFILES HAVING THICKNESS AT LEAST 0,5 MM	(3)									
4											
5											
6											
7											
8											
9											
10											
11											
12											
	SCHEDULED DATE :										
	QUANTITY :										

** If the temperature of the weather is below +5 C' (1), no jointing work may be done, otherwise score as 'NA' (not acceptable)*

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	ALUMINUM FAÇADE WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	PLUMB, BALANCE & SETSQUARE SHALL BE SMOOTH	(1) (3)									
2	END PRODUCT SHALL BE WATER RESISTENT	(1) (3)									
3	3-D ADJUSTABLE ANCHORAGE FIXING PROPERLY	(3)									
4	STAINLESS SCREW USE FOR FIXING	(3)									
5	FIXING SHALL BE DONE IN ORDER TO MAKE THE SYSTEM MOVEABLE İN CASE TEMPERATURE VARIATION	(3)									
6	FIRE HOLDERS SHALL BE CREATED 2MM GALVANIZ PLATE BY FIXING STRUCTURE SIDE AND BY PASTING THE FAÇADE SIDE WITH POLYIZOBUTHYLEN TAPE	(3)									
7	BOTH SIDES OF FIRE HOLDERS SHALL BE SILICONED	(3)									
8	GLASS WOOL SHALL BE USED BETWEEN FIRE HOLDERS IN ORDER TO PROVIDE SOUND ISOLATION	(3)									
9	EPDM RUBBER GLASS RUN CHANNELS SHALL BE USED	(3)									
10	50MM STRAIGHT COVERS SHALL BE USED AT HORIZONTAL PLANE OVER ALUMINUM PROFILES	(3)									
11	CHECK DIMENSIONS	(1) (4.A13.329)									
12	CHECK ACCESSORIES AND HARDWARE OF DOORS & WINDOWS	(1) (4.A13.329)									
13	CHECK OPENING SETTINGS OF DOORS & WINDIWS	(1) (4.A13.329)									
14											
15											

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	***FOR ALUMINUM PROFILES***										
2	ALL PROFILES SHALL BE UNCORROSED AND PAINTED WITH SPECIAL TECHNIQUES (ANODIZING, OVEN PAINT ETC)	(1) (3)									
3	JOINTING SHALL BE AT 45' ANGLES	(1) (3)									
4	UNIQUE PROFILE USE UNTIL 6 M OF LENGTH	(3)									
5	THICKNESS OF PROFILE SHALL BE GREATER THAN 2 MM	(3)									
6	***FOR ALUMINUM COMPOSITE PANELS***										
7	AT LEAST 30*40 MM X-SECTIONAL HAVING 1,5 MM THICKNESS GALVANIZE PROFILE SHALL BE USED AS MAIN CARRIER	(3)									
8	4MM MINERAL LAYER BETWEEN 0,5 MM ALUMINUM PANELS AT BOTH FACES SHALL BE USED AS COMPOSITE PANEL. OUTER SURFACE PVDF PAINTED. INNER SURFACE AT LEAST 5MICRON UNDERCOATED	(3)									
9											
10											
11											
12											
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +5 C' (1), no jointing work may be done, otherwise score as 'NA' (not acceptable)***

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	CEMENT PLASTERING WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CLEAR SURFACE	(1)									
2	NO METAL ON SURFACE	(1)									
3	EFFICIENT UNDERCOATING	(1)									
4	NETTING USE FOR INTERSECTION OF DIF.SURFACES	(1)									
5	CORRECT JOINT GAP FOR INTERSECTIONS	(1)									
6	EFFICIENT PLUMB & SMOOTHNESS (+-1,5MM)	(1)									
7	EFFICIENT TOTAL DEPTH (2CM-3CM)	(1)									
8	FIRST THICK LAYER (2CM)	(1)									
9	THIN FINISHING LAYER (8MM)	(1)									
10	SETSQUARE (+- 2 MM / 30 CM)	(1)									
11	CHECK FOR EFFICIENT CURING (FIRST 7 DAYS)	(1) (4.A13.330)									
12	CHECK FOR WEATHER TEMPERATURE ! (+4C<T<+35C)	(1)									
13	CHECK CRACKS & VOIDS	(1) (4.A13.330)									
14	NO HOLLOW SOUND WHEN TAPPED WITH A HARD OBJECT	(2)									
15	SURFACES SHOULD NOT BE UNDULY ROUGH OR PATCHY ESP NO BRUSH / TROWEL MARKS	(2)									
16	SURFACE EVENNESS (NOT MORE THAN 3MM OVER 1,2M)	(2)									

	MATERIAL QUALITY INDICATORS	**R.S.****	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	MIXTURE 250 DOSAGE (250 KG CEMENT-215LT WATER/ 1M3 SAND)	(1)									
2	MIXTURE 350 DOSAGE (350 KG CEMENT-245LT WATER/ 1M3 SAND)	(1)									
3	PC 32,5 CEMENT USE	(1)									
4	WEIGHT OF CLAY<%4 OF WEIGHT OF SAND	(3)									
5	WEIGHT OF ORGANIC MAT.<%0,5 OF TOTAL WEIGHT	(3)									
6	CLEAR SAND & WATER USE	(1) (3)									
7	PH OF WATER USED IN MORTAR >=7	(3)									
8	AT MOST 15GR DISSOLVED & 2 GR SETTLED SALT, 2 GR SULFATE MAY BE INCLUDED	(3)									
9	DO NOT USE ANY CEMENT PRODUCT IF 3 MONTHS PAST OVER PRODUCTION DATE	(3)									
10	MORTAR SHALL BE MIXED AT LEAST 3 MINUTES, AT LEAST 3 DRY 3 WET MIXING IF MANUAL M	(3)									
11	MORTAR SHALL NOT BE USED IF WAITED MORE THAN 1 HOUR	(3)									
12	WATER SHALL NOT BE INCLUDED ANY CLAY,OIL,ALCALI OR ACID COMPONENTS	(3)									
13	USE PRE-PACKED PLASTER ONLY	(2)									
14	MAXIMUM SAND DIAMETER (D<8MM)	(1) (3)									
15	COMPARE BRAND WITH CONTRACT	(1)									
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +4 C' (1), +5 C' (3) and no protection action will be done at least first 7 days, no mortar work may be done, otherwise score as 'NA' (not acceptable)***

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	CERAMICS CLADDING FAÇADE WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CLEAR SURFACE	(1)									
2	"L" BRACKET INSTALLMENT (PLASTIC FOR BRICK) LOC.	(1)									
3	"L" BRACKET INSTALLMENT (STEEL FOR RC) LOC.	(1)									
4	ANCHOR PLUG FOR MECHANICAL INSTALLMENT LOC.	(1)									
5	EFF.ROCKWOOL INSTALLMENT WITH NO SPACING	(1)									
6	PLUMB PERPENDICULAR T,L ALUMINUM FRAME INSTALL	(1)									
7	EFF.BELOW CARRYING FRAME INSTALLMENT WITH BOLT	(1)									
8	5MM.GLUING FOAM TAPE OVER CLIPS	(1)									
9	POLYURETHANE SILICONE B/W TAPES	(1)									
10	EFF.CERAMICS PLACING OVER BELOW CLIPS	(1)									
11	EFF.CERAMICS GLUING OVER SILICONE	(1)									
12	CHECK FOR WEATHER TEMPERATURE ! (+4C<T<+35C)	(1)									
13		(1)									
14		(1)									

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CHECK FOR UNDAMAGED ALUMINUM PROFILES	(1)									
2	NO DAMAGED, SCRATCHED CERAMICS USE	(1)									
3	CHECK FOR UNDAMAGED BRACKETS	(1)									
4	CHECK FOR FRESHNESS OF SILICONE	(1)									
5	CHECK BRANDS	(1)									
6	CHECK FOR ROCKWOOL (D>100KG/M3)(H>5CM)	(1)									
7											
8											
9											
10											
11											
12											
13											
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +5 C' (1), no jointing or siliconing work may be done, otherwise score as 'NA' (not acceptable)***

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	CORPORATION NAME :	
B.	PROJECT NAME:	
C.	DATE :	
D.	WEATHER CONDITIONS :	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	CERAMICS TILING WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CLEAR SURFACE	(1)									
2	EFFICIENT BINDING PASTE USE (>5KG/M2)	(1)									
3	CHECK FOR LEVELLING (+-0,5MM)	(1)									
4	CHECK FOR SYMMETRIC SPACING (TILE SPACER + USE)	(1)									
5	EFFICIENT CERAMICS JOINTING APPLICATION	(1)									
6	SETSQUARE (+- 2 MM / 30 CM)	(1)									
7	EFFICIENT PLUMB & SMOOTHNESS (+-1,5MM)	(1)									
8	CHECK FOR WEATHER TEMPERATURE ! (+4C<T<+35C)	(1)									
9	CHECK ALIGNMENT, ANGLES AND JOINTS	(4.A13.330)									
10	CHECK GROUTING	(4.A13.330)									
11	NO HOLLOW SOUND WHEN TAPPED WITH A HARD OBJECT	(2)									
12	JOINTS ARE ALIGNED AND CONSISTENT WITH SKIRTING AND WALL TILES	(2)									
13	CONSISTENT JOINT SIZE	(2)									
14	LIPPAGE BETWEEN 2 TILES SHOULD NOT BE MORE THAN 0,5MM	(2)									
15	EXPANSION JOINTS SHOULD BE PROVIDED AT INTERVAL	(2)									
16	SURFACE EVENNESS (NOT MORE THAN 3MM OVER 1,2M)	(2)									
17											
18											

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	MIXTURE (5 KG BINDING-1,5LT WATER)	(1)									
2	TENSILE STRENGTH OF BINDER (>0,5N/MM2)	(1)									
3	USE OF BINDER (>3KG/M2)	(1)									
4	NO BROKEN, CRACKED CERAMICS USE	(1)									
5	COMPARE BRAND WITH CONTRACT	(1)									
6	CHECK COLOR AND TEXTURE PATTERN	(1) (2) (4.A13.330)									
7	MINIMUM TENSILE STRENGTH ACCORDING TO PULL-OFF TEST : 0,15 N / MM2	(2)									
8											
9											
	SCHEDULED DATE :										
	QUANTITY :										

If the temperature of the weather is below +4 C' (1), +5 C' (3) and no protection action will be done at least first 7 days, no mortar work may be done, otherwise score as 'NA' (not acceptable)

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS		
A.	CORPORATION NAME :	
B.	PROJECT NAME:	
C.	DATE :	
D.	WEATHER CONDITIONS :	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	CONCRETE POURING WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	NON-SEGREGATED CONCRETE POURING (H<1M)	(1)									
2	CONCRETE SHOULD BE DROPPED ONLY THE ALLOWABLE DISTANCE (1,5M)	(4.64)									
3	NO WATER ADDITION TO CONCRETE	(1)									
4	MAINTAIN PROPER WATER / CEMENT RATIO	(4.64)									
5	EFFICIENT VIBRATION USE (8.000-12.000 RPM- 3-4 SEC.)	(1)									
6	PROCESS COMPACTION	(4.A10)									
7	CHECK ENOUGH NUMBER OF VIBRATORS	(1) (4.64) (4.A10)									
8	CHECK FOR ICE OVER REBAR AND FORMWORK	(1)									
9	CHECK NOT TO LOSE CEMENT PASTE / WATER CONTENT	(1)									
10	CHECK FOR SMOOTH LEVELLING (+-5MM)	(1)									
11	PROPER CASTING LEVEL	(4.A13.328)									
12	CHECK FOR EFFICIENT CURING (FIRST 7 DAYS)	(1)									
13	CURING START TIME CHECK	(4.A10)									
14	CLEAR MOLD SURFACE / GROUND SURFACE	(1) (4.64) (4.A13.328)									
15	NON-DISRUPTED / CONTINUOUS POURING	(1)									
16	CHECK FOR WEATHER TEMPERATURE ! (+4C<T<+35C)	(1)									
17	TOLERANCE FOR CROSS-SECTIONAL DIMENSION OF CAST IN SITU AND PRECAST ELEMENTS (+10MM/ -5MM)	(2)									
18	TOLERANCE FOR OPENING (+10MM FOR SIZE AND +-25MM FOR LOCATION)	(2)									
19	TOLERANCE FOR LENGTH OF PRECAST MEMBERS (MAJOR DIMENSION) (UP TO 3M:+-6MM), (3M TO 4,5M: +-9MM), (4,5M TO 6 M: +-12MM), ADDITIONAL DEVIATION FOR EVERY SUBSEQUENT 6M.: +-6MM)	(2)									
20	STRAIGHTNESS OF BOW (DEVIATION FROM INTENDED LINE) OF PRECAST MEMBER: (UP TO 3M:+-6MM), (3M TO 4,5M: +-9MM), (4,5M TO 6 M: +-12MM), ADDITIONAL DEVIATION FOR EVERY SUBSEQUENT 6M.: +-6MM)	(2)									
21	SQUARENESS OF PRECAST MEMBER – DIFFERENCE BETWEEN THE GREATEST AND SHORTEST DIMENSIONS SHOULD NOT EXCEED THE FOLLOWING: LENGTH OF SHORTER SIDES (UP TO INCLUDING 1,2M: 6MM) (OVER 1,2M BUT LESS THAN 1,8M: 9MM) (1,8M AND OVER: 12MM)	(2)									
22	TWIST OF PRECAST MEMBER – ANY CORNER SHOULD NOT BE MORE THAN THE DEVIATION STATED FROM THE PLANE CONTAINING THE OTHER 3 CORNERS: (UP TO 600MM WIDE AND 6M IN LENGTH:6MM) (OVER 600MM WIDE AND FOR ANY LENGTH: 12MM)	(2)									
23	FLATNESS (6MM PER 1,5M)	(2)									
24	TOLERANCE FOR DEPARTURE OF ANY POINT FROM ITS POSTITION: +- 10MM	(2)									
25	TOLERANCE FOR PLUMB (3MM/1M), MAX.20MM FOR FLOOR TO FLOOR HEIGHT AND 40MM FOR THE ENTIRE BUILDING HEIGHT	(2)									
26	MAXIMUM DEVIATION OF MEAN LEVEL (+-10MM)	(2)									
27	FOR CAST IN-SITU ELEMENTS, THE MAXIMUM DEVIATION OF LEVELS WITHIN THE ELEMENT (10MM)	(2)									
28	CAMBER AT MID-SPAN: ACCORDING TO SPECIFICATIONS	(2)									
29	EXPOSED SURFACE SHOULD NOT HAVE VISUAL EXPOSURE OF GROUPS OF COARSE AGGREGATES RESULTING FROM GROUT LEAKAGE	(2)									
30	COLD JOINT & FORMWORK JOINT MUST BE SMOOTH	(1) (2)									
31	NO BULGING OF STRUCTURAL ELEMENTS	(2)									
32	ALL FORMWORK, NAILS, ZINC STRIPS ETC. MUST BE REMOVED	(1) (2)									
33	NO CRACKS OR DAMAGES	(1) (2)									
34	***CHECK POINTS FOR PRECAST MEMBERS:***										
35	*LIFTING POINTS / INSERTS REQUIREMENTS*										
36	TOLERANCE FOR POSITION : +-20MM FROM CENTRE LINA LOCATION IN DRAWING	(2)									
37	LIFTING DEVICES AND INSERTS FREE FROM DAMAGES	(2)									

CONCRETE POURING WORKS - CONTINUING											
38	*SLEEVE SYSTEM / CONNECTIONS REQUIREMENTS*										
39	TOLERANCE FOR POSITION: +-6MM FROM CENTRE LINE LOCATION IN DRAWINGS	(2)									
40	BAR PROTRUSION LENGTH ACCORDING TO REQUIREMENTS. NO BENDING, CRACKING OR DAMAGES TO BARS	(2)									
41	BARS FREE FROM CONCRETE DROPPINGS OR CORROSION	(2)									
42	SLEEVES, GROUT HOLES, GROUT TUBES NOT CONGESTED WITH DEBRIS	(2)									
43	*INTERFACE/JOINT REQUIREMENTS*										
44	JOINT TAPER (OVER 3M LENGTH: 6MM), (MAXIMUM FOR ENTIRE LENGTH)	(2)									
45	ALIGNMENT OF HORIZONTAL AND VERTICAL JOINT: +-6MM	(2)									
46	JOG IN ALIGNMENT OF MATDHING EDGES: 6MM	(2)									
47	SITTING OF ELEMENT: ACCARDING TO SPECIFICATIONS	(2)									
48	INSTALLATION OF SEALANT AND WATERPROOFING: ACCORDING TO SPECIFICATIONS	(2)									
49	*CAST IN STEEL ITEMS/ WELDED % BOLTED CONNECTIONS*										
50	TOLERANCE FOR POSITION OF CAST-IN STEEL ITEMS: +-6MM FROM CENTRE LINE LOCATION IN DRAWINGS	(2)									
51	TOLERANCE FOR POSITION OF OPENINGS FOR BOLT CONNECTIONS: ±3MM FROM CENTRE LINE LOCATION IN DRAWINGS	(2)									
52	RELEVANT REQUIREMENTS IN CONQUAS STEELWORK STANDARDS TO BE USED WHERE APPLICABLE	(2)									
53	CHECK DEVIATION OR DEFLECTION OF FORMS CAUSED BY CASTING CONCRETE	(4.64) (4.A10)									
54	PREPARATION OF PREVIOUS CONSTRUCTION JOINTS	(4.A10)									
55	STOPPED AT PREPLANNED LOCATIONS	(4.A10)									
56	PREPARATION OF NEW CONSTRUCTION JOINTS	(4.A10)									
57	TERMITE CONTROL (UNEVEN SPRAY)	(4.A13.328)									

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CONCRETE STRENGTH TEST RESULT (7 DAYS, 28 DAYS) CUBIC / CYLINDRICAL SAMPLES	(1) (4.64) (4.A9) (4.A10) (4.A13.328)									
2	CONCRETE STRENGTH TEST RESULT (28 DAYS) (FOR 0%-2,5% NON COMPLIANCE: 100%POINTS, 2,6%-5% NC:75% PTS, 5,1%-7,5% NC: 50% PTS, 7,6%-10% NC: 25% PTS, >10% NC: 0% PTS)	(2)									
3	CHEMICAL TEST RESULT (IF NEEDED)	(1)									
4	CORRECT / EFFICIENT MIXTURE OF CONCRETE	(1) (4.64)									
5	CHECK FOR INORGANIC OR CHEMICAL MATERIAL	(1)									
6	MAKE **ULTRASONIC PULSE VELOCITY (UPV)** TEST TO CHECK THE DEGREE OF UNIFORMITY OF HARDENED CONCRETE: 5 COLUMNS PER SET & 2 READINGS PER COLUMN (ASSESSMENT IS BASED ON THE DIFFERENCE BETWEEN THE 2 UPV READINGS WITHIN A COLUMN SHALL NOT EXCEED 0,05 KM/S, METHOD AS PER SS78)	(2)									
7	MAKE **ELECTRO-COVERMETER TEST** TO CHECK THE CONCRETE COVER FOR REINFORCEMENT BARS AFTER CASTING: MINIMUM 25MM OR HIGHER ACC.TO SPECIFICATION. (5 STRUCTURAL SAMPLES PER SET INCLUDING:3 FOR SLAB SOFFIT AT 4 READINGS EACH, 1 FOR COLUMN AT 2 READINGS EACH ON BOTH AXIS OF THE COLUMN, 1 FOR BEAM AT 2 READINGS EACH ON THE SOFFIT AND ONE SIDE OF THE BEAM) (FOR EACH READING WITHIN A STRUCTURAL SAMPLE, FULL POINT FOR +-5MM AND HALF POINT FOR>+-5MM TO +-8MM.HOWEVER, NO POINTS WILL BE AWARDED IF ANY OF THE 4 READINGS WITHIN THE STRUCTURAL SAMPLE EXCEEDS +-12MM) (METHOD AS PER SS78)	(2)									
8	CHECK TRUCK TIME FROM START OF MIXING	(1) (4.64)									
9	TAKE SLUMP TEST IF REQUIRED	(1) (4.64) (4.A9) (4.A10)									
10	THERMOMETER	(4.A9) (4.A10)									
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +4 C' (1), +5 C' (3) and no protection action will be done at least first 7 days, no concrete work may be done, otherwise score as 'NA' (not acceptable)***

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SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	EXCAVATION & BACKFILLING								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CHECK FOR # & LOCATIONS OF ANCHORAGES	(1)									
2	CHECK FOR # & LOCATIONS OF CROSSBEAMS	(1)									
3	ADEQUATE SUPPORT / VERTICAL PLUMB / PROPER BRACING / ENOUGH DEPTH / APPROVED ANCHOR TEST FOR SHORING	(4.A13.328)									
4	PROVIDE NECESSARY SLOPE IF UNPILED EXC.	(1) (3)									
5	CHECK CORNER POINTS & BORDERS OF EXCAVATION	(1)									
6	CHECK FOR ALTITUDE / ELEVATION	(1) (4.A13.328)									
7	CHECK FOR WELL & GROUNDWATER LEVELS	(1) (3) (4.A13.328)									
8	CHECK FOR LANDSLIDES & EARTH MOVEMENTS	(1)									
9	REMOVE ORGANIC / CHEMICAL MATERIALS , DO NOT USE THOSE FOR BACKFILLING	(1) (4.A13.328)									
10	EFFICIENT COMPACTION FOR BACKFILLING	(1) (4.A13.328)									
11	EFFICIENT BACKFILLING THICKNESS, APPROVED SOIL TEST	(4.A13.328)									
12	CHECK FOR UNDERGROUND STRUCTURES NOT TO HARM	(1) (3)									
13	PROVIDE NECESSARY REVETMENT	(1) (3)									
14	IF THE WEATHER IS RAINY, STOP THE EXCAVATION	(1)									
15	REMOVE EXCAVATED MATERIAL FROM SITE	(4.A13.328)									
16											

	BACKFILLING MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CORRECT MATERIAL TO ALLOW DRAINAGE	(1)									
2	NO USE OF FOR ORGANIC / CHEMICAL MATERIAL	(1) (3)									
3	NO USE OF COAL, TRASH, ICE, VEGETABLE, ORGANIC MATERIALS	(1) (3)									
4	LIQUID LIMIT<70, PLASTICITY INDEX<40, DRY DENSITY>1,45 t/m3	(3)									
5	INORGANIC CLAY SHALL BE USED AT DRAINAGES	(3)									
6	STONE OR SOFT MATERIAL ON THE TOP & SIDES OF THE EXCAVATION	(3)									
7	WATERING SHALL BE DONE DURING BACKFILLING ACCORDING TO RESULTS OF PROCTOR TEST +-%5 IN CLAYEY SOIL, +-%2 IN SILTY SOIL	(3)									
8											
9											
10											
11											
12											
	SCHEDULED DATE :										
	QUANTITY :										

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	ROCKWOOL / XPS / EPS INSULATION WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CLEAR SURFACE	(1)									
2	CHECK FOR SMOOTHNESS (<1MM / 20CM)	(1)									
3	EFFICIENT BINDING PASTE USE (>4KG / M2)	(1)									
4	EFFICIENT DEPTH OF BINDING PASTE USE (<4CM)	(1)									
5	BINDER USE AT BORDERS & MIDDLE POINT	(1)									
6	SETSQUARE (+- 2 MM / 30 CM)	(1)									
7	DOWEL NUMBER (>6 PCS. / M2, D>BOARD DEPTH+4CM))	(1)									
8	DOWEL DISTANCE TO BORDERS (<10-15CM<)	(1)									
9	HEAD OF DOWEL MUST BE BURIED 1MM INTO INSULATION MEMBER	(1)									
10	NETTING USE FOR WHOLE SURFACE	(1)									
11	2 LAYERS OF PLASTERING (DENS>4KG/M2,D>3MM)	(1)									
12	CHECK FOR WEATHER TEMPERATURE ! (+4C<T<+30C)	(1)									
13	CHECK FIXATION	(4.A13.329)									
14	CHECK INSULATION THICKNESS	(4.A13.329)									

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	HEAT TRANSMISSION VALUE OF INSULATION BOARD (<=0,04 W/MK)	(1)									
2	NETTING DENSITY (>,160GR/M2)	(1)									
3	COMPARE BRAND WITH CONTRACT	(1)									
4	ROCKWOOL DENSITY (>150KG/M3)	(1)									
5											
6											
7											
8											
9											
10											
11											
12											
13											
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +4 C' (1), +5 C' (3) and no protection action will be done at least first 7 days, no mortar work may be done, otherwise score as 'NA' (not acceptable)***

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	FORMWORK WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CORRECT ALTITUDE / ELEVATION OF FORMWORK	(1)									
2	CORRECT SHAFTS / SPACINGS	(1) (4.A8)									
3	VERY CLEAR / OILED SURFACE	(1) (4.A8)									
4	2MM REVERSE DISPLACEMENT / 1M OF BEAM	(1)									
5	CHECK FOR COORDINATINS (+-3MM)	(1)									
6	HORIZONTAL LEVEL / SMOOTHNESS (+-3MM)	(1)									
7	CROSS-SECTIONAL DIMENSIONS (+10 MM / -5 MM)	(2)									
8	PENETRATION / OPENING FOR SERVICES (+10 MM FOR SIZE & +-25 MM FOR LOCATION)	(2)									
9	TOLERANCE FOR LENGTH OF PRECAST MEMBERS (MAJOR DIMENSION) (UP TO 3M:+-6MM), (3M TO 4,5M: +-9MM), (4,5M TO 6 M: +-12MM), ADDITIONAL DEVIATION FOR EVERY SUBSEQUYENT 6M.: +-6MM)	(2)									
10	TOLERANCE FOR DEPARTURE OF ANY POINT FROM ITS POSTITION: 10MM	(2)									
11	BEING PLUMB / PERPENDICULAR (+-3MM)	(1)									
12	TOLERANCE FOR PLUMB: 3MM/M, MAX 20MM	(2)									
13	MAX DEVIATION OF MEAN LEVEL OF STAIRCASE THREAD TO TEMPORARY BENCH MARK: +-5MM	(2)									
14	FOR CAST IN-SITU ELEMENTS, THE DEVIATION OF LEVEL OF ANY POINT FROM THE INTENDED LEVEL : +-10MM	(2)									
15	BEFORE CONCRETING, THE INTERIOR MUST BE FREE FROM DEBRIS	(2)									
16	ALL FORMWORK JOINTS MUST NOT HAVE GAPS TO PREVENT LEAKAGE	(1) (2) (4.A8)									
17	THERE MUST BE ADEQUATE SUPPORT, BRACING AND TIE-BACK FOR THE FORMWORK / SCAFFOLDING TO PREVENT BULGING OR DISPLACEMENT OF STRUCTURAL ELEMENTS	(1) (2) (4.64) (4.A8)									
18	CONSTRUCTION JOINT / EDGE CLEARANCE	(4.103)									
19	FORMWORK POSITION / DIMENSION/ SHAPE / SUPPORT SUITABILITY	(4.103) (4.A8)									
20	EMBEDDING ITEM PLACEMENT AND POSITION	(4.103)									
21	FOUNDATION WORKS FOR ELECTRICITY	(4.103)									
22	MECHANICAL ADVANCE WORK COMPLETION	(4.103)									
23	SETTING OUT	(4.A8)									
24	TOP OF CONCRETE LEVEL READY FOR CASTING	(4.A8)									
25	CHAMFERS	(1) (4.A8)									
26	SCREW JACKS	(4.A8)									
27	SPLICES OF VERTICAL MEMBERS	(4.A8)									
28	WORKING PLATFORMS AND WALKWAYS	(4.A8)									
29	SHUTTERING DIMENSIONS & PLUMB	(4.A13.328)									

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	NON-DEFECTED FORMWORKS	(1) (2)									
2	NON-DEFECTED BELTS / SUPPORTERS	(1)									
3	HIGH-QUALITY FORMWORK OIL USE	(1)									
	SCHEDULED DATE :										
	QUANTITY :										

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	GLASS INSTALLMENT / GLAZING WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	PLUMB, BALANCE & SETSQUARE SHALL BE SMOOTH	(1) (3)									
2	END PRODUCT SHALL BE WATER RESISTENT	(1) (3)									
3	IF A UNIQUE PIECE OF GLASS > 2 M2, USE SPECIAL SPECIFICATION	(3)									
4	HOUSING OF JOINERY SHALL BE CLEAR, SMOOTH & HAVE NO OTHER MATERIAL IN IT	(3)									
5	2/3 OF GLASS SHALL BE SETTLE IN THE HOUSING, 1/3 SHALL BE PLACED OUT OF HOUSING	(3)									
6	THE GAP BETWEEN FRAME & GLASS < 3 MM	(3)									
7	FOR GLASS WITHOUT STICK, 1 SCREW AT MOST 20 CM SPACING	(3)									
8	PASTING GLAZIER'S PUTTY WITH 45' ANGLE	(3)									
9	INSERTING EASILY DISJOINTABLE LATH OVER PUTTY	(3)									
10	INSERT GLASS WITHOUT STICK, IF GREATER SIDE OF GLASS > 80CM OR DEPTH OF GLASS > 5MM	(3)									
11	INSERT SCREWS OF STICK STARTING FROM 10CM AWAY OF THE CORNER, WITH AT MOST 35 CM SPACING	(3)									
12	CHECK FIXING METHOD	(4.A13.329)									
13											

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	IF GLASS IS USED AS DOOR LEAF, DEPTH OF GLASS > 1 CM	(3)									
2	EACH GLASS LAYER SHALL BE 3 MM AT LEAST	(3)									
3	IF GLASS IS USED AS DOOR LEAF, DEPTH OF GLASS > 1 CM	(3)									
4	EACH LAYER OF GLASS SHALL BE AT LEAST 3MM, FOR COMPOSITE GLASS LAYERS	(3)									
5	CHECK COLOR AND TYPE	(1) (4.A13.329)									
6	CHECK FOR CRACKS AND STRATCHES	(1) (4.A13.329)									
7	NO SIGN OF LEAKAGE USING BCA'S WINDOW WATER-TIGHTNESS TEST METHOD. LEAKAGE IS DEFINED AS "ANY APPEARANCE OF UNCONTROLLED WATER, OTHER THAN CONDENSATION, ON THE INDOOR FACE OF ANY PART OF THE WALL & WINDOW". BCA'S TEST PARAMETER: WATER INTENSITY 300MM/HR / 1 LITER/MIN/M OF JOINT / WIND PRESSURE : 240 PA / NOZZLE INCLINATION : 90' TO WINDOW, 1 SAMPLE = 2M LENGTH OF JOINT / SPRAY DURATION : 10 MINUTES. (IF 0% NON-COMPLIANCE WITH BCA CONDITIONS, %100 POINTS / IF 0%<X<15% NON-COMPLIANCE , ((15-X)*100/15)% POINTS, IF MORE THAN 15% NON-COMPLIANCE, %0 POINTS)	(2)									
8											
	SCHEDULED DATE :										
	QUANTITY :										

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS		
A.	CORPORATION NAME :	
B.	PROJECT NAME:	
C.	DATE :	
D.	WEATHER CONDITIONS :	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	GYPSUM BOARD WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CLEAR SURFACE	(1)									
2	FIXING METAL BODY ONTO STRUCTURE AT MOST 1 M SP	(1)									
3	AT LEAST 3 SCREEW PER 1 M OF METAL PROFILES	(1)									
4	AT LEAST 1 SCREEW PER 25 CM OF GYPSUM BOARD	(1)									
5	HEAD OF SCREED MUST BE BURIED 1MM INTO GB	(1)									
6	UNCORROSED METALS, SCREEWS MUST BE USED	(1)									
7	APPLY 45' JOINTING AT INTERSECTION POINTS	(1)									
8	APPLY JOINT FILLER WITH JOINTING TAPE	(1)									
9	NO CRACKS SHALL BE OCCUR ON JOINTINGS	(1)									
10	CHECK FOR WEATHER TEMPERATURE FOR JOINTING (+40	(1)									
11											
12											
13											
14											
15											

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CHECK FOR UNDAMAGED PROFILES & GB	(1)									
2	CHECK BRANDS	(1)									
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
	SCHEDULED DATE :										
	QUANTITY :										

** If the temperature of the weather is below +5 C' (1), no jointing work may be done, otherwise score as 'NA' (not acceptable)*

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION : MAIN LOCATION : SCORING EXPLANATION : ACTIVITY LOCATION : **LABOR QUALITY INDICATORS**	RELATED SPECIFICATION **	GYPSUM PLASTERING WORKS SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS CHECK POINT 1 / CHECK POINT 2 / CHECK POINT 3 EXPERT 1 / EXPERT 2 / EXPERT 3 (each check point)								
1	CLEAR SURFACE	(1)									
2	NO METAL ON SURFACE	(1)									
3	EFFICIENT UNDERCOATING	(1)									
4	NETTING USE FOR INTERSECTION OF DIF.SURFACES	(1)									
5	CORRECT JOINT GAP FOR INTERSECTIONS	(1)									
6	EFFICIENT PLUMB & SMOOTHNESS (+-1,5MM)	(1)									
7	CORRECT LAYER DEPTH AT ONE TIME (5MM - 2,5CM)	(1)									
8	ALUMINUM CORNER PROFILE USE	(1)									
9	EFFICIENT TOTAL DEPTH (5MM-1,6CM)	(1)									
10	EFFICIENT GYPSUM USE (>10KG/1CM DEPTH)	(1)									
11	SETSQUARE (+- 2 MM / 30 CM)	(1)									
12	CHECK FOR WEATHER TEMPERATURE ! (+4C<T<+35C)	(1)									
13	CHECK CRACKS & VOIDS	(1) (4.A13.330)									
14	NO HOLLOW SOUND WHEN TAPPED WITH A HARD OBJECT	(2)									
15	SURFACES SHOULD NOT BE UNDULY ROUGH OR PATCHY ESP NO BRUSH / TROWEL MARKS	(2)									
16	SURFACE EVENNESS (NOT MORE THAN 3MM OVER 1,2M)	(2)									

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CORRECT MIXTURE (6-6,5LT WATER 10KG GYPSUM)	(1)									
2	FOR MACHINE WORK (5,5-6LT WATER 10KG GYPSUM)	(1)									
3	COMPARE BRAND WITH CONTRACT	(1)									
4	NETTING DENSITY (>,160GR/M2)	(1)									
5	DO NOT ADD ANY CHEMICAL INTO GYPSUM MIXTURE	(3)									
6	USE PRE-PACKED PLASTER ONLY	(2)									
7											
8											
9											
10											
11											
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +4 C' (1), +5 C' (3) and no protection action will be done at least first 7 days, no mortar work may be done, otherwise score as 'NA' (not acceptable)***

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	MASONRY WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CLEAR SURFACE	(1)									
2	CHECK FOR COORDINATIONS (+-2MM)	(1)									
3	BEING PLUMB / PERPENDICULAR (+-2MM)	(1)									
4	HORIZONTAL PLUMB / ALIGNMENT (+-2MM)	(1)									
5	1 ANCHORAGE USING/3 LAYER AT INTERS. WITH RC MEMBER	(1)									
6	FILL-1CM SPACE-AT UPPER LAYER B/W CEILING WITH FOAM	(1)									
7	1CM MORTAR BETWEEN ALL BRICKS	(1)									
8	PERPENDICULAR FLANK USE IF LENGTH OF WALL>4M	(1)									
9	HORIZONTAL FLANK USE IF HEIGTH OF WALL>3M	(1)									
10	INSTALLMENT OF ALL BRICKS AS STAGGERRED SEQUENCE	(1) (3)									
11	CHIMNEYS SHALL BE RISED 50CM UPPER TO NEAREST ROOF RIDGE	(3)									
12	AT MOST 1,5 METER HEIGHT OF PRODUCTION IN SAME DAY FOR HALF BRICKS	(3)									
13	AT MOST 15MM HORIZONTAL, 10MM VERTICAL JOINTING	(1) (3)									
14	TRANSOM USE FOR HEAD OF ALL WINDOWS & DOORS	(1)									
15	CHECK ANCHOR BEADS	(4.A13.329)									
16	CHECK REINFORCEMENT MESH	(4.A13.329)									
17	CHECK MORTAR	(1) (4.A13.329)									
18	1CM SPACING AT INTERS. WITH ANY STR.STEEL	(1)									
19	CHECK FOR EFFICIENT CURING FOR MORTAR	(1)									
20	CHECK FOR WEATHER TEMPERATURE ! (+4C<T<+35C)	(1)									

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	MIXTURE 250 DOSAGE (250 KG CEMENT-125LT WATER/ 1	(1)									
2	PC 32,5 CEMENT USE	(1)									
3	CLEAR SAND (D<8MM)	(1)									
4	UNBROKEN BRICK USE	(1)									
5	STRENGTH TEST IF NEEDED	(1)									
6	UNCORROSED STEEL FOR FLANK & TRANSOM	(1)									
7	COMPARE BRAND WITH CONTRACT	(1)									
8	USE WATER SATURATED BRICKS	(1) (3)									
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +4 C' (1), +5 C' (3) and no protection action will be done at least first 7 days, no mortar work may be done, otherwise score as 'NA' (not acceptable)***

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	MARBLE / NATURAL STONE WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CLEAR SURFACE	(1)									
2	400 DOSAGE MORTAR (D>=4CM)	(1)									
3	CEMENT PASTE OVER MORTAR	(1)									
4	SAME-LEVELLED STONE INSTALLMENT (+-1MM)	(1)									
5	STAGGERED & SYMMETRICAL INSTALLATION CHECK	(1)									
6	EFFICIENT JOINTING APPLICATION	(1)									
7	CHECK FOR WEATHER TEMPERATURE ! (+4C<T<+35C)	(1)									
8	CHECK FIXATION	(4.A13.330)									
9	CHECK ALIGNMENT, ANGLES AND JOINTS	(4.A13.330)									
10	CHECK LINES	(4.A13.330)									
11											
12											
13											
14											
15											

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CHECK FOR UNDAMAGED STONES	(1)									
2	MIN.2CM DEPTH OF STONE USE	(1)									
3	MIXTURE 400 DOSAGE (400 KG CEMENT-260LT WATER/ 1	(1)									
4	CHECK BRANDS	(1)									
5	DENSITY SHALL BE GREATER THAN 2,55 TONNES / M3	(3)									
6	WATER ABSORBTION CAPACITY SHALL NOT BE MORE THA	(3)									
7											
8											
9											
10											
11											
12											
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +4 C' (1), +5 C' (3) and no protection action will be done at least first 7 days, no mortar work may be done, otherwise score as 'NA' (not acceptable)***

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SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	PAINTING WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CLEAR SURFACE (EFFICIENT SANDING)	(1)									
2	CRACKING REPAIR ON SURFACE	(1)									
3	CHECK FOR COLOR	(1) (4.A13.330)									
4	CHECK FOR SURFACE FINISHING (NO AIR BUBLE ETC)	(1)									
5	APPLICATION AS 2 LAYERS	(1)									
6	CHECK FOR WEATHER TEMPERATURE ! (+5C<T<+30C)	(1)									
7	CHECK NUMBER OF PAINTING	(4.A13.330)									
8	CHECK FOR TEXTURE	(4.A13.330)									
9	SURFACES SHOULD BE EVENLY PAINTED	(2)									
10	GOOD OPACITY, NO PATCHINESS RESULTED FROM TOUCH UP WORKS	(2)									
11	FREE FROM PEELING, BLISTER AND CHALKINESS	(2)									
12	NO DISCOLOURATION AND FADING	(2)									
13											
14											

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CHECK FOR PAINT MATERIAL QUALITY	(1)									
2	CHECK MIXTURE (NO EXTRA CHEMICAL)	(1)									
3	COMPARE BRAND WITH CONTRACT	(1)									
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +5 C' (1) and no protection action will be done until the paint get dry, no painting work may be done, otherwise score as 'NA' (not acceptable)***

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	PARQUET FLOORING WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CLEAR SURFACE	(1)									
2	USE UNDERHARDWOOD INSULATION MEMBRANE	(1)									
3	CHECK FOR LEVELLING (+-0,5MM)	(1)									
4	INSTALLMENT OF STAGGERRED SEQUENCE	(1)									
5	EFFICIENT JOINTING APPLICATION	(1)									
6	0,5-1CM JOINTING SPACE AT WALL BORDERS	(1)									
7	NO WARPAGE	(2)									
8	TIMBER STRIPS TO REST FIRMLY ON JOISTS OR SCREED	(2)									
9	NO VISIBLE GAPS IN BETWEEN TIMBER STRIPS	(2)									
10	EDGES OF THE FLOOR TO BE PROPERLY SEALED	(2)									
11											
12											
13											
14											

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	NO VOLUME LOSING INSULATION MEMBRANE USE	(1)									
2	NO BROKEN, STRATCHED, SWELLED HARDWOOD USE	(1)									
3	COMPARE BRAND WITH CONTRACT	(1)									
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +5 C' (1) and no protection action will be done until the glue get dry, no gluing work may be done, otherwise score as 'NA' (not acceptable)***

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	CORPORATION NAME :	
B.	PROJECT NAME:	
C.	DATE :	
D.	WEATHER CONDITIONS :	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	PARTITIONING WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CHECK STUD SPACING	(4.A13.329)									
2	CHECK FIXATION METHOD	(4.A13.329)									
3	CHECK INSULATION	(4.A13.329)									
4	CHECK ALIGNMENT OF PARTITIONING PANELS	(4.A13.329)									
5	CHECK JOINTS	(4.A13.329)									
6	CHECK PAINTING	(4.A13.329)									
7											
8											
9											
10											
11											
12											
13											
14											
15											

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
	SCHEDULED DATE :										
	QUANTITY :										

** If the temperature of the weather is below +4 C' (1), +5 C' (3) and no protection action will be done at least first 7 days, no mortar work may be done, otherwise score as 'NA' (not acceptable)*

** (1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	LEANING / PILING BEFORE EXCAVATION								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CORRECT DIAMETER OF REINFORCEMENT	(1)									
2	CORRECT SPACING OF REINFORCEMENT	(1)									
3	EFFICIENT TIEING OF REINFORCEMENT	(1)									
4	CLEAR CONCRETE COVER APPARATUS	(1)									
5	CORRECT / NON-DESTRUCTED PLACEMENT OF REINFORCEMENT	(1)									
6	NON-DESTRUCTED MOLD SURFACE	(1) (3)									
7	CORRECT DEPTH OF PILE	(1) (3)									
8	CLEAR PILE WELL	(1) (3)									
9	NON-SEGREGATED CONCRETE CASTING	(1)									
10	EFFICIENT VIBRATION USE	(1)									
11	CORRECT & FAST REMOVING OF MOLD	(1) (3)									
12	BEING PLUMB / PERPENDICULAR OF PILES(m>=0,02)	(1) (3)									
13	ANY ICE OVER THE REINFORCEMENT OR MOLD	(1)									
14	CHECK LOCATION / COORDINATION OF COMP.S	(1) (3)									
15											
16											

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	REINFORCEMENT BAR STRENGTH TEST RESULT	(1)									
2	NON-CORROSED REINFORCEMENT USE	(1)									
3	CONCRETE STRENGTH TEST RESULT	(1)									
4	CHEMICAL TEST RESULT (IF NEEDED)	(1)									
5	CORRECT / EFFICIENT MIXTURE OF CONCRETE	(1)									
6	CHECK FOR INORGANIC OR CHEMICAL MAT.	(1)									
7											
8											
9											
10											
11											
12											
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +4 C' (1), +5 C' (3) and no protection action will be done at least first 7 days, no concrete work may be done, otherwise score as 'NA' (not acceptable)***

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION : MAIN LOCATION : SCORING EXPLANATION : ACTIVITY LOCATION : **LABOR QUALITY INDICATORS**	RELATED SPECIFICATION **	PRECAST CONCRETE WORKS SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
			EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	NON-SEGREGATED CONCRETE POURING (H<1M)	(1)									
2	NO WATER ADDITION TO CONCRETE	(1)									
3	EFFICIENT VIBRATION USE (8.000-12.000 RPM- 3-4 SEC.)	(1)									
4	CHECK FOR ICE OVER REBAR AND FORMWORK	(1)									
5	CHECK NOT TO LOSE CEMENT PASTE / WATER CONTENT	(1)									
6	CHECK FOR SMOOTH LEVELLING (+-5MM)	(1)									
7	CHECK FOR EFFICIENT CURING (FIRST 7 DAYS)	(1)									
8	CLEAR MOLD SURFACE / GROUND SURFACE	(1)									
9	NON-DISRUPTED / CONTINUOUS POURING	(1)									
10	CHECK FOR WEATHER TEMPERATURE ! (+4C<T<+35C)	(1)									
11	TOLERANCE FOR CROSS-SECTIONAL DIMENSION OF CAST IN SITU AND PRECAST ELEMENTS (+10MM/ -5MM)	(2)									
12	TOLERANCE FOR OPENING (+10MM FOR SIZE AND +-25MM FOR LOCATION)	(2)									
13	TOLERANCE FOR LENGTH OF PRECAST MEMBERS (MAJOR DIMENSION) (UP TO 3M:+-6MM), (3M TO 4,5M: +-9MM), (4,5M TO 6 M: +-12MM), ADDITIONAL DEVIATION FOR EVERY SUBSEQUENT 6M.: +-6MM)	(2)									
14	STRAIGHTNESS OF BOW (DEVIATION FROM INTENDED LINE) OF PRECAST MEMBER: (UP TO 3M:+-6MM), (3M TO 4,5M: +-9MM), (4,5M TO 6 M: +-12MM), ADDITIONAL DEVIATION FOR EVERY SUBSEQUENT 6M.: +-6MM)	(2)									
15	SQUARENESS OF PRECAST MEMBER – DIFFERENCE BETWEEN THE GREATEST AND SHORTEST DIMENSIONS SHOULD NOT EXCEED THE FOLLOWING: LENGTH OF SHORTER SIDES (UP TO INCLUDING 1,2M: 6MM) (OVER 1,2M BUT LESS THAN 1,8M: 9MM) (1,8M AND OVER: 12MM)	(2)									
16	TWIST OF PRECAST MEMBER – ANY CORNER SHOULD NOT BE MORE THAN THE DEVIATION STATED FROM THE PLANE CONTAINING THE OTHER 3 CORNERS: (UP TO 600MM WIDE AND 6M IN LENGTH:6MM) (OVER 600MM WIDE AND FOR ANY LENGTH: 12MM)	(2)									
17	FLATNESS (6MM PER 1,5M)	(2)									
18	TOLERANCE FOR DEPARTURE OF ANY POINT FROM ITS POSTITION: +- 10MM	(2)									
19	TOLERANCE FOR PLUMB (3MM/1M), MAX.20MM FOR FLOOR TO FLOOR HEIGHT AND 40MM FOR THE ENTIRE BUILDING HEIGHT	(2)									
20	MAXIMUM DEVIATION OF MEAN LEVEL (+-10MM)	(2)									
21	FOR CAST IN-SITU ELEMENTS, THE MAXIMUM DEVIATION OF LEVELS WITHIN THE ELEMENT (10MM)	(2)									
22	CAMBER AT MID-SPAN: ACCORDING TO SPECIFICATIONS	(2)									
23	EXPOSED SURFACE SHOULD NOT HAVE VISUAL EXPOSURE OF GROUPS OF COARSE AGGREGATES RESULTING FROM GROUT LEAKAGE	(2)									
24	COLD JOINT & FORMWORK JOINT MUST BE SMOOTH	(1) (2)									
25	NO BULGING OF STRUCTURAL ELEMENTS	(2)									
26	ALL FORMWORK, NAILS, ZINC STRIPS ETC. MUST BE REMOVED	(1) (2)									
27	NO CRACKS OR DAMAGES	(1) (2)									
28	ALIGNMENT WITH ADJACENT PLANKS NOT MORE THAN 3MM	(2)									
29	PLANE TOLERANCE (3MM / 1,2M)	(2)									

	MATERIAL QUALITY INDICATORS	R.S. **	CHECK POINT 1	0	0		0	0	CHECK POINT 3	0	0
1	CONCRETE STRENGTH TEST RESULT	(1)									
2	CHEMICAL TEST RESULT (IF NEEDED)	(1)									
3	CORRECT / EFFICIENT MIXTURE OF CONCRETE	(1)									
4	CHECK FOR INORGANIC OR CHEMICAL MAT.	(1)									
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +4 C' (1), +5 C' (3) and no protection action will be done at least first 7 days, no concrete work may be done, otherwise score as 'NA' (not acceptable)***

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	PRE-STRESSED CONCRETE WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	***CONDITION OF TENDONS & ANCHORAGES***										
2	THREAD PARTS TO BE GREASED WRAPPED AND TAPPED HOLES PROTECTED UNTIL USE	(2)									
3	***INSTALLATION OF SHEATHING***										
4	SHEATHING PROPERLY SECURED AND PROTECTED AND FREE FROM DAMAGE OR PUNCTURE	(2)									
5	SHEATHING PROFILE ACCORDING TO DRAWINGS THROUGHOUT THE LENGTH WITH POSITION TOLERANCE: ±5MM	(2)									
6	SPLICE TO SHEATHING SHALL BE MORTAR TIGHT	(2)									
7	AIR VENTS OR GROUT TUBES PROVIDED ACCORDING TO THE DRAWING	(2)									
8	***STRESSING & GROUTING PROCESS***										
9	TENDON DUCTS CLEAN AND FREE FROM FOREIGN OBJECTS AND TENDON FREE MOVING IN THE DUCT	(2)									
10	STRANDS STRESSED TO THE FINAL PRESSURE / ELONGATION WITHIN THE SPECIFIC % ACCURACY OF THE STIPULATED VALUE	(2)									
11	ALL GROUTING OPERATIONS OF THE TENDONS MUST BE SMOOTH AND ACHIEVED WITHOUT NEED TO FLUSH OUT IN THE FIRST GROUTING	(2)									
12	***DEBONDING***										
13	OPEN ENDS OF DEBOND TUBES OVER THE DEBOND LENGTH OF STRANDS SEALED	(2)									
14	DEBOND LENGTHS ACCORDING TO THE DRAWINGS	(2)									
15	DEBONDING MATERIALS NOT PUNCTURED OR DAMAGED	(2)									
16											

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	***CONDITION OF TENDONS & ANCHORAGES***										
2	ALL PRE-STRESSING STRANDS AND WIRES SHOULD COMPLY WITH THE SPECIFIED STANDARDS AND REQUIREMENTS AND BE FREE FROM LOOSE RUST, OIL, TAR, PAINT AND ANY FOREIGN OBJECTS	(2)									
3	ALL TENDON ANCHORAGE ARE TO COMPLY WITH THE SPECIFIED STANDARDS AND PROTECTED FROM CORROSION	(2)									
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +4 C' (1), +5 C' (3) and no protection action will be done at least first 7 days, no concrete work may be done, otherwise score as 'NA' (not acceptable)***

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	PVC JOINERY FAÇADE WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	PLUMB, BALANCE & SETSQUARE SHALL BE SMOOTH	(1) (3)									
2	END PRODUCT SHALL BE WATER RESISTENT	(1) (3)									
3	SUPPORTING UNCORROSED METAL COMPONENTS SHALL BE SCREWED AT MOST 40 CM SPACING	(3)									
4	JOINTING SHALL BE AT 45' ANGLES	(1) (3)									
5	UNIQUE PROFILE USE UNTIL 6 M OF LENGTH	(1) (3)									
6	2MM BOX PROFILE IN THE MIDDLE, 1,5MM U PROFILE AT FRAME AND LEAF SHALL BE USED	(3)									
7	EACH WINDOW LEAF SHALL HAVE AT LEAST 2, DOOR AT LEAST 3 HINGES	(1) (3)									
8	PVC PROFILE FIXING TO METAL FRAME SHALL BE MADE BY SCREWING AT MOST 50 CM SPACING	(3)									
9	METAL FRAME SHALL BE AT LEAST 2MM DKP PLATE U SECTION OR BOX SECTION METAL	(3)									
10	METAL FRAME SHALL BE PAINTED AGAINST CORROSION	(3)									
11	IF METAL FRAME IS T-CROSS SECTION, USE EPDM RUBBER; IF L PROFILE, SILICONE THE GAP IN ORDER TO PROVIDE INSULATION	(3)									
12	NO VISIBLE GAP BETWEEN OR WITHIN WINDOW / DOOR LEAF AND FRAME	(2)									
13	NEAT JOINT BETWEEN WINDOW AND WALL INTERNALLY AND EXTERNALLY	(2)									
14	CONSISTENT AND NO VISIBLE GAPS AT MITRE JOINTS	(2)									
15	ALIGNMENT / LEVEL WITH WALL OPENINGS	(2)									
16	WINDOW LEAF AND FRAME CORNERS MAINTAINED AT RIGHT ANGLES	(1) (2)									
17	EASE IN OPENING, CLOSING AND LOCKING	(1) (2)									
18	NO WATER LEAKAGE	(1) (2)									
19	NO SQEUEAKY SOUND DURING SWINGING THE LEAF	(2)									
20	LOCK SETS WITH GOOD FIT AND ALIGNED	(2)									
21	NO SIGN OF CORROSION	(2)									
22	NO MISSING OR DEFECTIVE ACCESSORIES	(2)									
23	COUNTERSUNK SCREWS LEVELLED AND FLUSHED. NO OVER-TIGHTENED SCREWS	(2)									
24	STAINLESS STEEL SCREWS AT HINGES FOR SWING WINDOW	(2)									

	MATERIAL QUALITY INDICATORS	**R.S. ****	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	NO STAIN MARKS AND ANY VISIBLE DAMAGE / DEFECTS	(1) (2)									
2											
3											
4											
	SCHEDULED DATE :										
	QUANTITY :										

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	REINFORCEMENT WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CORRECT DIAMETER OF REINFORCEMENT	(1) (2)									
2	CORRECT SPACING / NUMBERS OF REINFORCEMENT	(1) (2) (4.A13.328)									
3	EFFICIENT TIEING	(1) (2)									
4	CLEAR CONCRETE COVER APPARATUS USE	(1)									
5	CHECK FOR LOCATION / COORDINATION	(1) (4.A13.328)									
6	CHECK FOR DETAILING COMPONENTS (STIRRUPS, LINKS, TRIMMING BARS)	(1) (2)									
7	CHECK FOR MINIMUM SPACEMENT B/W REBARS	(1)									
8	REQUIRED LAP LENGTH NOT LESS THAN THAT SPECIFIED	(1) (2)									
9	COVER PROVISION (ACC.TO SPECIFICATION WITH TOLERANCE OF +5MM)	(2)									
10											
11											
12											
13											
14											
15											
16											

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	REINFORCEMENT BAR STRENGTH TEST RESULT	(1) (2)									
2	NON-CORROSED REINFORCEMENT USE	(1) (2)									
3	NON-DESTRUCTED / NON-DAMAGED BAR USE	(1) (2)									
4	CHEMICAL TEST RESULT (IF NEEDED)	(1)									
5	CLEAR REBAR SURFACE	(1) (2)									
6	CHECK WELDED STEEL FABRIC	(2)									
7											
8											
9											
10											
11											
12											
	SCHEDULED DATE :										
	QUANTITY :										

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	ROOF WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	***FLAT ROOF***										
2	PONDING LESS THAN 3MM	(1)									
3	SURFACE TO LEVEL TO AVOID TRIPPING	(1)									
4	PROPER DRESSING FOR ANY PROTRUSION	(1)									
5	OPENINGS TO BE SEALED TO PREVENT PEST INVASION	(1)									
6	CLEAN AND NO STAIN MARKS	(1)									
7	***PITCHED ROOF***										
8	NO LEAKING	(1)									
9	NO RUST OR STAINS	(1)									
10	GOOD PAINTING TO ROOF STRUCTURAL MEMBERS	(1)									
11	ROOF TILES IN ALIGNMENT	(1)									
12	OPENINGS TO BE SEALED TO PREVENT PEST INVASION	(1)									
13	CONSISTENT COLOUR TONE	(1)									
14	PROPER DRESSING FOR ANY PROTRUSION	(1)									
15	***WATERPROOFING***										
16	SHOULD BE EVENLY INSTALLED, NO SHARP PROTRUSION	(1)									
17	COMPLETE ADHESION TO BASE	(1)									
18	GOOD LAPS AT JOINTS AND PROPER VERTICAL ABUTMENT DETAILS	(1)									
19	NO LEAKING AND SIGN OF DAMAGE TO MEMBRANE / COATING	(1)									
20	CLEAN AND NO MORTAR STAINS	(1)									
21	NO PAINT DEFECTS	(1)									
22	***GUTTERS***										
23	NO PONDING AND CHOKAGE	(1)									
24	NO CRACKS, CHIPS AND ANY OTHER VISIBLE DAMAGES / DEFECTS	(1)									
25	RWDP INLET SHOULD BE LOWER THAN THE SURROUNDING GUTTER INVERT LEVEL	(1)									
26	GUTTER AND RWDP INLET TO BE COVERED TO PREVENT CHOKAGE WHERE PRACTICAL	(1)									
27	CLEAN AND NO CEMENT STAINS	(1)									

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1											
2											
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +5 C' (1), no jointing work may be done, otherwise score as 'NA' (not acceptable)***

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SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	SCREED WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CLEAR SURFACE	(1)									
2	USE UNDERSCREED INSULATION MEMBRANE	(1)									
3	USE INS.MEMBRANE AT BORDERS OF WALLS	(1)									
4	EFFICIENT DEPTH (4CM<D)	(1)									
5	EFFICIENT POLISHING & HELICOPTERING	(1)									
6	CHECK FOR LEVELLING (+-3MM)	(1)									
7	SURFACES SHOULD NOT BE UNDULY ROUGH OR PATCHY	(2)									
8	CHECK FOR EFFICIENT CURING (FIRST 7 DAYS)	(1)									
9	CHECK FOR WEATHER TEMPERATURE ! (+4C<T<+35C)	(1)									
10	NO VISIBLE TROWEL MARKS	(2)									
11	EXPANSION JOINTS SHOULD BE PROVIDED AT INTERVAL	(2)									
12											
13											
14											
15											

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	MIXTURE 300 DOSAGE (300 KG CEMENT-230LT WATER/ 1M3 SAND)	(1)									
2	PC 32,5 CEMENT USE	(1)									
3	CLEAR SAND (D<8MM)	(1)									
4	COMPARE BRAND WITH CONTRACT	(1)									
5											
6											
7											
8											
9											
10											
11											
12											
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +4 C' (1), +5 C' (3) and no protection action will be done at least first 7 days, no mortar work may be done, otherwise score as 'NA' (not acceptable)***

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS		
A.	CORPORATION NAME :	
B.	PROJECT NAME:	
C.	DATE :	
D.	WEATHER CONDITIONS :	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	STRUCTURAL STEEL WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CHECK CROSS-SECTIONAL TOLERANCE (FOR LENGTH : +-3MM) (FOR BOLT HOLE SIZE : =<2MM FOR BOLT DIAMETER <24MM, =<3MM FOR BOLT DIAMETER>=24MM, FOR BOLT HOLE POSITION : +-2MM)	(2)									
2	CHECK SURFACE ROUGHNESS	(2)									
3	CHECK WELD SIZE, LENGTH AND PROFILE	(2)									
4	CHECK BOLTS AND WASHERS, TYPE, SIZE AND NUMBER	(2)									
5	CHECK DRILLED HOLES WHETHER BE FREE FROM BURRS	(2)									
6	THE CONDITION OF BOLTED PARTS ADJACENT TO THE BOLT HEADS, NUTS, FLAT WASHERS, CONNECTION GUSSETS AND SPLICE PLATES SHALL BE FREE FROM OIL, PAINT AND LOOSE MILL SCALES	(2)									
7	GAP BETWEEN ADJACENT PARTS SHALL NOT EXCEEDED 2MM	(2)									
8	BOLTS SHALL BE TIGHTENED TO SPECIFIED TORQUE	(2)									
9	THREADED BOLTS PROTRUDING AT LEAST ONE THREAD LENGTH WITH WASHERS	(2)									
10	CORRECT TYPE AND THICKNESS OF METAL DECKING	(2)									
11	ALL DECKING JOINTS MUST NOT HAVE GAPS	(2)									
12	ALL METAL DECKING MUST BE PROPERLY SECURED IN PLACE	(2)									
13	METAL DECKING MUST BE FREE FROM DEFECTS AND VISIBLE DAMAGES	(2)									
14	BEFORE CONCRETING, THE DECKING MUST BE FREE FROM GREASE, OIL, PAINT, AND ALL OTHER FOREIGN MATERIALS	(2)									
15	CORRECT NUMBER AND TYPE OF SHEAR STUDS	(2)									
16	CHECK SPACING AND POSITION	(2)									
17	CHECK STRENGTH OF SHEAR STUD WELDS	(2)									
18	WELDS SHOULD SHOW A FULL 360-DEGREE WELD FILLET AND FREE FROM VISIBLE DAMAGES	(2)									
19	TOLERANCE FOR COLUMN VERTICALITY: +-H/600 OR 5MM, MAXIMUM +-25MM; WHERE H IS THE FLOOR HEIGHT IN MM	(2)									
20	THE POSITION IN PLAN OF A STEEL COLUMN AT THE BASE SHALL NOT DEVIATE FROM THE SPECIFIED POSITION BY MORE THAN 10MM ALONG EITHER OF THE PRINCIPAL SETTING OUT AXES	(2)									
21	MAXIMUM DEVIATION OF LEVEL AT EACH END OF THE SAME BEAM: +-5MM	(2)									
22	FOR BEAM, THE LEVEL OF THE TOP OF THE STEELWORK AT ANY STOREY SHALL BE WITHIN +--10MM OF THE SPECIFIED LEVEL	(2)									
23	BEAMS SHALL NOT DEVIATE FROM THEIR SPECIFIED POSITIONS RELATIVE TO THE COLUMN TO WHICH THEY ARE CONNECTED BY MORE THAN 5MM	(2)									
24	AVERAGE THICKNESS OF THE COATING OR THE PROTECTIVE LAYER MUST NOT BE LESS THAN SPECIFIED	(2)									
25	NO SPALLING OF COATING OR PROTECTIVE LAYER FROM STRUCTURAL STEEL MEMBERS	(2)									

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	MATERIAL USED MUST BE TRACEABLE TO ITS ORIGINAL MILL CERTIFICATES	(2)									
2	MAKE WELDING TEST (RADIOGRAPHY ETC.) IF NEEDED	(2)									
3	NO VISIBLE DAMAGES	(2)									
4	MAKE STRENGTH TEST OF STEEL IF NEEDED	(2)									
5	* FOR TEST RECORDS; (%100 POINTS, IF %100 COMPLY / %75 POINTS, IF %95-100 COMPLY / %50 POINTS, IF %90-95 COMPLY / %25 POINTS, IF %85-90 COMPLY, %0 POINTS, IF LESS THAN %85 COMPLY)	(2)									
	SCHEDULED DATE :										
	QUANTITY :										

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	WALLCOVERING / WALLPAPER WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CLEAR SURFACE (EFFICIENT SANDING)	(1)									
2	SURFACE MOISTURE QUANTITY (<= %4)	(1)									
3	EFFICIENT UNDERCOATING	(1)									
4	EFFICIENT GLUE USE	(1)									
5	HARMONY AT INTERSECTIONS	(1)									
6	SMOOTH SURFACE (NO AIR BUBBLE ETC)	(1)									
7	SMOOTH CUT AT END & EDGE POINTS	(1)									
8	EFFICIENT CLEANING	(1)									
9	CHECK FOR WEATHER TEMPERATURE ! (+5C<T<+35C)	(1)									
10	CHECK FOR POSITIONING WITH RIGHT ANGLE	(1)									
11	STRETCHED AND EVEN SURFACE	(2)									
12	JOINT SHOULD NOT BE VISIBLE	(2)									
13	EDGES SHOULD BE NEATLY LAID AND FINISHED	(2)									
14	PROPER ANCHORING AT ALL EDGES	(2)									
15											

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	NO DAMAGED, TORN PAPER USE	(1)									
2	SAME COLOR TONE	(1)									
3	CHECK BRANDS	(1)									
4	CHECK GLUE MIXTURE	(1)									
5											
6											
7											
8											
9											
10											
11											
12											
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +5 C' (1) and no protection action will be done until the glue get dry, no gluing work may be done, otherwise score as 'NA' (not acceptable)***

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

QUALITY CHECKLIST FORM FOR CONSTRUCTION WORKS

A.	**CORPORATION NAME :**	
B.	**PROJECT NAME:**	
C.	**DATE :**	
D.	**WEATHER CONDITIONS :**	

SEQUENCE #	ACTIVITY NAME / ID / EXPLANATION :	RELATED SPECIFICATION **	GEOTEXTILE WATER ISOLATION WORKS								
	MAIN LOCATION :										
	SCORING EXPLANATION :		SCORE IN BETWEEN 0 - 10 FOR CERTAIN LOCATIONS								
	ACTIVITY LOCATION :		CHECK POINT 1			CHECK POINT 2			CHECK POINT 3		
	LABOR QUALITY INDICATORS		EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CLEAR SURFACE	(1)									
2	SMOOTH FILLING TIE-ROD HOLES WITH MORTAR	(1)									
3	EFFICIENTLY APPLYING 2 LAYERS OF HEATED MEMBRANE	(1)									
4	CHECK NUMBER OF MEMBRANES	(4.A13.329)									
5	CHECK OVERLAPPING	(1) (4.A13.329)									
6	CHECK NUMBER OF COATS	(4.A13.329)									
7	CHECK SKIRTING	(4.A13.329)									
8	CHECK LEAKAGE TEST RESULT	(1) (4.A13.329)									
9	EFFICIENTLY GLUING OF XPS LAYERS OVER MEMBRANE	(1)									
10	EFFICIENTLY INSTALLMENT OF DRAINAGE PLATE OVER XPS	(1)									
11	AGGREGATE BACKFILLING OVER DRAINAGE PLATE	(1)									
12	CHECK INTERSECTION & EDGE POINTS	(1)									
13	CHECK FOR WEATHER TEMPERATURE ! (+2C<T<+35C)	(1)									
14											
15											

	MATERIAL QUALITY INDICATORS	R.S. **	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3	EXPERT 1	EXPERT 2	EXPERT 3
1	CHECK FOR UNDAMAGED MATERIALS	(1)									
2	2 LAYERS BITUMED MEMBRANE (3MM+4MM)	(1)									
3	XPS (H>=2CM) (D>26KG/M3)	(1)									
4	DRAINAGE PLATE (D>400GR/M2)	(1)									
5	CHECK BRANDS	(1)									
6	NO SIGN OF LEAKAGE AFTER PONDING WET AREAS OVER A MINIMUM PERIOD OF 24 HOURS	(2)									
7	PONDING WITH FINAL FINISH IN-PLACE	(2)									
8	(IF 0% NON-COMPLIANCE WITH BCA CONDITIONS, %100 POINTS / IF 0%<X<2% NON-COMPLIANCE , ((2-X)*100/2)% POINTS, IF MORE THAN 2% NON-COMPLIANCE, %0 POINTS)	(2)									
9											
10											
11											
12											
	SCHEDULED DATE :										
	QUANTITY :										

**** If the temperature of the weather is below +2 C' (1), no adhering work may be done, otherwise score as 'NA' (not acceptable)***

** **(1) Private Specifications, (2) CONQUAS 9, (3) General Specification of Republic of Turkey, Ministry of Environment & Urbanisation, (4) From Literature**

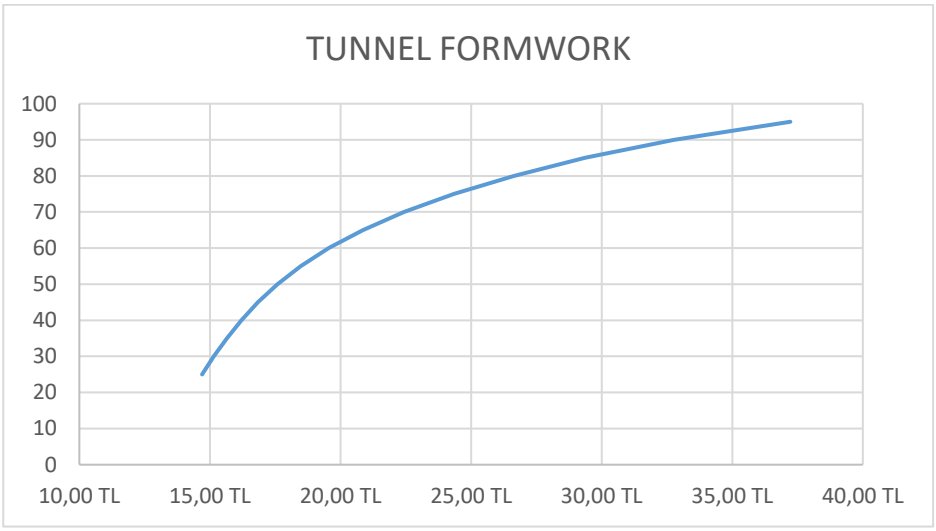
SIGNATURES / APPROVAL	
QUALITY INSPECTOR	*QUALITY CHIEF*

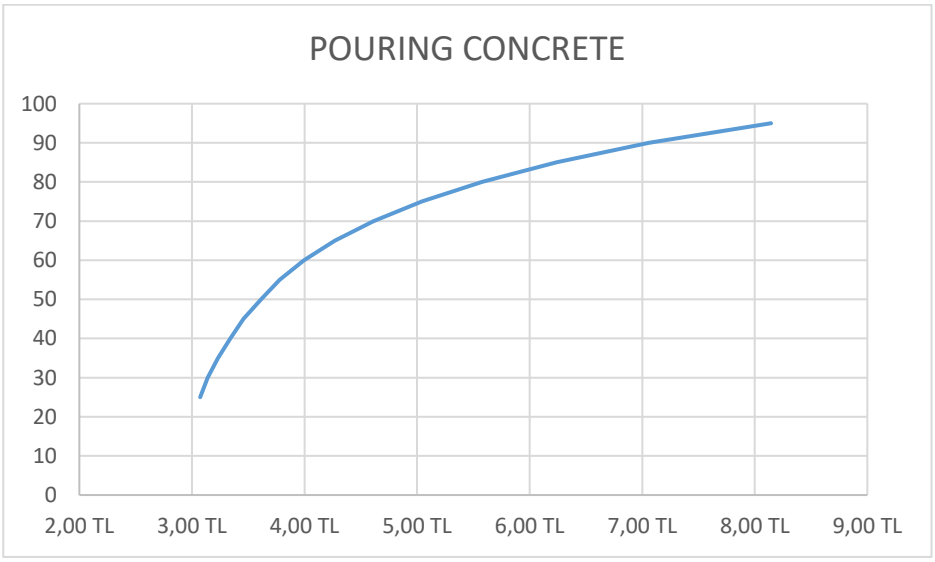
Appendix B

Developed Value Functions for 2017 Prices:

QUALITY	UNIT COST (TL/1UNIT)								
	TUNNEL FORMWORK	POURING CONCRETE	REINFORCE MENT	CONVENT. FORMWORK	19CM PUMICE MASONRY	SCREED (LEVELLING CONCRETE)	MARBLE SLAB	MARBLE STAIRHEAD	MARBLE STAIR
95	37,22 TL	8,14 TL	413,46 TL	24,45 TL	23,27 TL	16,07 TL	28,10 TL	42,35 TL	21,04 TL
90	32,77 TL	7,06 TL	371,30 TL	21,99 TL	20,49 TL	14,54 TL	23,95 TL	36,30 TL	18,07 TL
85	29,37 TL	6,24 TL	339,48 TL	20,01 TL	18,68 TL	13,39 TL	20,87 TL	31,74 TL	15,90 TL
80	26,63 TL	5,58 TL	315,59 TL	18,38 TL	17,40 TL	12,46 TL	18,62 TL	28,20 TL	14,21 TL
75	24,34 TL	5,04 TL	297,91 TL	17,06 TL	16,37 TL	11,70 TL	16,98 TL	25,47 TL	12,88 TL
70	22,44 TL	4,61 TL	284,85 TL	15,99 TL	15,51 TL	11,05 TL	15,75 TL	23,41 TL	11,83 TL
65	20,86 TL	4,27 TL	275,22 TL	15,13 TL	14,78 TL	10,48 TL	14,79 TL	21,82 TL	11,00 TL
60	19,55 TL	3,99 TL	268,33 TL	14,45 TL	14,15 TL	9,96 TL	14,01 TL	20,62 TL	10,33 TL
55	18,47 TL	3,78 TL	262,60 TL	13,92 TL	13,59 TL	9,50 TL	13,34 TL	19,65 TL	9,80 TL
50	17,58 TL	3,61 TL	257,63 TL	13,50 TL	13,09 TL	9,08 TL	12,77 TL	18,83 TL	9,36 TL
45	16,84 TL	3,46 TL	253,18 TL	13,18 TL	12,64 TL	8,70 TL	12,27 TL	18,11 TL	8,99 TL
40	16,20 TL	3,34 TL	249,13 TL	12,92 TL	12,23 TL	8,36 TL	11,83 TL	17,46 TL	8,68 TL
35	15,65 TL	3,23 TL	245,37 TL	12,70 TL	11,86 TL	8,07 TL	11,43 TL	16,86 TL	8,39 TL
30	15,15 TL	3,14 TL	241,82 TL	12,51 TL	11,52 TL	7,82 TL	11,07 TL	16,30 TL	8,13 TL
25	14,70 TL	3,07 TL	238,42 TL	12,34 TL	11,20 TL	7,61 TL	10,74 TL	15,73 TL	7,90 TL

QUALITY	UNIT COST (TL/1UNIT)								
	BASEBOARD	CERAMICS TILE	WOOD PARQUET	CEILING PAINTING	WALL PAINTING	CEMENT PLASTER	GYPSUM PLASTER	CEILING GYP.PLAS.	WALL COVERING
95	8,31 TL	27,07 TL	4,88 TL	4,58 TL	5,52 TL	20,66 TL	19,25 TL	12,83 TL	6,79 TL
90	7,24 TL	23,41 TL	4,15 TL	3,95 TL	4,97 TL	17,99 TL	16,73 TL	11,36 TL	5,83 TL
85	6,42 TL	20,67 TL	3,71 TL	3,53 TL	4,60 TL	16,36 TL	15,20 TL	10,32 TL	5,12 TL
80	5,78 TL	18,60 TL	3,41 TL	3,23 TL	4,35 TL	15,22 TL	14,10 TL	9,50 TL	4,58 TL
75	5,27 TL	17,04 TL	3,16 TL	3,03 TL	4,16 TL	14,38 TL	13,20 TL	8,83 TL	4,16 TL
70	4,87 TL	15,84 TL	2,97 TL	2,89 TL	4,00 TL	13,60 TL	12,41 TL	8,29 TL	3,83 TL
65	4,55 TL	14,91 TL	2,80 TL	2,78 TL	3,88 TL	12,90 TL	11,72 TL	7,83 TL	3,56 TL
60	4,31 TL	14,18 TL	2,65 TL	2,69 TL	3,78 TL	12,25 TL	11,08 TL	7,45 TL	3,32 TL
55	4,12 TL	13,60 TL	2,52 TL	2,63 TL	3,70 TL	11,65 TL	10,50 TL	7,12 TL	3,12 TL
50	3,96 TL	13,13 TL	2,41 TL	2,57 TL	3,64 TL	11,10 TL	9,98 TL	6,84 TL	2,93 TL
45	3,84 TL	12,73 TL	2,32 TL	2,52 TL	3,59 TL	10,58 TL	9,49 TL	6,61 TL	2,76 TL
40	3,74 TL	12,39 TL	2,25 TL	2,46 TL	3,55 TL	10,09 TL	9,05 TL	6,41 TL	2,62 TL
35	3,66 TL	12,07 TL	2,19 TL	2,41 TL	3,52 TL	9,67 TL	8,65 TL	6,23 TL	2,48 TL
30	3,58 TL	11,79 TL	2,15 TL	2,37 TL	3,50 TL	9,28 TL	8,27 TL	6,07 TL	2,36 TL
25	3,52 TL	11,54 TL	2,12 TL	2,34 TL	3,48 TL	8,92 TL	7,95 TL	5,92 TL	2,25 TL


TUNNEL FORMWORK
100
90
80
70
60
50
40
30
20
10
0
10,00 TL
15,00 TL
20,00 TL
25,00 TL
30,00 TL
35,00 TL
40,00 TL


POURING CONCRETE
100
90
80
70
60
50
40
30
20
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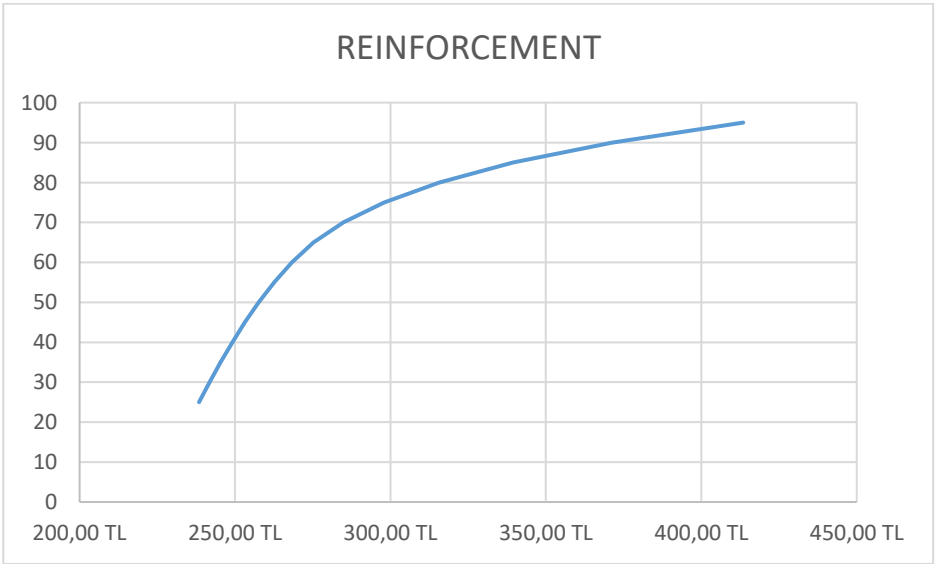
3,00 TL
4,00 TL
5,00 TL
6,00 TL
7,00 TL
8,00 TL
9,00 TL


REINFORCEMENT
100
90
80
70
60
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40
30
20
10
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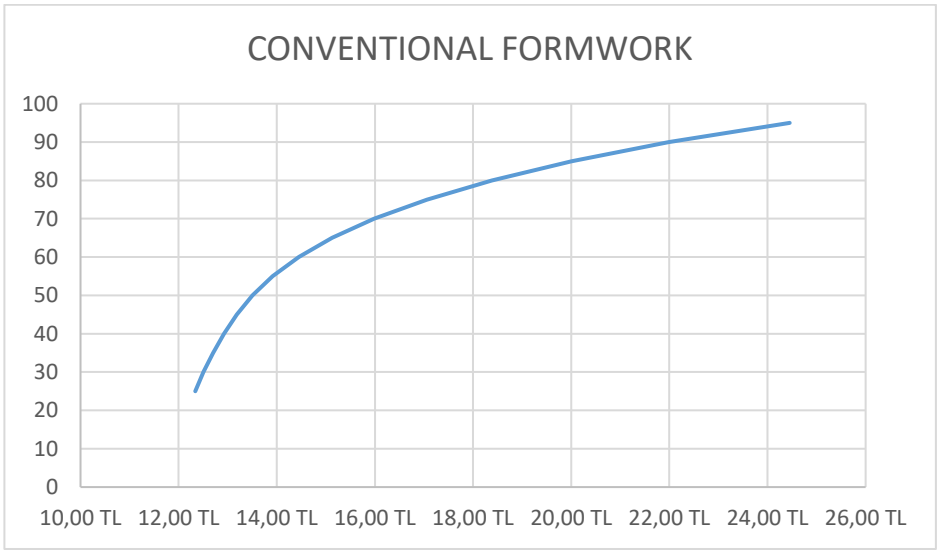
200,00 TL
250,00 TL
300,00 TL
350,00 TL
400,00 TL
450,00 TL


CONVENTIONAL FORMWORK
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50
40
30
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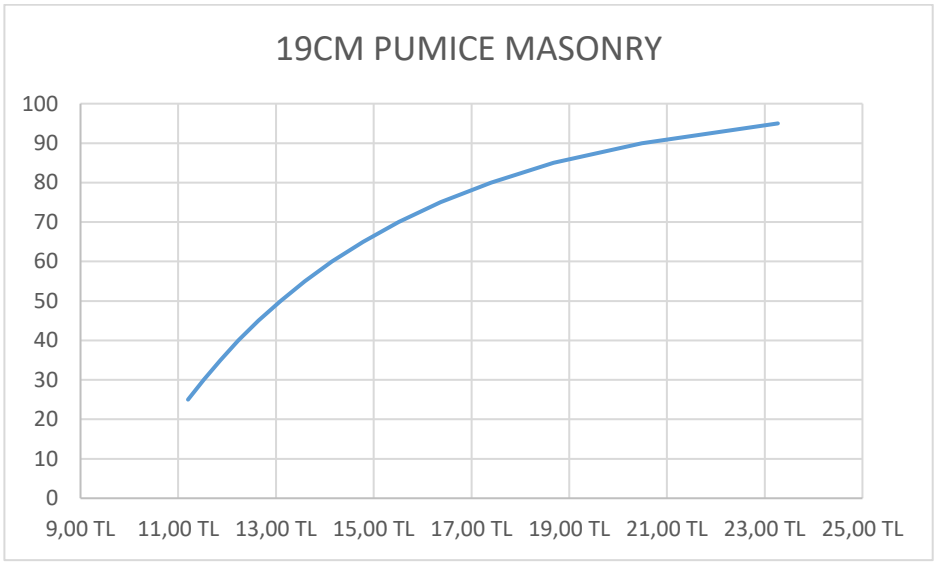
26,00 TL


19CM PUMICE MASONRY
100
90
80
70
60
50
40
30
20
10
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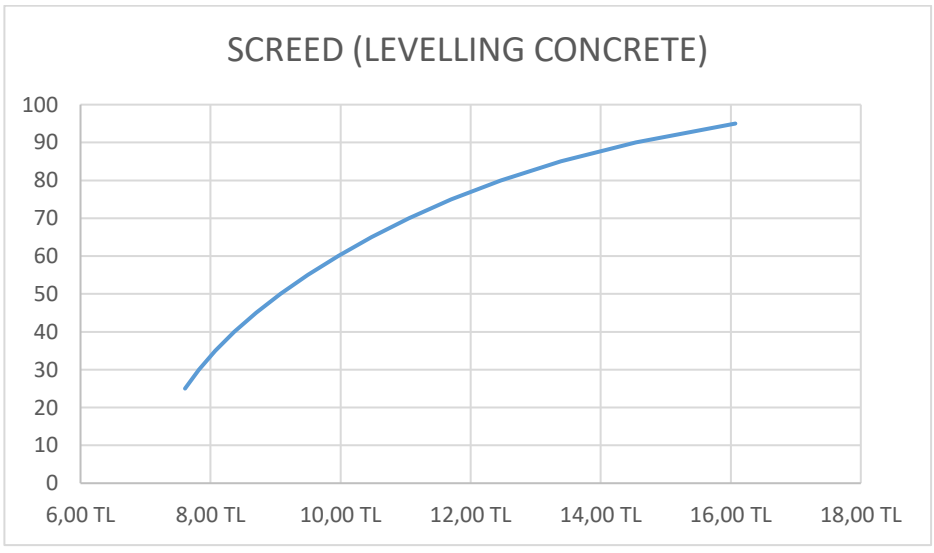
25,00 TL


SCREED (LEVELLING CONCRETE)
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90
80
70
60
50
40
30
20
10
0
6,00 TL
8,00 TL
10,00 TL
12,00 TL
14,00 TL
16,00 TL
18,00 TL


MARBLE SLAB
100
90
80
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50
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10
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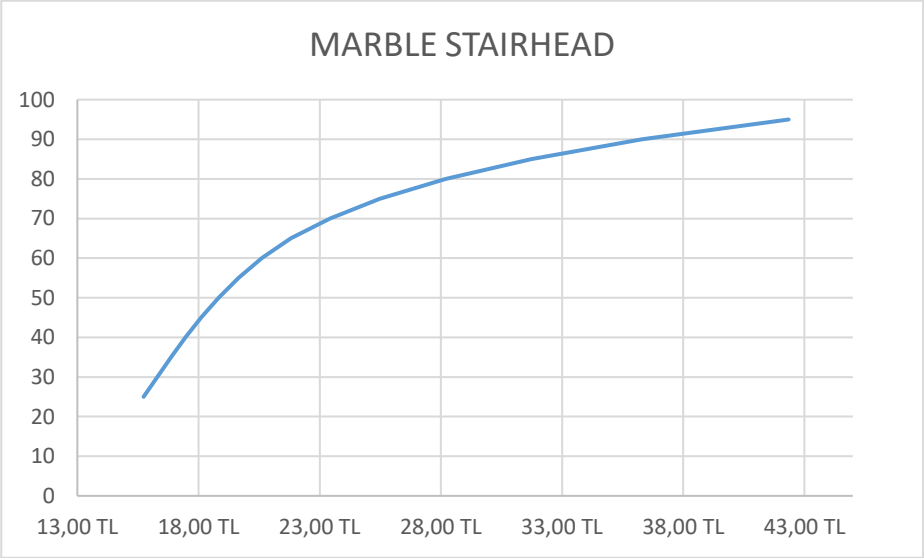
13,00 TL
18,00 TL
23,00 TL
28,00 TL


MARBLE STAIRHEAD
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80
70
60
50
40
30
20
10
0
13,00 TL
18,00 TL
23,00 TL
28,00 TL
33,00 TL
38,00 TL
43,00 TL


MARBLE STAIR
100
90
80
70
60
50
40
30
20
10
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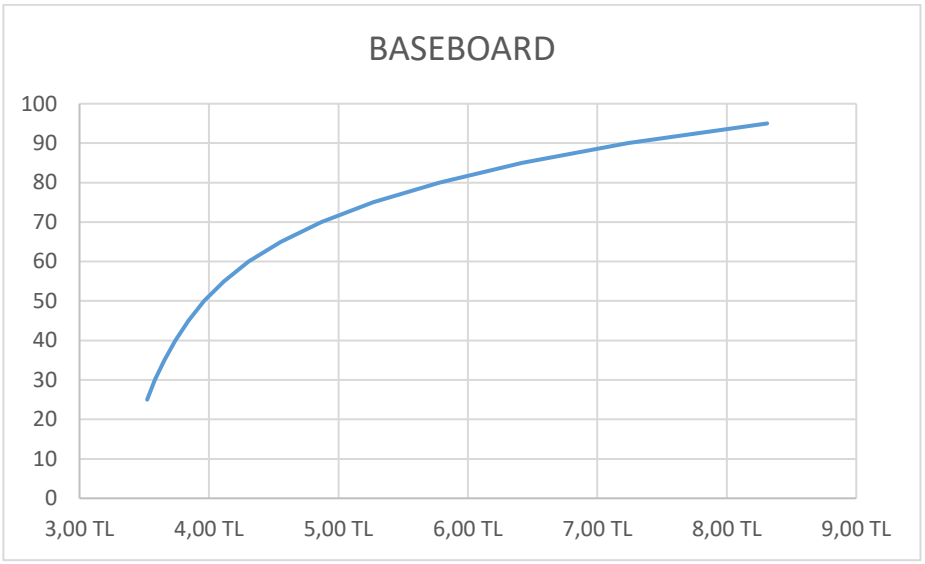
10,00 TL
12,00 TL
14,00 TL
16,00 TL
18,00 TL
20,00 TL
22,00 TL


BASEBOARD
100
90
80
70
60
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10
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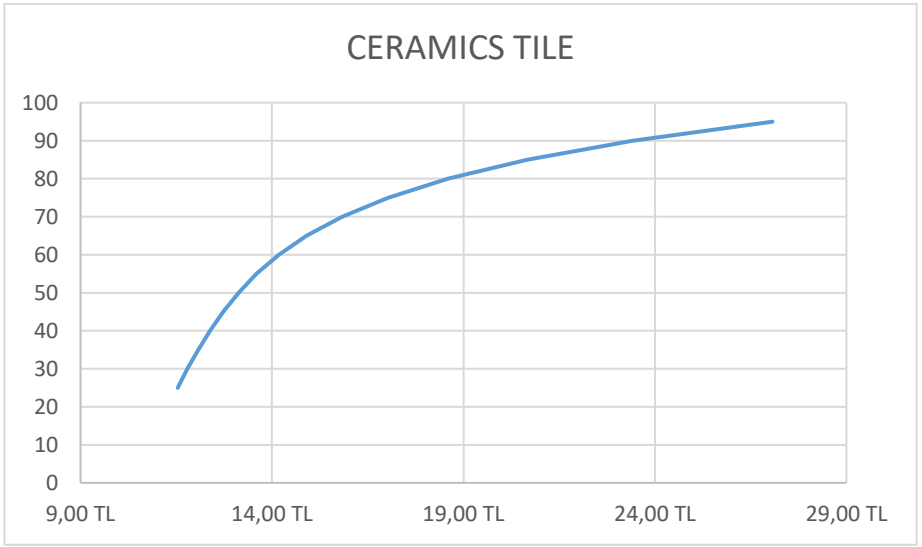
3,00 TL
4,00 TL
5,00 TL
6,00 TL
7,00 TL
8,00 TL
9,00 TL


CERAMICS TILE
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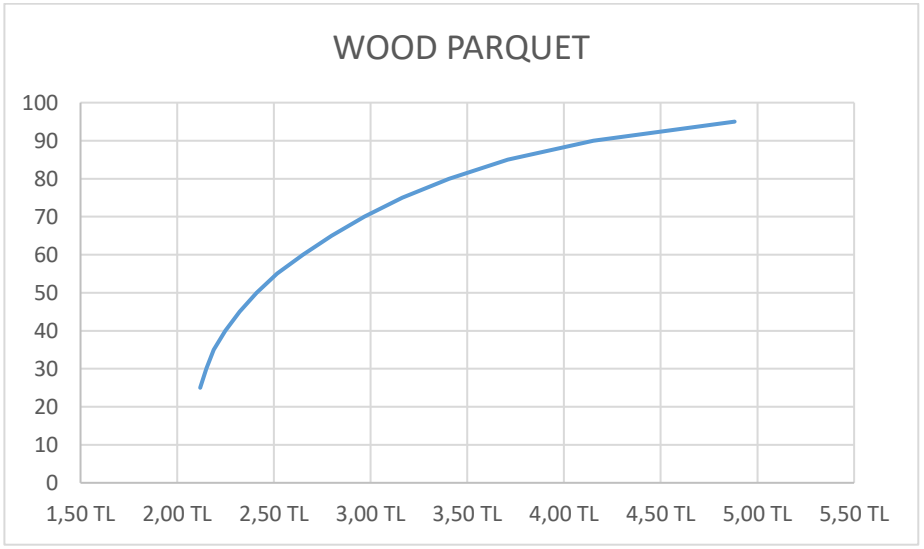
30
20
10
0
9,00 TL
14,00 TL
19,00 TL
24,00 TL
29,00 TL


WOOD PARQUET
100
90
80
70
60
50
40
30
20
10
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2,00 TL
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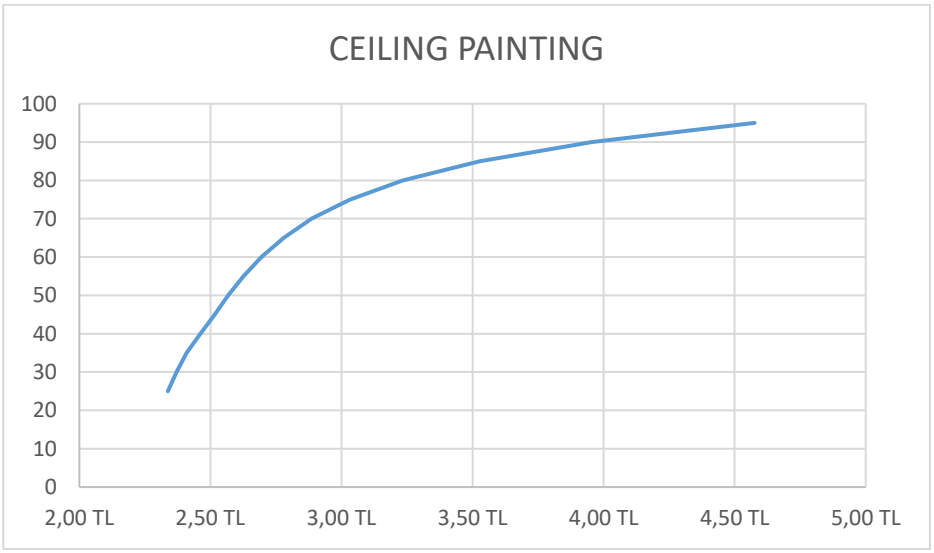
3,50 TL
4,00 TL
4,50 TL
5,00 TL
5,50 TL


CEILING PAINTING
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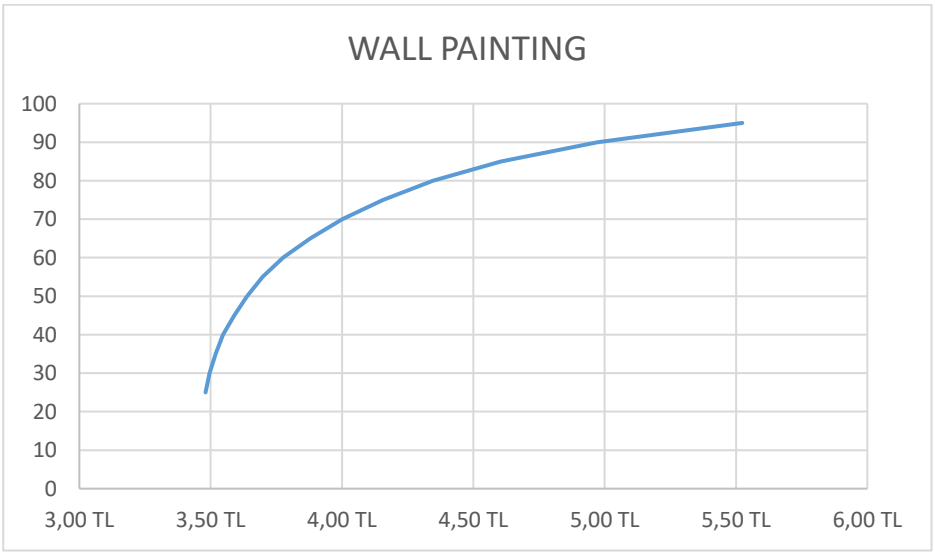
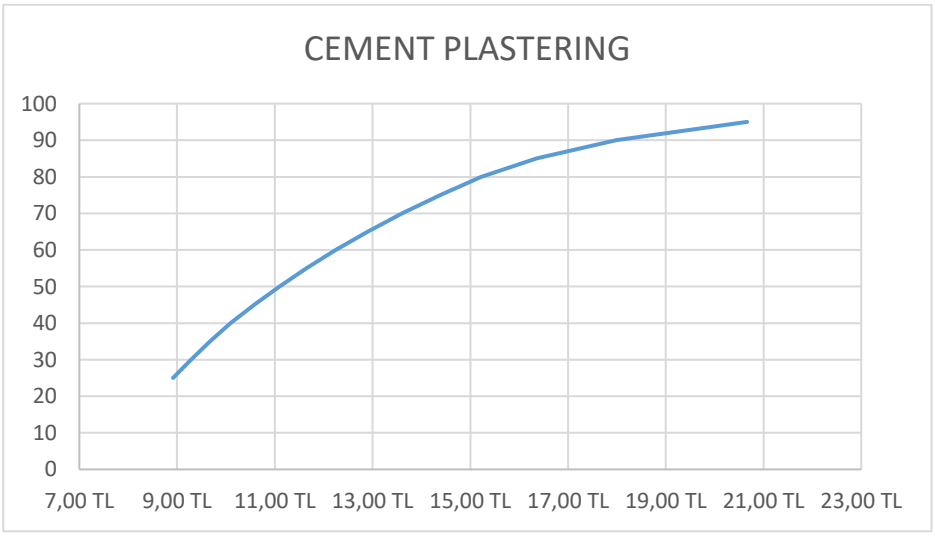
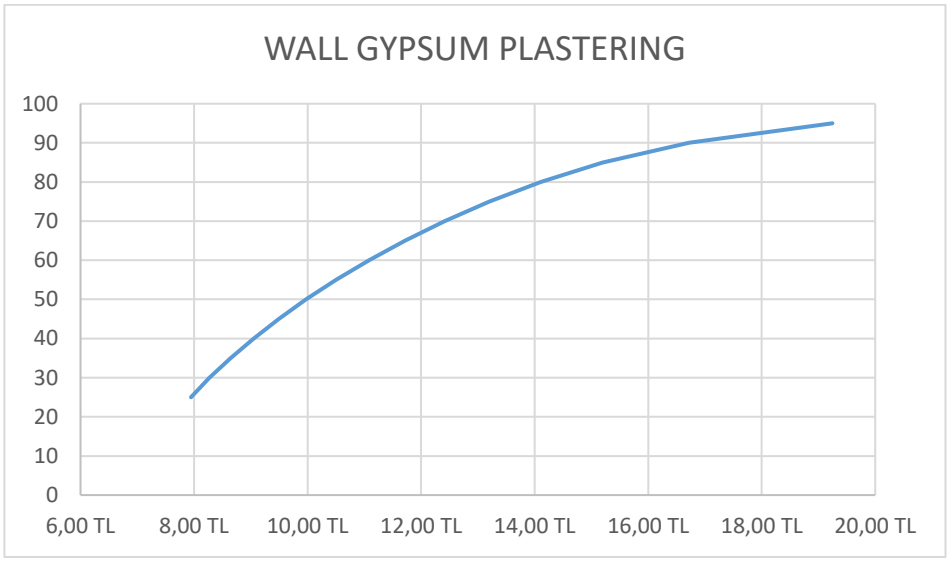
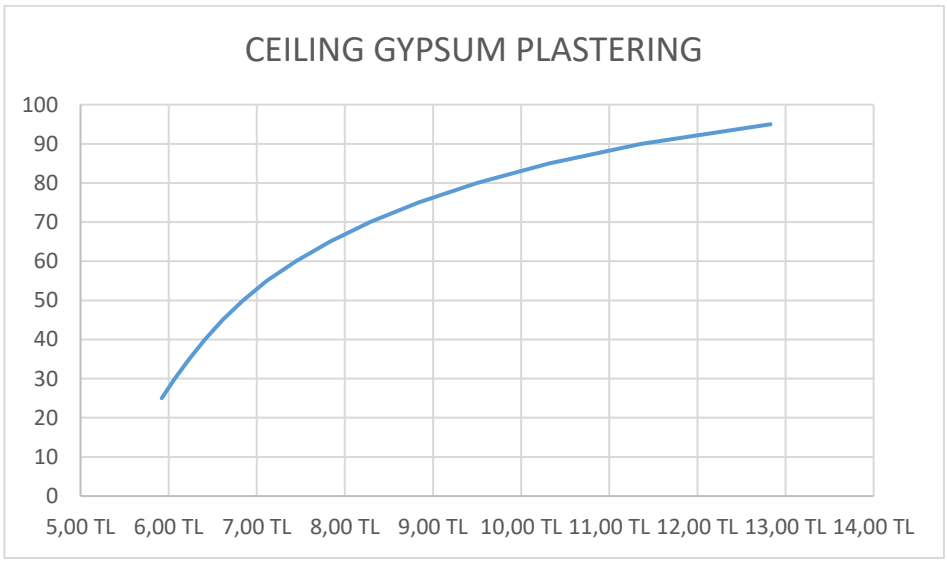
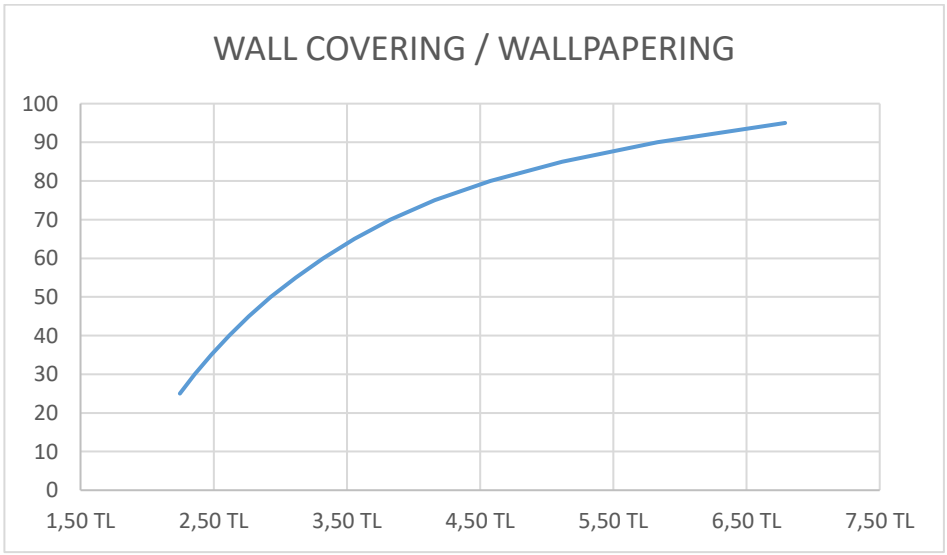
80
70
60
50
40
30
20
10
0
2,00 TL
2,50 TL
3,00 TL
3,50 TL
4,00 TL
4,50 TL
5,00 TL


WALL PAINTING
100
90
80
70
60
50
40
30
20
10
0
3,00 TL
3,50 TL
4,00 TL
4,50 TL
5,00 TL
5,50 TL
6,00 TL


CEMENT PLASTERING
100
90
80
70
60
50
40
30
20
10
0
7,00 TL
9,00 TL
11,00 TL
13,00 TL
15,00 TL
17,00 TL
19,00 TL
21,00 TL
23,00 TL


WALL GYPSUM PLASTERING
100
90
80
70
60
50
40
30
20
10
0
6,00 TL
8,00 TL
10,00 TL
12,00 TL
14,00 TL
16,00 TL
18,00 TL
20,00 TL


CEILING GYPSUM PLASTERING
100
90
80
70
60
50
40
30
20
10
0
5,00 TL
6,00 TL
7,00 TL
8,00 TL
9,00 TL
10,00 TL
11,00 TL
12,00 TL
13,00 TL
14,00 TL


WALL COVERING / WALLPAPERING
100
90
80
70
60
50
40
30
20
10
0
1,50 TL
2,50 TL
3,50 TL
4,50 TL
5,50 TL
6,50 TL
7,50 TL

Appendix C

#	Numbered Studies in Related Tables	#	Numbered Studies in Related Tables
1	Dodson, Defavari, & Carvalho (2015)	48	Ledbetter W.B. (1994)
2	Solomon P.J. (2006)	51	Davis K., Ledbetter W.B. & Burati Jr. J.L. (1989)
5	Gao X. & Ye Z. (2011)	53	Jafari A. & Love P.E.D. (2013)
7	Ma X. & Yang B. (2012)	55	Stevens J.D., Members C.G. & Ledbetter W.B. (1994)
8	Xu J., Zhang H. & Li F. (2010)	56	De Saram D.D., Ahmed S.M. & Anson M. (2004)
12	Yan Z. (2016)	59	Likins G., Piscsalko G., Rausche F. & Hussein M. (2004)
13	Pollack-Johnson B. & Liberatore M.J. (2006)	60	Huang S., Kang Y., Wang Z. & Zhao D. (2010)
14	Paquin J.P., Couillard J. & Ferrand D.J. (2000)	61	Koziołek S. & Derlukiewicz D. (2011)
15	Fuming L, Wang F. & Song Y. (2009)	62	Akinci B., Boukampa F., Gordona C., Huberb D., Lyonsb C. & Park K. (2005)
16	Xi W. (2014)	63	Yanga Y.Q., Wangb S.Q., Dulaimic M. & Low S.P. (2003)
18	Song S.H., Lee H.S.& Park M. (n.d.)	64	China S., Kimb K. & Kim Y.S. (2003)
21	Liu L., Chen I.M., Kayacan E., Tiong L.K. & Maruvanchery V. (2015)	65	Lee D.E., Lim T.K. & Arditi D. (2008)
25	Lee D.H. & Arditi D. (2006)	66	Laofor C. & Peansupap V. (2012)
26	Yasamis-Speroni F.; Lee D.E. & Arditi D. (2012)	67	Wang L.C. (2007)
29	Deffenbaugh R.L. (1993)	70	Zhong B.T., Ding L.Y., Luo H.B., Zhou Y., Hu Y.Z. & Hu H.M. (2012)
30	Rounds J.L. & Chi N.Y. (1985)	71	Lim C.W., Yu J.H. & Kim C.D. (2010)
31	AlMaian R.Y., Needy K.L., Walsh K.D. & Alves T.C.L. (2016)	73	Boukamp F. & Akinci B. (2007)
33	Federle M.O. & Chase G.W. (1993)	74	Navon R. (2004)
34	Stukhart G. (1989)	75	Wang Q., Kim M.K., Chenga J.C.P. & Sohn H. (2016)
37	Chase G. W. (1993)	77	Lee M.H., Chou C.P. & Li K.H. (2009)
38	Hensey M. (1993)	78	Montero R., Victores J.G., Martínez S., Jardón A.& Balaguer C. (2015)
40	Woldesenbet A. & Jeong H.D. (2014)	79	Liu J.N.K. (1997)
41	Samuels A.F. & Young J.D. (2013)	81	Lam K.C. & Ng S.T. (2005)
44	Wu Y., Huang Y., Zhang S. & Zhang Y. (2014)	82	Chow L.K. & Ng S.T. (2006)
45	Burati Jr.J.L., Matthews M.F. & Kalidindi S.N. (1991)	83	Omar T. & Nehdi M.L. (2006)
47	Sullivan K.T. (2011)	84	Rodríguez-Martín M., Lagüela S., González-Aguilera D. & Martínez J. (2015)

#	Numbered Studies in Related Tables	#	Numbered Studies in Related Tables
87	Hoxley M. (2000)	127	Chen L. & Luo H. (2014)
88	Zavadskas E.K., Liias R. & Turskis Z. (2008)	129	Atasoy G., Tang P. & Akinci B. (2009)
89	Tam C.M., Deng Z.M., Zeng S.X. & Ho C.S. (2000)	130	Ong H.Y., Wang C. & Zainon N. (2018)
90	Gordon C. & Akinci B. (2005)	131	de Souza A.D., Rocha A.R.C., Cristina D. & Constantino B.A. (2014)
91	Schubert P., Guiver T., MacDonald R. & Yu F. (2006)	133	Love P.E.D. & İrani Z. (2002)
93	Chan A.P.C. & Chan A.P.L. (2004)	134	Pheng L.S. & Wee D. (2011)
95	Willis T.H. & Willis W.D. (1995)	135	Carson R.S. & Zlicaric B. (2008)
96	Hughes S.W., Tippett D.D. & Thomas W.K. (2004)	136	Hammad D.B., Shafiq N. & Nuruddin M.F. (2014)
97	Dikmen I., Birgonul M.T. & Kiziltas S. (2004)	137	Daher S., Zayed T., Elmasry M. & Hawari A. (2017)
98	Kim Y.S., Oha S.W., Cho Y.K. & Seo J.W. (2007)	139	Arditi D. & Günaydın M. (1997)
99	Loushine T.W., Hoonakker P.L.T., Carayon P. & Smith M.J. (2007)	140	Boydak A. (2013)
100	Ahmed H.M. & Yusuff R.M. (2016)	141	Kalyana T.S., Zadehb P.A., Staub-Frenchc S. & Froesed T.M. (2016)
101	Taneja S., Akinci B., Garrett J.H., Soibelman L., Ergen E., Pradhan A., Tang P., Berges M., Atasoy G., Liu X., Shahandashti S.M. & Anil E.B. (2011)	142	Achkar E. (2017)
102	Golparvar-Fard M., Bohn J., Teizer J., Savarese S. & Peña-Mora F. (2011)	143	Building and Construction Authority of Singapore (2017)
103	Kwahk K.J., Park M.H., Kim J.H. & Kim J.J. (2011)	144	Rumane A.R. (2018)
104	Wang J., Sun W., Shou W., Wang X., Wu C., Chong H.Y., Liu Y. & Sun C. (2015)	145	Wardle T. & Duncan A. (2017)
105	Luo H. & Gong P. (2014)	146	Ministry of Environment & Urbanisation, Republic of Turkey (2007)
106	Czemplik A. (2015)	150	Ying H. (2016)
107	Hu Y.Z., Zhong B., Luo H. & Hu H.M. (2012)	151	Huang H. & Zheng J. (2018)
109	Khalid T.A. & Yeoh E.T. (2015)	155	Constructıon Industry Development Board of Malaysıa (n.d.)
110	Hernandez J.I.M., Olaso J.R.O. & Gomez J.R. (2013)	156	Miguel A., Madria W. & Polancos R. (2019)
113	Yerabolu R. (2010)	157	Khesal T., Khalilzadeh M., Galankashi M.R. & Soltani R. (2018)
122	Efe P. (2015)	158	THE EFQM Board of Directors (2012)