ANKARA YILDIRIM BEYAZIT UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

INCREASE IN EFFICIENCY OF COLD ROLLING MILL ERECTION PROCESS

M.Sc. Thesis by

Hatice ÇETİN

Department of Mechanical Engineering

June 2019

ANKARA

INCREASE IN EFFICIENCY OF COLD ROLLING MILL ERECTION PROCESS

A Thesis Submitted to

The Graduate School of Natural and Applied Sciences of

Ankara Yıldırım Beyazıt University

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Mechanical Engineering, Department of Mechanical Engineering

by

Hatice ÇETİN

June 2019

ANKARA

M.Sc. THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"INCREASE IN EFFICIENCY OF COLD ROLLING MILL ERECTION PROCESS"** completed by **HATİCE ÇETİN** under the supervision of **PROF. DR. EROL ARCAKLIOĞLU** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Prof. Dr. Erol ARCAKLIOĞLU

Supervisor

Prof. Dr. Saadettin ORHAN

Jury Member

Doç. Dr. Fatih Emre BORAN

Jury Member

Prof. Dr. Ergün ERASLAN

Director

Graduate School of Natural and Applied Sciences

I hereby declare that, in this thesis which has been prepared in accordance with the Thesis Writing Manual of Graduate School of Natural and Applied Sciences,

- All data, information and documents are obtained in the framework of academic and ethical rules,
- All information, documents and assessments are presented in accordance with scientific ethics and morals,
- All the materials that have been utilized are fully cited and referenced,
- No change has been made on the utilized materials,
- All the works presented are original,

and in any contrary case of above statements, I accept to renounce all my legal rights.

Date: 24.06.2019 **Signature: ……..**

Name & Surname: Hatice ÇETİN

ACKNOWLEDGEMENT

First and foremost I would like to offer my sincere gratitude to my supervisor Prof. Dr. Erol Arcaklıoğlu. Without his guidance and patience, this thesis would not have been possible.

Secondly, I am grateful to GEMONT- General Assembly Industry and Trade Limited Company for providing technical support.

I would like to also acknowledge the division chiefs Aykut Azak, Ömer Özden and Erdal Yazımcı for their assistance.

2019, 6 June **Hatice ÇETİN**

INCREASE IN EFFICIENCY OF COLD ROLLING MILL ERECTION PROCESS

ABSTRACT

By 1930s, infrastructure of the iron and steel industry in Turkey has been shaped. KARDEMIR was establish in 1937 to meet the demand for iron and steel flat demands. Particularly after 2001, the steel sector gained a rapid growth. Within the recent fifteen-years, Turkey has been one of the fastest growing countries in iron and steel sector. The fact that the sectors with intense metal inputs such as automotive and machinery industries have the tendency to grow and become prominent in this development.

With the increasing investments on flat and structural steel production facilities, various courses of businesses have emerged. One of them is processes of cold rolling mill erection which involves a relatively complex process. The process management is carried out in three main sections such as mechanical, piping and electrical works. Therefore, it is important to ensure effective communication and coordination between these departments. Proper planning of this process and efficient organization of systems may increase project efficiency.

In this study, it is aimed to examine two similar projects of cold rolling mill complex, to compare them through the project planning process and to produce more effective solutions for future projects. For this purpose, firstly the systems of these two cold rolling mills complex were defined, and their differences and similarities were described. Initially, the encountered problems and the possible causes of these problems were identified by comparing the project details, and the most appropriate total assembly time was determined by using one of the project management techniques, in this case, the PERT Analysis. Then, erection progresses of the production lines were compared in terms of actual times and the number of employees.

Keywords: Cold rolling, cold rolling mill complex, erection, assembly, erection progress, PERT, project management, project planning, time analysis, man-hour, efficiency, steel, steel production plant

SOĞUK HADDEHANE MONTAJININ VERİMLİLİĞİNİN ARTIRILMASI

ÖZ

1930'lu yıllarda Türkiye'de demir çelik sektörünün altyapısı atılmış, 1937 yılında Karabük Demir çelik yassı ürün talebini karşılamak için kurulmuştur. Çelik sektörü özellikle 2001 yılından sonra, hızlı bir büyüme ivmesi kazanmıştır. Son on beş yıllık süreçte Türkiye, Demir Çelik sektöründe hızlı büyüyen ülkelerden biri olmuştur. Otomotiv ve makine imalatı gibi yoğun metal girdisi olan sektörlerin büyüme eğiliminde olması bu gelişmede ön plana çıkmaktadır.

Yassı ve yapısal çelik üretim tesislerine artan yatırımlarla, farklı iş sahaları ortaya çıkmıştır. Bunlardan birisi de soğuk haddehane kurulum süreçleridir. Soğuk haddehane montajında süreç yönetimi üç ana bölümde mekanik, borulama ve elektrik olmak üzere çalışılmaktadır. Bu yüzden birimler arasında iletişimin ve koordinasyonun etkin bir şekilde sağlanması önemlidir. Bu sürecin doğru planlaması ve sistemlerin organizasyonu etkin bir şekilde sağlanması proje verimliliğini arttıracaktır.

Bu çalışmada iki benzer soğuk haddehane kompleks montajının incelenmesi, proje planlama süreci üzerinden karşılaştırılması ve buna gelecek projeler için daha etkin çözümler üretilmesi hedeflenmiştir. Bu amaçla, öncelikle bu iki haddehanenin sistemleri tanımlanmış ve farklılıkları ile benzer yönleri tarif edilmiştir. Öncelikle, proje detayları karşılaştırılarak, karşılaşılan sorunlar ve bu sorunların muhtemel sebepleri tanımlanarak, proje yönetim tekniklerinden PERT analizi ile en uygun toplam montaj süresi belirlenmiştir. Sonrasında üretim hatlarını gerçekleşen süreler ve çalışan eleman sayıları ile karşılaştırma yapılmıştır.

Anahtar Kelimeler: Soğuk hadde, soğuk haddehane, montaj, montaj süresi verimliliği, PERT, proje yönetimi, proje planlama, tesis kurulumu, verimlilik, çelik, çelik üretimi tesisi, zaman analizi, time, adam saat.

TABLE OF CONTENT

ACKNOWLEDGEMENT iv
ABSTRACT v
ÖZ vi
TABLE OF CONTENT vii
LIST OF SYMBOLS x
NOMENCLATURE x
LIST OF TABLES xii
LIST OF FIGURES xiv
1 INTRODUCTION 1
1.1 Overview 1
1.2 Literature 3
1.3 Objectives 4
2 ROLLING MILL 6
2.1 Mounted Lines and Their Functions 9
2.1.1 Pickling Line and Tandem Cold Mill (PL&TCM) 10
2.1.2 Electrolytic Cleaning Line (ECL) 11
2.1.3 Batch Annealing Furnace (BAF) 11
2.1.4 Skin Pass Mill – Temper Mill (SPM) 12
2.1.5 Hot Dip Galvanizing Line (HDGL) 12
2.1.6 Color Coating Line (CCL) 13
3 PROJECT MANAGEMENT 15
3.1 Phases of Project Management 16
3.1.1 Initiating Process 17
3.1.2 Planning Process 17
3.1.3 Executing Process 18
3.1.4 Controlling Process 18
3.1.5 Closing Process 18
3.2 Project Planning 18
4 PROJECT MANAGEMENT TECHNIQUES 21
4.1 Gant Chart 26
4.2 The Network Method 28
4.3 Critical Path Method (CPM) 29

4.4 Program Evaluation and Review Technique (PERT) 34
5 METHODOLOGY 38
5.1 Mechanical Works 40
5.2 Piping Works 41
5.3 Electrical Works 41
5.4 The Project Time Analysis 43
5.4.1 Time Analysis for Mechanical Works 44
5.4.2 Time Analysis for Piping Works 46
5.4.3 Time Analysis for Electrical Works 47
5.5 PERT Analysis 49
6 RESULTS AND DISCUSSION 56
6.1 PL&TCM 57
6.1.1 Mechanical works of PL&TCM 57
6.1.2 Piping works of PL&TCM 58
6.1.3 Electrical works of PL&TCM 59
6.2 ARP 60
6.2.1 Mechanical works for ARP 60
6.2.2 Piping Works for ARP 61
6.2.3 Electrical Works of ARP 61
6.3 HDGL 62
6.3.1 Mechanical works of HDGL 62
6.3.2 Piping Works of HDGL 63
6.3.3 Electrical Works of HDGL 63
6.4 TM 64
6.4.1 Mechanical Works of TM 64
6.4.2 Piping Works of TM 64
6.4.3 Electrical Works of TM 65
6.5 BAF 66
6.5.1 Mechanical Works of BAF 66
6.5.2 Piping Works of BAF 66
6.5.3 Electrical Works of BAF 67
6.6 CCL 68
6.6.1 Mechanical Works of CCL 68
6.6.2 Piping Works of CCL 68

6.6.3 Electrical Works of CCL 69
6.7 ECL 70
6.7.1 Mechanical Works of ECL 70
6.7.2 Piping Works of ECL 70
6.7.3 Electrical Work of ECL 71
6.8 UTILITY 72
6.8.1 Mechanical Works of Utility 72
6.8.2 Piping Works of Utility 72
6.8.3 Electrical Work of Utility 73
7 CONCLUSION 75
REFERENCES 80
APPENDICES 84
Appendix A Cold Rolling Mill Complex Project Organization Chart 84
Appendix B Data of Mounted Lines 85
Appendix C GANT Chart of Project A 86
Appendix D GANT Chart of Project B 87
Appendix E - Comparisons of Mounted Lines 88
CURRICULUM VITAE 113

LIST OF SYMBOLS

a optimistic time

b pessimistic time

Ki activities on critical path

m most likely time

σ standard deviation

t_e expected time

TL desired project completion date

TE period on critical path

v variance

z Standard normal distribution

NOMENCLATURE

ARD Arrow Diagram Method

ARP Acid Regeneration Plant

BAF Batch Annealing Furnace

CCL Color Coating Line

CPM Critical Path Method

ECL Electrolytic Cleaning Line

GERT Graphical Evaluation and Review Technique

HDGL Hot Dip Galvanizing Line

PDM Precedence Diagram Method

PERT Program Evaluation and Review Technique

PL&TCM Pickling Line and Tandem Cold Mill

SOW Statement Of Work

SPM Skin Pass Mill (Temper Mill)

TLV	Tension Leveler Section
TM	Temper Mill
WBS	Work Breakdown Structure

LIST OF TABLES

Table 5.1 Differences and similarities between Project A and Project B 39

Table 5.2 The amounts of cable, instrument, and panel for Project A and Project B…… 42

Table 5.3 Assumptions related to the degree of effect for each activity on the total electrical project 42

Table 5.4 Data of Project A and Project B 43

Table 5.5 Data of the personnel who work in mechanical works per month 45

Table 5.6 Data of the personnel who work in piping works per month 47

Table 5.7 Data of the personnel who work in electrical works 49

Table 5.8 Total numbers of problems and average solution times of problems for Project A and Project B 49

Table 5.9 Time table of the project lines 51

Table 6.1 PLTCM Mechanical Progress /Man-hour 58

Table 6.2 PLTCM Piping Progress/ Man-hour 59

Table 6.3 PLTCM Electrical Progress /Man-hour 60

Table 6.4 ARP Mechanical Progress /Man-hour 60

Table 6.5 ARP Piping Progress /Man-hour 61

Table 6.6 ARP Electrical Progress /Man-hour 62

Table 6.7 HDGL Mechanical Progress /Man-hour 62

Table 6.8 HDGL Piping Progress /Man-hour 63

Table 6.9 HDGL Electrical Progress /Man-hour 64

Table 6.10 TM Mechanical Progress /Man-hour 64

Table 6.11 TM Piping Progress /Man-hour 65

Table 6.12 TM Electrical Progress /Man-hour 66

Table 6.13 BAF Mechanical Progress /Man-hour 66

Table 6.14 BAF Piping Progress /Man-hour 67

Table 6.15 BAF Electrical Progress /Man-hour 68

Table 6.16 CCL Mechanical Progress /Man-hour 68

Table 6.17 CCL Piping Progress /Man-hour 69

Table 6.18 CCL Electrical Progress /Man-hour 70

Table 6.19 ECL Mechanical Progress /Man-hour 70

Table 6.20 ECL Piping Progress /Man-hour 71

Table 6.21 ECL Electrical Progress /Man-hour 72

Table 6.22 Utility Mechanical Progress /Man-hour 72

Table 6.23 Utility Piping Progress /Man-hour 73

Table 6.24 Utility Electrical Progress /Man-hour 74

Table B.1 Data of mounted lines 85

Table E.1 Data of the personnel who work in PL&TCM mechanical works per month…. 89

Table E.2 Data of the personnel who work in PL&TCM piping works per month .. 90

Table E.3 Data of the personnel who work in PL&TCM electrical works per month…… 91

Table E.4 Data of the personnel who work in ARP mechanical works per month... 92

Table E.5 Data of the personnel who work in ARP piping works per month..... 93

Table E.6 Data of the personnel who work in ARP electrical works per month… .. 94

Table E.7 Data of the personnel who work in HGDL mechanical works per month 95

Table E.8 Data of the personnel who work in HGDL piping works per month 96

Table E.9 Data of the personnel who work in HGDL electrical works per month... 97

Table E.10 Data of the personnel who work in TM mechanical works per month .. 98

Table E.11 Data of the personnel who work in TM piping works per month 99

Table E.12 Data of the personnel who work in TM electrical works per month….100

Table E.13 Data of the personnel who work in BAF mechanical works per month…….. 101

Table E.14 Data of the personnel who work in BAF piping works per month..... 102

Table E.15 Data of the personnel who work in BAF electrical works per month ……..... 103

Table E.16 Data of the personnel who work in CCL mechanical works per month ……..... 104

Table E.17 Data of the personnel who work in CCL piping works per month..... 105

Table E.18 Data of the personnel who work in CCL electrical works per month…….. 106

Table E.19 Data of the personnel who work in ECL mechanical works per month107

Table E.20 Data of the personnel who work in ECL piping works per month..... 108

Table E.21 Data of the personnel who work in ECL electrical works per month .. 109

Table E.22 Data of the personnel who work in Utility mechanical works per month…... 109

Table E.23 Data of the personnel who work in Utility piping works per month….110

Table E.24 Data of the personnel who work in Utility electrical works per month 111

LIST OF FIGURES

Figure 2.1 Rolling process 7
Figure 2.2 Casting, hot rolling and cold rolling 8
Figure 2.3 Cold rolling mill flow chart 9
Figure 2.4 Pickling Line and Tandem Cold Mill schematic diagram 10
Figure 2.5 ECL schematic diagram 11
Figure 2.6 A typical batch annealing furnace 12
Figure 2.7 HDGL Flow Diagram 13
Figure 2.8 CCL flow diagram 14
Figure 3.1 An overview to project management 15
Figure 3.2 Project Management Process Groups 16
Figure 3.3 Overlap of Process Groups in a Phase 17
Figure 4.1 A sample of network diagram 29
Figure 4.2 Typical PERT chart 31
Figure 4.3 Finish-to-Finish (FF) 31
Figure 4.4 Start to Start (SS) 32
Figure 4.5 Finish to Start (FS) 32
Figure 4.6 Start to Finish (SF) 32
Figure 4.7 Percent Complete 33
Figure 4.8 Sample of critical path 36
Figure 5.1 Work breakdown structure (WBS) of an erection company 39
Figure 5.2 Total progress in mechanical works of Project A and Project B 45
Figure 5.3 Total number of personnel employed in mechanical works for Project A and Project B 45
Figure 5.4 Total progress in piping works of Project A and Project B 46
Figure 5.5 Total number of personnel employed in piping works for Project A and Project B 47
Figure 5.6 Total progress in electrical works of Project A and Project B 48
Figure 5.7 Total number of personnel employed in electrical works for Project A and Project B 48
Figure 5.8 GANT diagram of PERT analysis results 54
Figure 5.9 Network diagram of PERT analysis results 55
Figure 6.1 Standard normal distribution of the conducted PERT analysis 57
Figure A.1 Organization chart of installation company 84

Figure C.1 Gant chart of Project A 86

Figure D.1 Gant chart of Project B 87

Figure E.1 PL&TCM Total progress in mechanical works of Project A and Project B…. 88

Figure E.2 PL&TCM Total number of personnel employed in mechanical works for Project A and Project B 88

Figure E.3 PL&TCM Total progress in piping works of Project A and Project B…89

Figure E.4 PL&TCM Total number of personnel employed in piping works for Project A and Project B 89

Figure E.5 PL&TCM Total progress in electrical works of Project A and Project B……. 90

Figure E.6 PL&TCM Total number of personnel employed in electrical works for Project A and Project B 90

Figure E.7 ARP Total progress in mechanical works of Project A and Project B.... 91

Figure E.8 ARP Total number of personnel employed in mechanical works for Project A and Project B 91

Figure E.9 ARP Total progress in piping works of Project A and Project B 92

Figure E.10 ARP Total number of personnel employed in piping works for Project A and Project B 92

Figure E.11 ARP Total progress in electrical works of Project A and Project B 93

Figure E.12 ARP Total number of personnel employed in electrical works for Project A and Project B 93

Figure E.13 HDGL Total progress in mechanical works of Project A and Project B……. 94

Figure E.14 HDGL Total number of personnel employed in mechanical works for Project A and Project B 94

Figure E.15 HDGL Total progress in piping works of Project A and Project B 95

Figure E.16 HDGL Total number of personnel employed in piping works for Project A and Project B 95

Figure E.17 HDGL Total progress in electrical works of Project A and Project B……... 96

Figure E.18 HDGL Total number of personnel employed in electrical works for Project A and Project B 96

Figure E.19 TM Total progress in mechanical works of Project A and Project B ... 97

Figure E.20 TM Total number of personnel employed in mechanical works for Project A and Project B 97

Figure E.21 TM Total progress in piping works of Project A and Project B 98

Figure E.22 Total number of personnel employed in piping works for Project A and Project B 98

Figure E.23 TM Total progress in electrical works of Project A and Project B 99

Figure E.24 TM Total number of personnel employed in electrical works for Project A and Project B 99

Figure E.25 BAF Total progress in mechanical works of Project A and Project B 100

Figure E.26 BAF Total number of personnel employed in mechanical works for Project A and Project B 100

Figure E.27 BAF Total progress in piping works of Project A and Project B 101

Figure E.28 BAF Total number of personnel employed in piping works for Project A and Project B 101

Figure E.29 BAF Total progress in electrical works of Project A and Project 102

Figure E.30 BAF Total number of personnel employed in electrical works for Project A and Project B 102

Figure E.31 CCL Total progress in mechanical works of Project A and Project B 103

Figure E.32 CCL Total number of personnel employed in mechanical works for Project A and Project B 103

Figure E.33 CCL Total progress in piping works of Project A and Project B 104

Figure E. 34 CCL Total number of personnel employed in piping works for Project A and Project B 104

Figure E.35 CCL Total progress in electrical works of Project A and Project B. .. 105

Figure E.36 CCL Total number of personnel employed in electrical works for Project A and Project B 105

Figure E.37 ECL Total progress in mechanical works of Project A and Project B 106

Figure E.38 ECL Total number of personnel employed in mechanical works for Project A and Project B 106

Figure E.39 ECL Total progress in piping works of Project A and Project B 107

Figure E.40 Total number of personnel employed in piping works for Project A and Project B 107

Figure E.41 ECL Total progress in electrical works of Project A and Project B.. . 108

Figure E.42 ECL Total number of personnel employed in electrical works for Project A and Project B 108

Figure E.43 Utility Total number of personnel employed in mechanical works for Project A and Project B 109

Figure E.44 Utility Total progress in piping works of Project A and Project B 110

Figure E.45 Total number of personnel employed in piping works for Project A and Project B 110

Figure E.46 Utility Total progress in electrical works of Project A and Project B 111

Figure E.47 Utility Total number of personnel employed in electrical works for Project A and Project B..... 111

Figure E.48 General Total number of personnel employed in mechanical works for Project A and Project B..... 112

CHAPTER 1

1 INTRODUCTION

1.1 Overview

Iron plays an important role for the development of humanity from past to present. Iron-steel takes place in almost every area in our daily lives. Automobiles, bicycles, kitchen utensils, computers and cables are only a few of them. Steel is a main input in both industries of consumption goods and investment goods. Also, it is an intermediate product that is used for many industries such as construction, automotive and machinery. Developments in steel sectors are directly related to macroeconomic environment and long-term structural changes. In other words, steel-based production is one of the leading sectors of the industry and requires large-scale investments [1].

The iron – steel industry is a sector in which many products are used, and transactions are made in terms of bank and finance. In other words, effective presentation and efficiency of the products have the potential to increase the profits of banking and finance establishments. Iron is an indispensable product for all countries due to its durable and reliable, long-lasting and affordable, recyclable and environment-friendly feature. Accordingly, its technicality and competitiveness contribute to becoming a driving force of development as a basic industrial input with a widespread use. Thus, iron – steel industry defines the development level of the respective country [2].

In 1928, Steel production in Turkey was initiated by corporation facility of Mechanical and Chemical Industry Corporation to meet for the needs of the defense industry. By the 1930s, Steel Production gained attention and a significant role in development of the national economy as well as in industrialization.

The first integrated plant producing long steel products in Turkey was KARDEMIR, which became active in 1937. ERDEMIR was established in 1965 as second integrated plant producing flat steel products. In order to meet product demands for long steel products and semi-manufactured steel products, a third integrated plant ISDEMIR was

established in 1975. Since 1960s, plants with electric arc furnace began to operate in steel production sector. In this way, liquid steel production capacity reached to 4.2 million tons by 1980 with the help of five additional companies entering the sector in 1970s.

After 2001, the steel sector gained a rapid growth momentum, especially in flat steel and structural steel productions. Accordingly, investments in flat steel production have increased. Therefore, slab production capacity reached 18.4 million tons by 2016. Investments for flat products experience an incremental change since the current production doesn't correspond to the national demand [3].

Countries in which iron-steel consumption is continuously increasing and have production capacities with corresponding consumption rates, are considered to have stronger economies. The fact that production and consumption rate of flat steel products in total iron-steel in developed countries is higher than in developing countries shows the relationship between steel consumption and the development level of countries [1]. Therefore, steel sector needs to maintain its tendency towards the budget and steel production facilities have established and installed with billions of dollar investment in a way that will contribute to the economy of our country to the utmost extent. For this purpose, investment and production opportunities are facilitated and supported as a national development plan [4].

Additionally, in North America and European countries with developed industries especially in automotive and machinery sectors have been shifting their establishments to other countries with trained but cheaper labor potential such as Turkey [5]. The main material input for automotive and machinery sector is flat steel products. In this sense, the level of consumption of flat steel products is considered as an important indicator of development for countries [6].

Achieving a good level of efficiency in the production and maintenance of this input material will result in favor of the development plans of the respective countries. At that part project management plays an essential role and recently it has become the survival issue of the firms. However, it comes with challenges. Each project has to be considered by their own characteristics, since each of them are unique, not repeated,

and a great number of uncertainties will always be part of the picture [7]. By increasing the production capacity of iron and steel, new factories will come into action. The same challenges in project management of assembly will apply to these new factories as well. Thus, conducting a successful management plan will come with benefits in terms of saving time, money and reducing manpower.

The main purpose of project management in erection works is to ensure the project carrying out in line with the determined objectives despite all the risks and problems that will arise during the implementation of the installation project. Thus, a good planning and a good implementation with experienced staff are essential. The project is planned according to time estimations. There are various techniques to work with this estimations and Gant diagrams, CPM and PERT methods are some of them [8].

1.2 Literature

There are numerous studies regarding management in investment projects and as well as in construction projects [9-12]. However, few studies are conducted related to factory construction [13,14] or even fewer in the area of equipment installation management in industrial plants [15] . Given the large amount of investments on industrial plants an appropriate planning will increase the efficiency of production, both the employer company and the respective country/-ies will benefit from it in terms of time, money and manpower. Therefore, conducting a successful project management in both constructing the industrial plant and assembling the equipment is one of the important activity. Nevertheless, not many studies about project management in factory assembling are conducted.

There are exist companies specialized in the field of factory assembly. They mainly employ their own methods for project management, and experience covers a large part in that manner. In short term, this provides efficient solutions. Yet sometimes regular reports and/or documentation of completed works does not take part in these methods and the firm faces the threat of losing its credibility when the experienced personnel left. Therefore, a best practice guideline for project management in factory assembly will not only enable the companies to conduct projects efficiently, but also will translate the experience to the future projects without any threats of losing them.

On the other hand, managing an erection process is quite similar to managing construction projects, therefore the same project planning techniques can easily be adapted. These techniques are used mainly in the planning and control of projects. Namely, they allow us to determine the duration of the activities in the project and the activities behind it. Over the course of assembling, when a problem is encountered real time analysis of time and cost parameters, immediate intervention and altering the plan will be possible [8].

Unfortunately, the culture of project management is not yet well established in Turkey and along with the incompetent standards in project management of construction fields become the biggest challenges facing the construction project management field in this country [10].

The details of the literature research are included in the second, third and fourth chapters of the study. Second chapter provides information about rolling process and mounted cold rolling lines. In the third chapter, the characteristics of the project management study are examined, while the fourth chapter explains the techniques used in project management.

1.3 Objectives

Different business areas have been emerged along with the growing investments in flat steel and structural steel manufacturing. One of them is erection companies specialized in installation of steel production-based factories. Like any other project, assembly projects have a complex structure and include numerous uncertainties. The process starts with an agreement made between the employer company and the erection company that will manage the installation project. After the civil works are delivered, project starts with preparing the factory ground, and continues with installing the productions lines, commissioning those lines by conducting relevant tests, and delivering the lines to the employer company.

These companies manage erection process of the production lines after the civil works of factory are completed. The erection of cold rolling mill complex is a comparatively complicated process. There are three primary departments for process management:

(1) mechanical, (2) piping and (3) electrical works. Therefore, ensuring efficient communication and coordination between these departments is essential. The appropriate planning of this process and effective system organization can improve the overall effectiveness of the project.

In this study it is aimed to question current project management techniques on assembly processes applied in Turkey and to determine the expected completion time with an optimum number of personnel in order to achieve an efficient project management.

For this purpose, two separate projects of similar cold rolling mills conducted by the same erection company are compared in terms of efficiency. While the similarities and differences are determined, a PERT analysis is conducted to estimate expected completion times for each and total work. Several problems were encountered in both cases and delays occurred in work completions. The effectiveness's of both installation processes are evaluated and compared to each other. Then the erection progress of the manufacturing lines was compared in terms of the real periods and the amount of staff. Thus, it is aimed to increase the efficiency of erection time. Discussions were made according to the results and suggestions were provided for future assembly projects.

CHAPTER 2

2 ROLLING MILL

Rolling is a process that materials pass through between the rotating rolls while a certain pressure applied for a required size and quality of materials. During rolling process width of the materials increases along with its length. It is impossible to produce very thin materials by rolling at once due to deformation rates [37,39].

Generally, steel production includes continuous casting and rolling process. Continuous casting machines can be classified into three main groups according to the size of the produced product: bloom, billet and slab. Billet is the machine producing long products. It is a multi-path machine capable of casting up to 160x160 mm square cross section. Bloom's section sizes are larger than billet's sizes. It produces long products with width of 160-400 mm and thicknesses up to 600 mm. Slab is a machine that produces flat products for high production with large pot tonnages. Slab's thickness varies between 130-300 mm, its width varies between 750-2700 mm. In Figure 2.1, various rolling processes are illustrated. Since the most commonly used product is flat steel products, slabs are considered to be more important than the other two. To achieve an efficient production with a good quality of products, preparing the factory construction for assembly and the proper installation of equipment play an important role. Accordingly, this study focuses on erection of cold rolling lines used in flat steel productions.

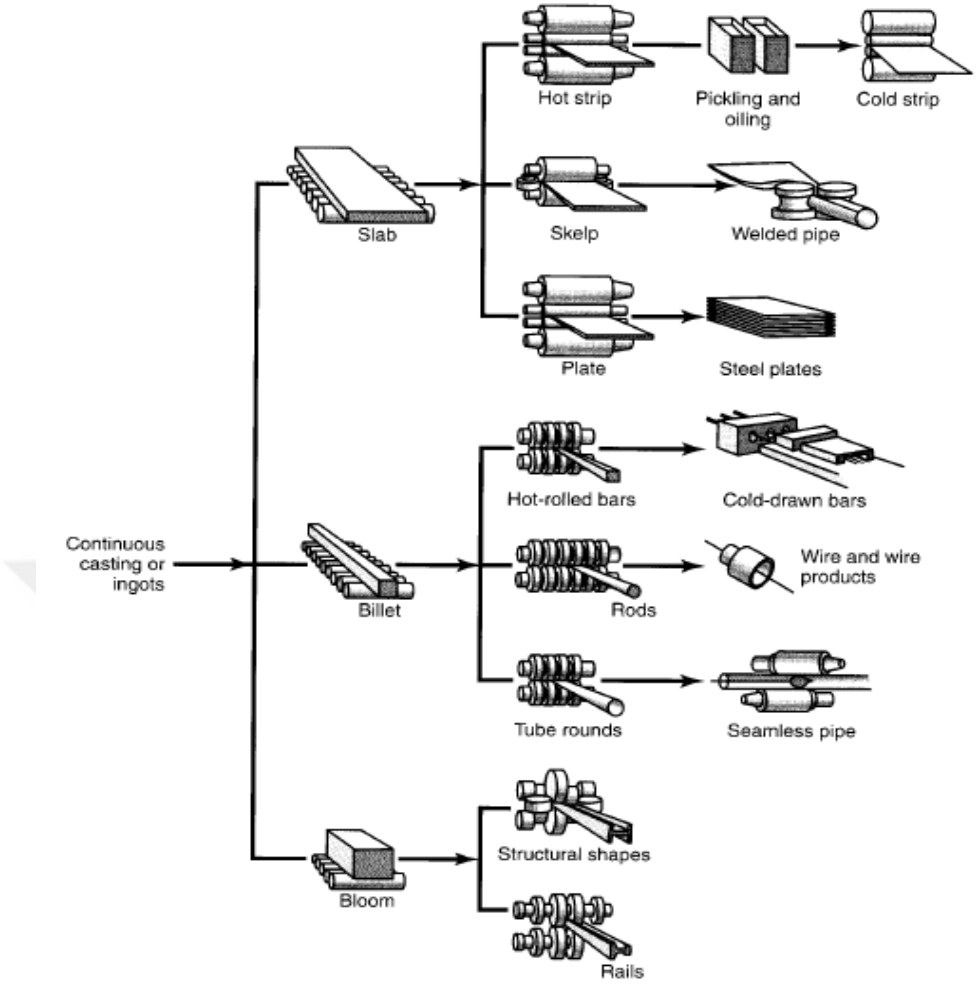


Figure 2.1 Rolling process [17]

Firstly, rolling process is performed at high temperatures. To put it all in simple terms, the reason of roughing hot rolling is to eliminate fractures and spaces inside materials. Following with the roughing, the hot rolling process continues to obtain materials with a finer grain and several properties such as strength and stiffness of this outcome are enhanced. Then, cold rolling process is performed to get rolled products with higher levels of strengths and stiffness's and smoother surfaces.

Hot rolling mills comprise sub-processes surface preparation (scarfing, descaling, and shot blasting), (re-) heating, hot rolling and finishing operations according to needs of manufacturer. If appropriate, related downstream activities like processing or treatment of recyclable materials are also considered. Processing of steel in cold rolling

mills is considerably different from hot rolling mills. The process includes: sub-processes surface cleaning (mostly pickling), cold rolling, heat treatment (annealing) and finishing operations. A model of casting process and rolling processes is illustrated in Figure 2.2. In some processes similar to this model, there are also various lines like electrolytic cleaning line, electrolytic tinning line, etc.

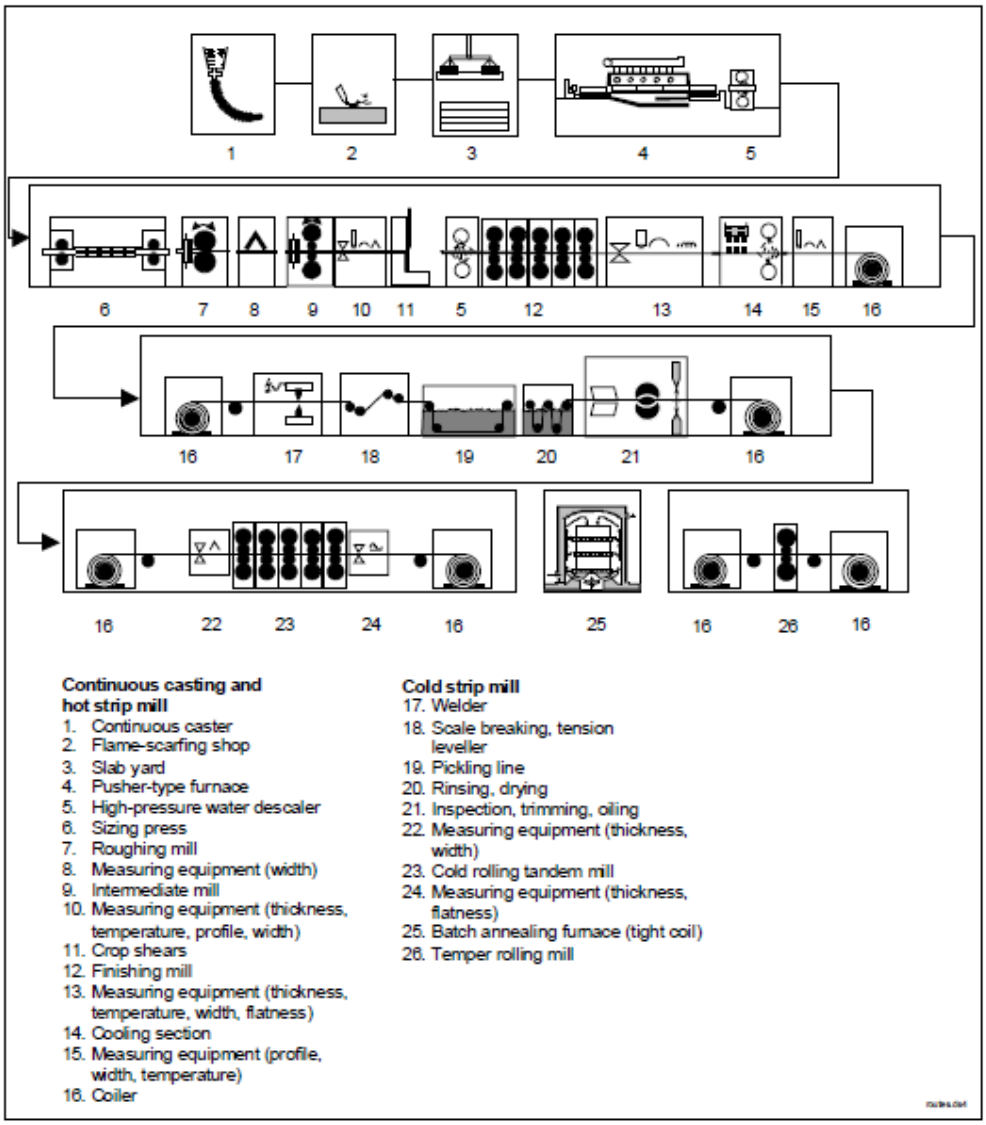


Figure 2.2 Casting, hot rolling and cold rolling [18]

2.1 Mounted Lines and Their Functions

Production methods of flat steel are modified, according to the market demand. Cold rolling mill is one of these methods. A flowchart of a cold rolling mill model plant is shown in Figure 2.3. As shown in the flowchart, while the products coming from some lines can be offered directly to the market, the final product can be obtained through different processes. In addition to these lines there are utility plants; for example, acid regeneration plant (ARP), water treatment plant, roll coolant, roll shop etc. There are also steel service centers consisting of sections such as cutting, slitting and trapezoidal sheet metal making etc.

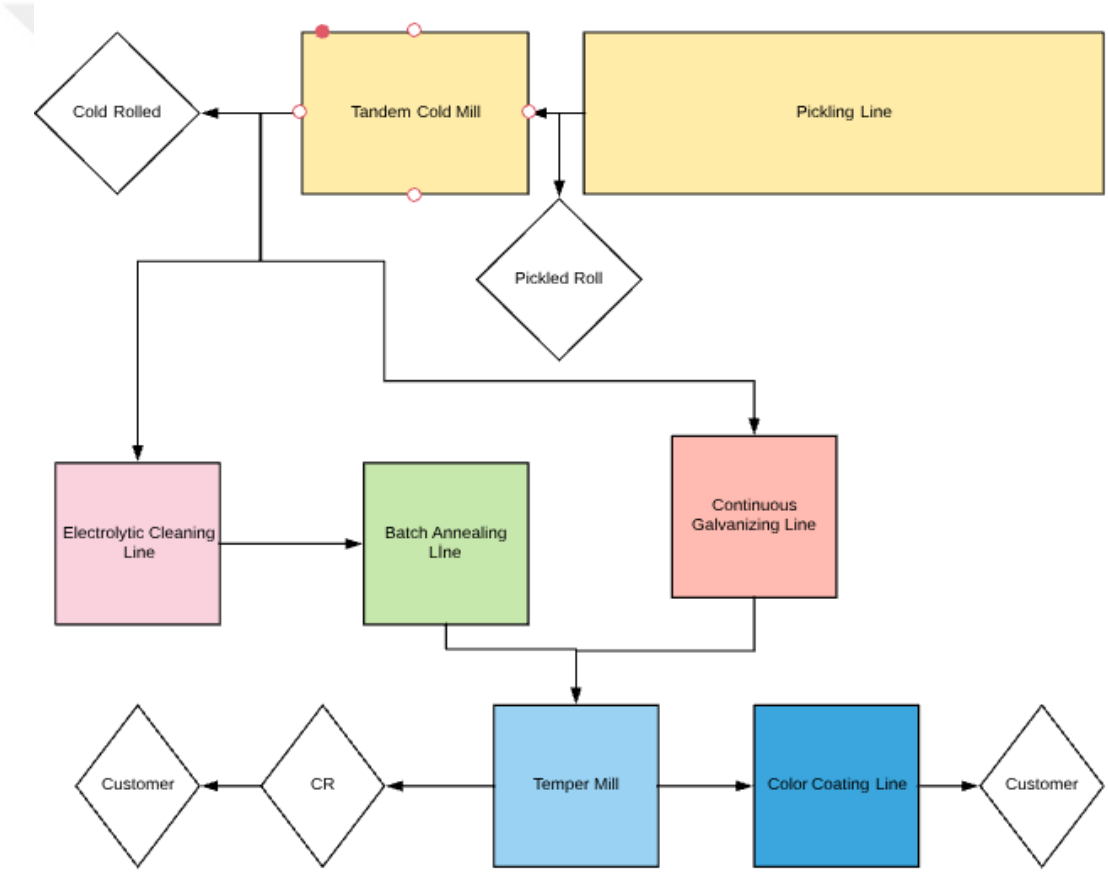


Figure 2.3 Cold rolling mill flow chart

2.1.1 Pickling Line and Tandem Cold Mill (PL&TCM)

In cold rolling, usually no heat is applied to the working piece before forming. Only some special steels like spring steel, tool steel or tempering steels may be subjected to heat treatment before pickling and rolling.

Hot rolled strip is first descaled (usually pickled, sometimes both shot blasted and pickled), then it is cold rolled and heat treated. Pickling process uses a multi tank, cascading type hydrochloric acid pickling section with surface agitation to remove the scale and oxide layer formed on the surface of hot rolled steel coils. Before drying, strip is coupled with a rinse section utilizing -a demineralized water for a final rinse spray- in order to ensure a perfectly clean and dry strip. After pickling process, the strip is cold rolled by Tandem Cold Mill (Figure 2.4).

It is essential to obtain flat steel products with better properties in terms of strength and hardness. There are several ways to achieve these properties. For instance, the resistance of materials to corrosion is increased by galvanizing. Galvanizing is a delicate process. There are standards to be fulfilled in achieving an efficient production. Galvanizing process input strip's thickness should be between 0.2 to 2.5 mm with a width between 700 to 1600 mm. The PL & TCM input strip’s thickness varies from 1.6 to 5.0 mm and a width varying from 700 to 1620 mm. Tandem Cold Mill consist of high five stands with six/four-high mills per stand. The pickled strip passes through in stands. In this way, thickness of the material is reduced at each stand. [38,40]

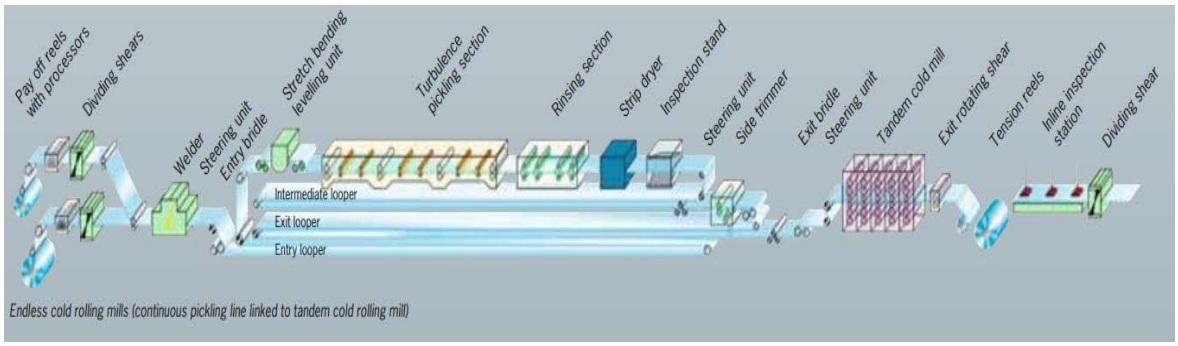


Figure 2.4 Pickling Line and Tandem Cold Mill schematic diagram [19]

2.1.2 Electrolytic Cleaning Line (ECL)

ECL is a process in which the rolling emulsion and the remaining iron fines on the strip surface are cleaned after cold rolling. The cleaning process is attained by using high current density on cold rolled strips. This operation is called alkaline cleaning. Thus, a clean strip surface is obtained before annealing (Figure 2.5) [36].

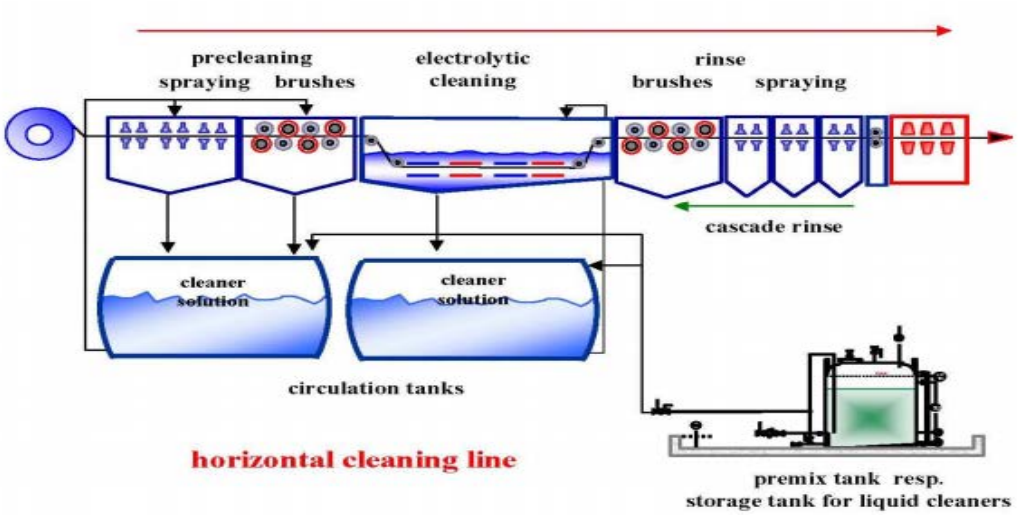


Figure 2.5 ECL schematic diagram [20]

2.1.3 Batch Annealing Furnace (BAF)

Annealing is the process of heating a material at a high temperature and holding it for a while at a specific temperature. Then, the material is cooled slowly until it reaches to the room temperature. The purpose of this process is to improve the strength of the steel. Annealing can be carried out batch or continuously.

Batch Annealing Furnace consists of annealing bases, inner covers, furnaces and coolers (Figure 2.6). The inner cover seals and protects the charge from the direct temperature of the burner. Keeping pollutants away from the annealing atmosphere prevents the formation of oxides and soot on the metal meanwhile it avoids also chemical changes. The furnace changes the load to the desired temperature to ensure occurrence of metallurgical changes. Direct firing, tangential firing, radiant tube and electrical resistance are the types of systems used in furnaces. After heat treatment, the furnace is removed by cooling-keeping the inner cover stays in place to keep the

protective air. If a glossy surface is desired, the metal must be cooled to ambient temperature before exposing it to air. In this case, another piece of equipment is used: a forced cooler. The forced cooler replaces the furnace at the end of the heating cycle and sprays air and sometimes water to accelerate the cooling of the exterior surface of the inner cover.

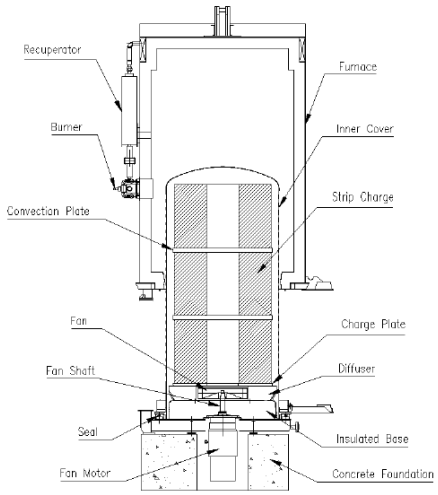


Figure 2.6 A typical batch annealing furnace [21]

2.1.4 Skin Pass Mill – Temper Mill (SPM)

Skin pass rolling is used for improving the mechanical properties and the surface structure of the steel material such as hot-rolled steel sheets, cold-rolled steel sheets, and stainless-steel plates in order to form them. In SPM process, thickness of the material is reduced by 1 to 3%. In addition to skin pass milling, the process has tension leveler section (TLV). It provides extension of strip length, also the sheet surface is completely flat without any wrinkles. It is finalized by further steps such as passivation and lubrication.

2.1.5 Hot Dip Galvanizing Line (HDGL)

Continuous hot dip galvanizing process is coating the surface of the steel strip with molten zinc. HDGL consists of the following sections; treatment, annealing, galvanizing and cooling. Treatment section provides cleaning of scales and rolling emulsions resulting from cold rolling while annealing section provides to obtain

required the mechanical properties and galvanizing section provides coating strip (Figure 2.7). It has a gas wiping system which includes a pair of gas-wiping jets working in harmony with an air knife system. Thus, it is used to ensure the coating thickness to be the same all over the strip. Consequently, cooling section provides cooling of the strip. A further but optional step would be skin pass milling. The decision is left to the customer request.

Galvanized steel provides high corrosion resistance rates therefore this steel is widely used in various sectors such as automotive, construction, machinery and agricultural instruments[41].

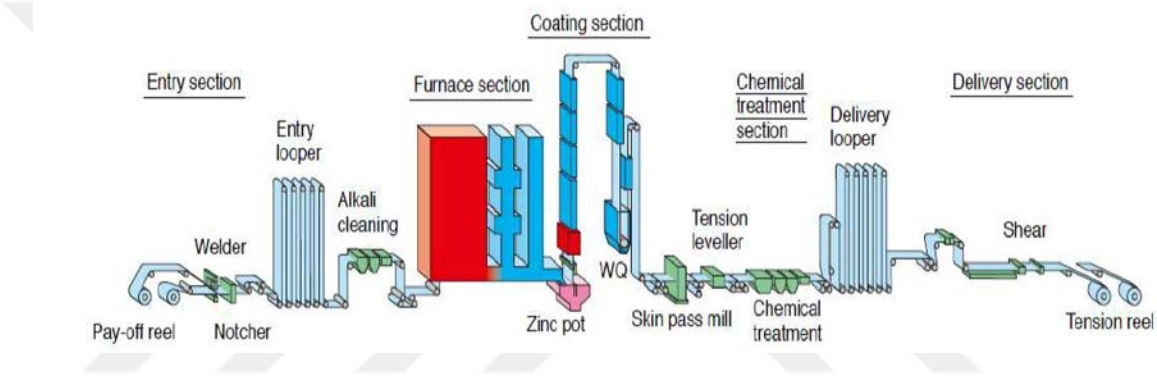


Figure 2.7 HDGL Flow Diagram [22]

2.1.6 Color Coating Line (CCL)

Coating coils of metals requires an efficient method which can be realized by continuous and highly automated industrial process, since the metal is exposed to various operations such as cutting and folding. In the meantime the complete surface is cleaned and processed while enabling firmly bonded finishes. For instance, parts may come with various size of holes, recessed areas, valleys and hidden areas which causes destructions in cleaning and uniform painting (Figure 2.8). Compared to conventional painted metals, coil coated metals are more durable and more resistant to corrosion [23].

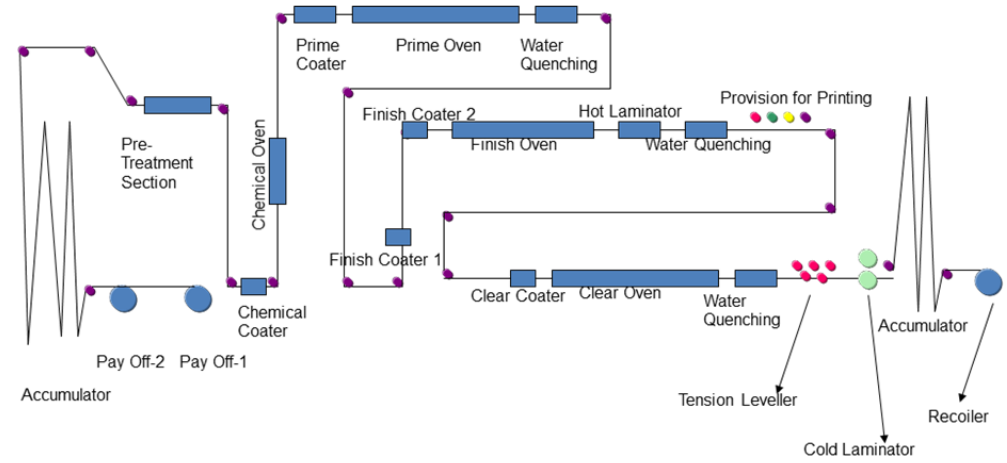


Figure 2.8 CCL flow diagram [23]

CHAPTER 3

3 PROJECT MANAGEMENT

From past to present, people have sought solutions to complex problems in all areas, since they want to make their lives easier and achieve success in their sectors. Searching for solutions is increasing day by day due to developing technology and therefore competition is increasing. Thus, companies desire to achieve better quality in jobs while aiming more efficiency with fewer employees [24, 25].

Projects are processes which have beginnings and endings, thus they are temporary. When a project is completed, the result is measurable. Each project has a purpose to fulfill. Therefore, a plan is made to achieve this goal. As the project progresses, unpredictable situations may occur. The progress is continued by making arrangements in the Project according to these new situations. To sum up, project management requires a holistic approach of organizing the process by considering all incidences that may occur such as risks and as well as prospects from the beginning of the project till the end. Project objectives should be achieved for a successful project management. Generally, project management objectives consist of time, cost, reaching a desired performance and technology level, utilizing assigned resources effectively and satisfying the customer (Figure 3.1) [26-28].

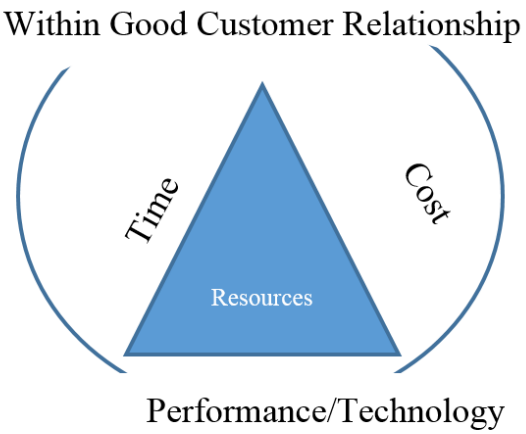


Figure 3.1 An overview to project management [27]

3.1 Phases of Project Management

A project is composed of numerous processes which are related to each other in many ways. Before starting a new project, a planning process is necessary. Estimations are made by measures such as project budget, project duration and product quality while all the risks and prospects are taken into account. When the tasks are completed, it is often compared to the original plan in order to analyze the difference of the original plan and final outcome. All these processes form the project management phases stated as below [7]:

- Initiating Processes
- Planning Processes
- Executing Processes
- Controlling Processes
- Closing Processes

These phases are linked to each other by cause and effect relationship which is illustrated in the Figure 3.2. These phases are linked to each other by an iterative process that each phase may affect the other and create another input parameter which changes the consecutive phase. The updates are documented, and project progress is ensured to continue according to the plan with these updates. This cycle is repeated in this manner. Additionally, the executing phase passes through the controlling phase at each step. In the last check, if everything is in harmony with the plan, the project will be concluded.

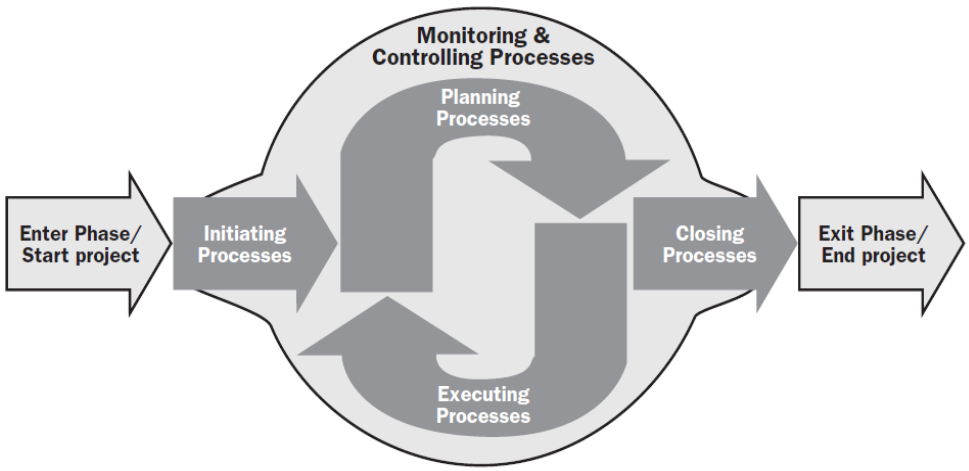


Figure 3.2 Project Management Process Groups [7]

All project management phases use the result of another one as an input parameter. However, border between phases are not defined specifically. This constant interaction also disables the discreteness on time events. In project management continuous interaction among phases are unavoidable. Each stage of the project overlaps with activities at different intensity levels which is summarized in the Figure 3.3.

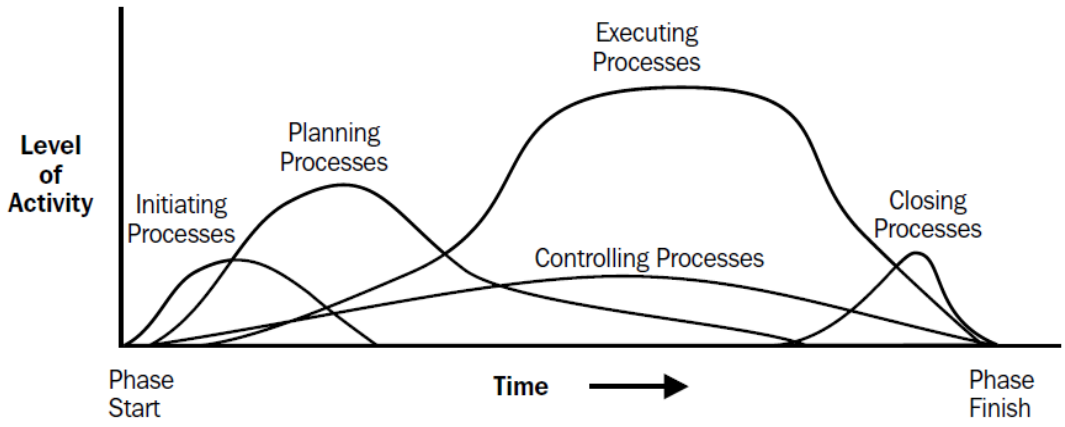


Figure 3.3 Overlap of Process Groups in a Phase [7]

3.1.1 Initiating Process

Problems, requirements and targets of the project are defined at this stage as a result of initial researches. Thus, project scope is defined, and initial project financial resources are determined. Shortly, all initial data is collected in this phase.

3.1.2 Planning Process

Planning process is considered to be most influential phase among the others, since all details of the project are tried to be predicted in the phase and it spans through the entire project. Firstly, objectives are determined and clarified. Then, the best practice of plan is selected and organized. Implemented plan should be proportional to the scope of the project and to information acquired.

3.1.3 Executing Process

Executing process is the phase where the plan is performed. Employees and the other resources are coordinated in this phase. The overall project performance is regularly assessed to ensure relevant quality standards. An information network is regulated to transmit the needed information in real-time to the project stakeholders. Additionally, every operation is recorded.

3.1.4 Controlling Process

Controlling process is a comparison phase between actual progress and the project plan. Namely, it monitors and measures the progress of the project in order to determine the differences in the plan and corrective actions that can be taken. Therefore, it enables the project to achieve its goals.

3.1.5 Closing Process

Closing process is the phase of the project finalization. In other words, it is the successive completion of all the activities and is also a formal closure of the project. Likewise, the information is produced, collected and disseminated in order to formulate the completion of the project, including the evaluation of the project and collating lessons learned for use in future projects' planning.

3.2 Project Planning

Planning is a technique that used for allocating the resources efficiently to achieve the specific aim within a given time and a particular budget. The technique can be defined by efforts to control and coordinate the changes in economic and social areas such as investment, consumption and education in line with the project goals by taking certain priorities into consideration. Planning must be flexible, systematic, multifunctional and disciplined.

Planning progress has three phases, (1) preparation, (2) executing – monitoring and (3) evaluation. For planning preparation, it is necessary to define scope of resources, feasibility, especially request. So, the process includes researching and analyzing. If a good plan is to be prepared, a thorough research and analysis should be carried out.

Similarly, planning organizes the information that determines the benefits and costs of alternative policies, aims and targets. Planning includes all events from the beginning till the end and it aims to shape the future events while making predictions about them. In other word, it forces managers to look forward, to anticipate changes, and to develop appropriate pathways by taking into account the impact of these changes. Thus, loss of time, unnecessary operations and unexpected events will be reduced [29].

Without proper planning, programs and projects can start off. However, poor planning comes with various results according to Harold Kerzner [27]:

- Project initiation without defined requirements
- Wild enthusiasm
- Disillusionment
- Chaos
- Search of guilty
- Punishment of the innocent
- Promotion of the nonparticipants

It was previously mentioned that planning is a continuous process of making decisions for the future and it organizes the effort to make these decisions. If a successful project is desired, targets should be organized with a systematic plan.

Time and cost analysis of a project should be based on the work program prepared at the planning stage and companies should be sensitive to planning. Similarly, during the formation of a plan misinterpretations or misevaluations have the potential to harm the project progress. The whole project will never take place exactly as planned. However, the planning allows us to predict the problems that may occur [29].

In this study efficiency of projects in terms of proper planning is discussed. The main subject is formed around proper programming since it plays an essential role in proper planning. Companies with successful backgrounds in planning and experienced employees who fully understand their role in the planning process only together may have the potential to achieve a successful project. A previously assessed good planning may not remove the need for modification, but may reduce the amount of required changes. Major employee responsibilities are:

Project Manager is responsible for defining the aims and targets, major milestones, assessing the requirements, stating the basic rules and assumptions, determining the time, cost and performance limitations, operating procedures, working with administrative policies and reporting the requirements.

Line Manager, on the other hand, is responsible to deliver detailed task descriptions to implement objectives, also deals with requirements and milestones, submits detailed schedules and manpower allocations to support budget and schedule, and identifies areas of risk and deals with uncertainty and conflict.

Consequently a **senior manager** also known as project sponsor, acts as the negotiator for disagreements between project and line management, provides clarification of critical issues, and lastly is responsible for communication link with customer's senior management [27].

CHAPTER 4

4 PROJECT MANAGEMENT TECHNIQUES

Project management techniques start with a phase of project planning and end with a closing phase. As the planning phases is mentioned above, it is necessary to understand all stages: preparation, analysis, selection, implementation, commissioning and evaluation of the project thoroughly. Thereby project management techniques are provided by an iterative process and applied in a reliable way.

Until recently, projects were assessed hardly by any assistance of scheduling. However, the size and complexity of today's projects needed more efficient scheduling methods. This requirement resulted in development of Network Diagrams. Thus, project scheduling has gained a new dimension with the successful integration of network diagrams in project management. The most common methods are Gant or bar chart, Program Evaluation and Review Technique (PERT), Critical Path Method (CPM) also known as Arrow Diagram Method (ARD), Precedence Diagram Method (PDM) and Graphical Evaluation and Review Technique (GERT). These methods are known as efficient methods for determining problems, defining, controlling and taking precautions. Also, they are tools that schematically show project’s flow structure, logical and timewise sequence of events and processes [27, 29].

Certain information is required for making an effective total program plan, such as the feasibility and the extent of the particular project. Before starting with the plan this information should be evaluated. It consists of various types of information which are the statement of work (SOW), the project specifications, the milestone schedule, the work breakdown structure (WBS) must be completed. The statement of works is a report of the work items to be achieved. It describes the work briefly, funds constraint if exist, states objectives of the project and the schedule. The schedule mainly, consists of start date, end date, major milestones and written reports. The project specification includes man-hour, equipment and estimate materials. Minor changes in the specification may result in large overrun costs. It is necessary to make sure that the specifications are identified correctly. Therefore, the specification must be at the

utmost updated version. The milestone schedules consist of project start date, project end date, the other major milestones and data items. The other major items are meeting notes, procurement, existing models or samples. Generally, data items are unnoticed. Since the schedule designates that managers may be required to assign staff who is good at writing skills. Also, people who collect data items should have the following capabilities: writing, editing, proofing, rewriting, graphic arts, and duplication. The work breakdown structure is the last major item, also second major item in the planning process. As it is mentioned before the major step is the definition of project requirements. WBS is the subsection of the family tree which is generated from the hardware, services and necessitated data to produce the final product. WBS displays the project costs and the way data is compiled and ultimately reported. Also, it consists of required arranged data such as schedule, configuration management, contract budgets and technical parameters [27].

The step after collecting the data and preparing program is the control part. The purpose of this part is to prepare progress reports of the project regularly by using a time diagram. In this way, the project is analyzed and it is updated if any changes are encountered. It continues till the project is finished. Gant diagram method, which is one of the methods that is used to manage the whole process, is usually employed for small projects. On the other hand, methods such as CPM and PERT are commonly used in big scale projects, therefore deals better with complex projects. However, Gant diagram is utilized in such projects as well, to summarize project status [29, 30].

There are several advantages of project scheduling system. A successful project scheduling system [29]:

- Divides the entire project into applicable pieces of work.
- Indicates order of events and activities and their relationships.
- Defines how each event and activity affects the completion of the next step.
- Determines exactly where the process will be completed and how much more work needs to be done in a responsive manner.
- Defines required budget to complete project.
- Identifies required resources to achieve goals.

- Shows problems of preventing the process from completing or slowing down the process, gives solutions to these problems and reports what will happen in case any precaution hasn't taken.
- Leads to the effective management of the project and enables the completion of the project.

The main purpose of the project scheduling is to make sure the completion of the project. Extension of the project's critical duration will delay the entire project. It is necessary to avoid this critical situation by preparing the schedule. Therefor schedule represents an important step in project management. So, project time management must be understood thoroughly to apply project management techniques effectively. Since it comprises a review of the major processes in the project time schedule such as activity definition, activity sequencing, activity duration estimating, schedule development and schedule control. Each of these process involves three elements (1) inputs, (2) tools and techniques and (3) outputs [7].

Project time schedule is categorized by Project Management Instıtute (2001) [7]:

1. Activity definition:
    a. Input consist of
        i. WBS,
        ii. Scope statement,
        iii. Historical information,
        iv. Constraints,
        v. Assumptions,
        vi. Expert judgement.
    b. Tools and techniques include
        i. Decomposition,
        ii. Templates.
    c. Output consists of
        i. Activity list,
        ii. Supporting detail
        iii. WBS updates.

2. Activity Sequencing:
    a. Input consist of
        i. Activity list,
        ii. Product description,
        iii. Mandatory dependencies,
        iv. Discretionary dependencies,
        v. External dependencies ,
        vi. Milestones.
    b. Tools and techniques include
        i. Precedence diagramming method (PDM),
        ii. Arrow diagramming method (ADM),
        iii. Conditional diagramming methods.
    c. Output consists of
        i. Project network diagrams,
        ii. Activity list updates.
3. Activity Duration Estimating:
    a. Input consist of
        i. Activity list,
        ii. Constraints,
        iii. Assumptions,
        iv. Resource requirements,
        v. Resource capabilities,
        vi. Historical information,
        vii. Identified risks.
    b. Tools and techniques include
        i. Expert Judgment,
        ii. Analogous estimating,
        iii. Qualitatively based durations,
        iv. Reserve time (contingency).
    c. Output consists of
        i. Activity duration,
        ii. Basis of estimates,

iii. Activity list updates.

4. Schedule development:
    a. Input consist of
        i. Project network diagrams,
        ii. Activity duration estimates,
        iii. Resource requirements,
        iv. Resource pool description,
        v. Calendars,
        vi. Constraints,
        vii. Assumptions,
        viii. Leads and lags,
        ix. Risk management plan,
        x. Activity attributes.
    b. Tools and techniques include
        i. Mathematical analysis,
        ii. Duration compression,
        iii. Simulation,
        iv. Resource leveling heuristics,
        v. Project management software,
        vi. Coding structure.
    c. Output consists of
        i. Project schedule,
        ii. Supporting detail,
        iii. Schedule management plan,
        iv. Resource requirement updates.
5. Schedule Control:
    a. Input consist of
        i. Project schedule,
        ii. Performance reports,
        iii. Change requests,
        iv. Schedule management plan.
    b. Tools and techniques include

i. Schedule change control system,
ii. Performance measurement,
iii. Additional planning,
iv. Project management software,
v. Variance analysis.

c. Output consists of
i. Schedule updates,
ii. Corrective action,
iii. Lesson learned.

In summary, there are some requirements to be considered in order to achieve successful processes when making the project schedule. First of all project activities are subdivided by WBS in order to create a logical structure of the project. Firstly, the order of the subdivided processes and their relationships to each other are identified. Secondly, the duration of each process is determined by deciding each event's and process' start and end time. Meanwhile the project's the longest path and critical path are analyzed. Each event and process are determined how they are affected by previous process or event and how their affect will be to the next process or event. Suitable team members are selected for the project. Lastly, outsourced contribution, stakeholders and general information are determined [7, 29].

4.1 Gant Chart

Gant chart, also known as bar chart, is a project schedule and monitoring tool. This tool was invented by Karol Adamiecki who is a Polish engineer, but it was developed in 1918 by Henry Grant who was an American industrial engineer [31]. It is the most basic, most common and maybe one of the oldest project management technique. Gant method has been widely used to prepare a project schedule recently, as it has the advantage of simple graphical displays [32, 33].

Gant chart does not use too much detail, only events or processes and the relationships between events or processes are shown. In other words, Gant chart is formed by determining the start and end dates of the planning and actual duration of each activity. Also, Gant chart is practiced making coordination and realistic output standards in the

scheduling of employees or production units. Gant chart's processes or events are ordered vertically while period of time is ordered horizontally. Namely, by carrying out this graphical representation for each activity, the overall picture of the work required for a project can be seen at a brief look. Progress of an events or process may be put down by drawing a second line below the baseline, or coloring the baseline to display progress on a daily, weekly or monthly basis. Thus, the project is represented in a simple graphical display to ensure a quick apprehension [29, 31, 34].

Gant chart may be formed manually or using a computer. The advantage of using computer for scheduling is the automatic generation of Gant charts. So, even if the process takes a long time due to the recording of events by taking the sequences and dependencies into consideration and firming up, the chart is automatically updated as the data input changes. Thus, the program is easily and quickly modified with the possible changes and actual activities to determine the optimum completion date.

Gant chart is a suitable implementation for identifying, monitoring and reporting small-sized projects that involve a small number of employees. The chart has a little benefit as a control mechanism. It may be used to manage time and find problems, but it should be monitored regularly. The most important property of Gant chart is its quick and easy preparation. However, it is an insufficient method for projects that consist of large data input and include complex technology. Namely, it doesn't display critical points, it doesn't coordinate requirements and it doesn't show how the delay in process affects the following process.

Gant diagram can be prepared by several methods such as block method, symbol method and filling method. Starting with the block method, it is mainly used for preparing Gant charts in industry. In this method, the project processes are shown in block form where blocks represent activities including information of planning and actual dates. Also, start point of blocks point out the start time, end point the end time. The difference between the first and the last point indicates the duration of the activity. This enables the user to easily monitor the compliance of the actual progress in the project with the plan [29, 31]. Examples of scheduling of line assembly for Project A and Project B are given in Appendix C and Appendix D.

Consequently, Gant diagram is relatively easy to use, especially for projects consisting of a restricted number of activities. Although it has deficiencies, effective planning, scheduling, controlling and reporting may be done with this method.

4.2 The Network Method

CPM and PERT are the most known and most applied network methods. The network methods developed for programming and monitoring of the project summarize the project visually. Even though these two methods are the same, CPM and PERT are assumed to differ in terms of their application. In the late fifties, PERT is developed in order to manage massive engineering projects where Gant was unable to contribute. PERT was firstly presented on Polaris Weapon System in 1958, a U.S. Navy Project, as a part of military development program. Thereafter, PERT gained a wide audience and applied in numerous types of industries. Meanwhile, another technique, CPM is introduced by the DuPont Company which similarly gain attention and mainly employed in construction and process related industries [27]. At that time PERT and CPM had different audiences; PERT was considered as being more suitable for R & D projects where uncertainty is a major issue, CPM is more useful in particular projects where time and costs can be estimated. However, these differences have recently decrease gradually or even disappeared [35].

CPM and PERT show critical and non-critical works, because they demonstrate relationships between events and activities. They indicate results of each event and activity that are planned and performed. Thus, planned project is completed within a determined period. All these events are indicated by a scheme what is called a *network diagram*.

Network diagrams consist of combination with arrows and nodes. A sample of network diagram is illustrated below (Figure 4.1). Network diagram include some elements such as activities and events. Activity is part of each work that is performed and separated to complete the project. The activity is indicated by arrows in the diagram. There are determined starting and end points. Events, on the other hand, are illustrated with starting and end points of activities. Events and activities are interrelated with each other logically and timewise [29].

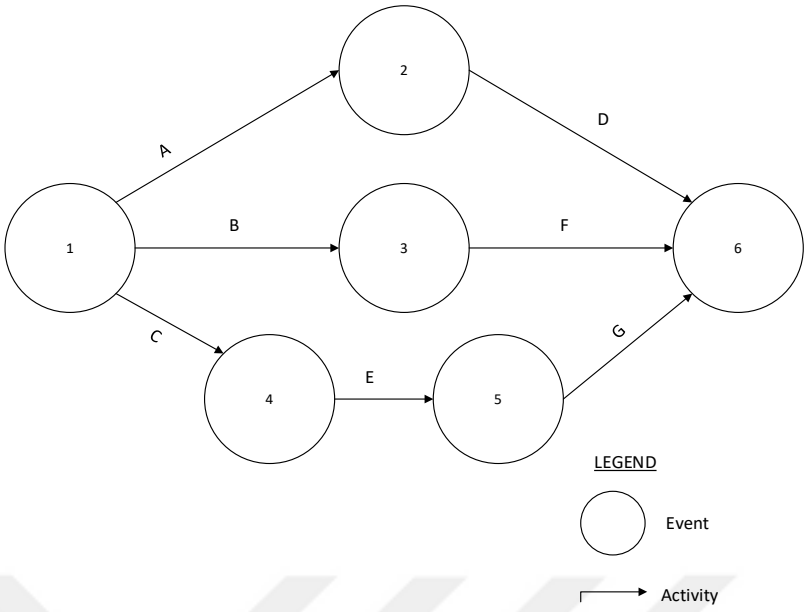


Figure 4.1 A sample of network diagram

Basic Rules in network diagram preparation are [29]:

- Processes and events are defined by WBS to ensure that the entire project is logical.
- Team members' responsibilities, time control, reports, forms and outsourced information are defined.
- Each activity or event is created by previously assigned activities or events which are called predecessors. In other words, no activity can be created without any previous activity or event.
- An activity cannot start before a preceding activity or event is completed.
- Interacted activities and unrelated activities are defined.
- Critical activities and noncritical activities are described.
- If weak points are detected, delays in the program will be prevented.
- Team member should be trained to understand thoroughly and apply the events and activities.

4.3 Critical Path Method (CPM)

As it is mentioned before CPM is a network method. In other words, CPM brings light into events and the relationships between them. Arrows demonstrate relationships between events. In addition, critical path is defined by this method. Generally, critical

path is defined by chains of critical activities that combine project's start and end events. In other words, it is a way of connecting all the nodes with the same earliest and latest starting times. The delay times of activities on the critical path are zero. Other activities have slack time. It means that noncritical activities may not affect project end time. It depends on the type and the length of slack time [29]. Moreover, project control activities are checked through critical path. Precautions are taken according to the critical path while project is in progress. Therefore, the aim is to finish the project on time.

In order to calculate the critical path, periods of activities should be known. Activity period is the period between activity start and end time. Since, these periods have the potential to affect the project completion, optimistic and pessimistic time should be avoided. Therefore, by the definition of the period; amount of work, resources, construction method, climatic conditions, disruptions due to progress of the project such as engine troubles, delays in material supply, design problems should be considered [29].

After calculating activity periods, for each activity the earliest time the activity can start (ES), the earliest time the activity can finish (EF), the latest time the activity can start (LS), the latest time the activity can finish (LF) can be calculated. As it is shown in Figure 4.2 where the slack identification example is displayed the earliest and latest times of activities are calculated [27].

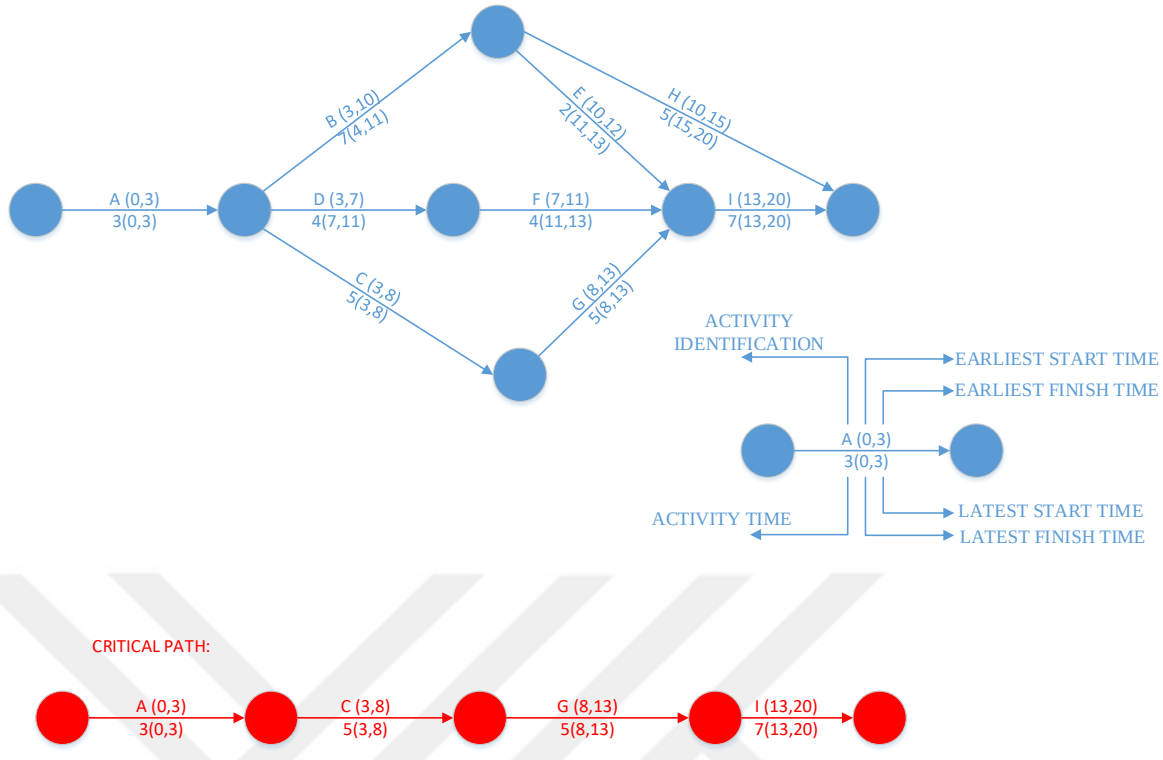


Figure 4.2 Typical PERT chart

Activity relation figures:

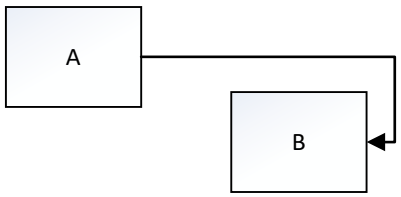


Figure 4.3 Finish-to-Finish (FF)

Finish to finish: activity ends in the same time with preceding activity. In short, B cannot end before A (Figure 4.3).

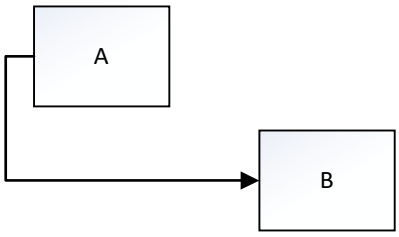


Figure 4.4 Start to Start (SS)

Start to start: activity starts in the same time with preceding activity. In short, B cannot start before A (Figure 4.4).

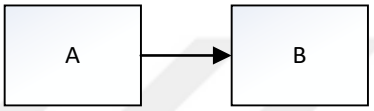


Figure 4.5 Finish to Start (FS)

Finish to start: activity starts after the preceding activity ends. In short, B cannot start before A ends (Figure 4.5).

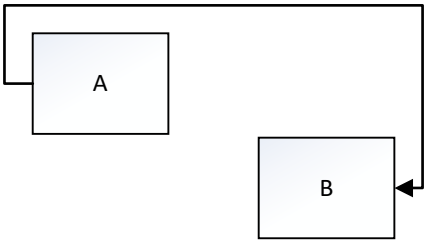


Figure 4.6 Start to Finish (SF)

Start to finish; activity ends before the preceding activity starts. It is not very commonly used in applications. In short B cannot end before A starts (Figure 4.6).

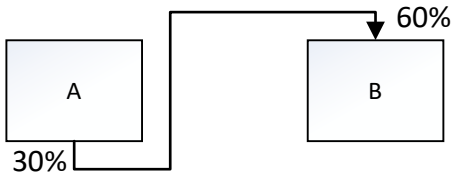


Figure 4.7 Percent Complete

Percent Complete: Activity starts after a while preceding activity starts. 60% of activity B cannot start before 30 % of activity A finishes (Figure 4.7).

To calculate critical path;

The earliest starting times are calculated by forward pass method. There are two assumptions in this method: firstly, project start point is zero, secondly each event or activity is initiated after its predecessors are completed. In this way, the earliest starting time of an activity is determined by the earliest finish dates of its predecessor's latest time. In other words, the earliest finishing time is found by adding activity duration to the earliest starting time [27].

$$EF(x) = ES(x) + activity\ period \quad \textbf{(4.1)}$$

The latest starting times are calculated by backward pass method. This method is applied from the project last event to the initial event. Namely, the latest starting time of an activity is found by the latest finish dates where the activity time is subtracted from latest finishing time [27].

$$LS(x) = LF(x) - activity\ period \quad \textbf{(4.2)}$$

All these calculations are applied for each activity. Thus, critical path can be found out as it is illustrated in Figure 4.2. As it is mentioned before, slack time should be zero to define the critical path. Slack time helps us to assess how early an activity can start or how late it can end. Generally, slack expression is known also as float, but it is not commonly used. Calculation of maximum float helps us to determine slack time of noncritical path events. Slack time may be determined by the difference between the

latest allowed date and the earliest expected date. Slack times and maximum float can be calculated by the following formula [27]:

$$Slack\ time = LS - ES \text{ or } Slack\ time = LF\text{-}EF \quad \textbf{(4.3)}$$

$$Maximum\ float = latest\ finish - earliest\ start - duration \quad \textbf{(4.4)}$$

In order to illustrate this equation, based on figure 4.2 maximum float of the activity F and B are calculated and shown below:

F activity float = 13-7-4=2

B activity float = 11-3-7=1

4.4 Program Evaluation and Review Technique (PERT)

PERT and CPM methods are almost identical each other. Namely, similar to CPM, PERT also depends on the project completion with the shortest duration. However, the most important difference among them is the way of determining the time. In PERT periods are calculating by taking the uncertainties into account. In other words, uncertainties that may occur in the project should be taken into consideration. Thus, in PERT method firstly activity periods should be obtained, the effects of these periods on project success should be analyzed, and the uncertainties of activity periods should be considered. The uncertainties of activity periods can be decreased by estimating three possible times of each activity, with the help of similar projects and experienced people. Nevertheless, in estimation of these three times, Delphi method should be applied. Therefore, the following three different time estimation are made by each member of estimation team separately for each activity [29].

Optimistic Completion time (a) = everything will go on as planned, minimal difficulties will be encountered.

Pessimistic Completion time (b) = everything won't continue as planned and maximum number of difficulties will be encountered.

Most likely completion time (m) = estimating the time of activity by the help of similar projects and experienced people [27].

Two assumptions should be stated before extracting a single value for the expected time. Firstly, standard deviation which is the one-sixth of the time requirement range. Three standard deviations form a probability curve. Secondly, assumption of beta distribution which is basically the probability distribution of time required for an activity.

The expected time between events can be calculated by the following formula:

$$t_e = \frac{a+4m+b}{6} \quad \textbf{(4.5)}$$

t_e = expected time *b=most pessimistic time*

a=most optimistic time *m=most likely time*

The probability of project completion on time requires the knowledge of a standard deviation values of every single activity and it can be calculated by the following formula:

$$\sigma_{t_e} = \frac{b-a}{6} \quad \textbf{(4.6)}$$

σ_{t_e}=standard deviation of the expected time (t_e).

Two useful expressions for this case are the standard deviation and its square also known as variance, *v*. Comparing expected values are possible by calculating the variance. Standard deviation can be simply calculated as long as type of sigma deviations are determined [27].

In these calculation if *v* is larger than one, that means the uncertainty value is high. In this case, optimistic and pessimistic assumptions are quite different. If *v* is lower than one, that means the uncertainty value is low. This means optimistic and pessimistic assumptions are close to each other [29].

The square root of the total path's standard deviation is the sum of squares of each activities' square deviation and expressed in the following formula [27]:

$$\sigma_{total} = \sqrt{\sigma_1^2+\sigma_2^2+\sigma_3^2+\sigma_4^2} = \sqrt{v_1 + v_2 + v_3 + v_4} \quad \textbf{(4.7)}$$

The critical path in Figure 4.8 is calculated by using the previously mentioned formula:

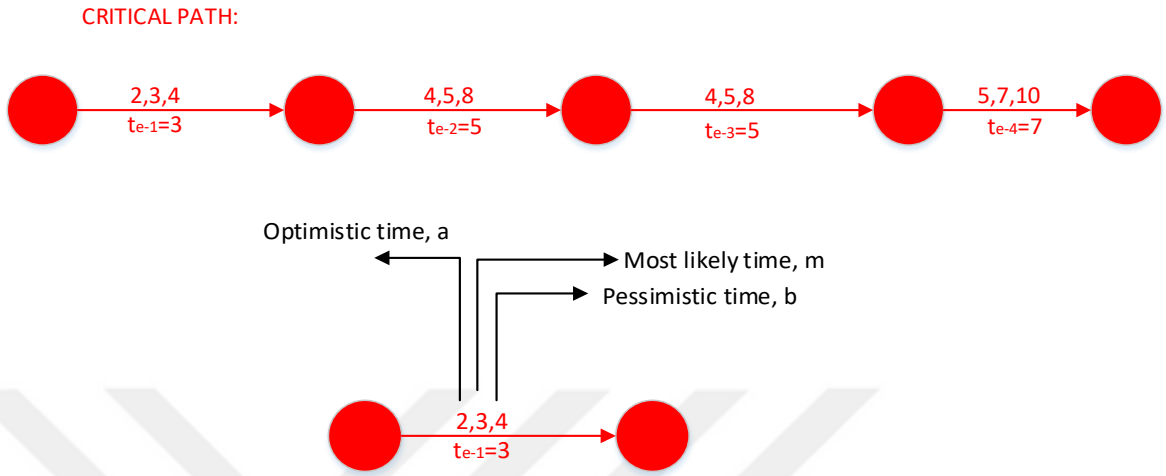


Figure 4.8 Sample of critical path

In Figure 4.8 for each activity an expected time is determined. The relevant standard deviations are shown below:

$$\sigma_{t_1}=0.33 \;\; \sigma_{t_2}=0.67 \; \sigma_{t_3}=0.67 \; \sigma_{t_4}=0.83 \qquad \textbf{(4.8)}$$

Standard deviation of total path is calculated as it follows:

$$\sigma_{total}=\sqrt{0.33^2+0.67^2+0.67^2+0.83^2}=1.3 \qquad \textbf{(4.9)}$$

Calculating sigma enables us to define a confidence interval for each activity and the relevant critical path [27].

To probability of exceeding the specified desired date; activities on critical path K is calculated by the following formula:

$$K=\frac{T_L-T_E}{\sigma_{total}}=P(z\leq K) \qquad \textbf{(4.10)}$$

K = activities on critical path, T_L = desired project completion date, T_E = period on critical path, z= Standard normal distribution

Afterwards, the probability of completion time is determined from Z-table [29].

CHAPTER 5

5 METHODOLOGY

The order of events plays an essential role on efficiency of a project. Without ordering the events a project may face numerous problems. The main reason of staying behind the schedule in some projects is due to lack of sensible order of events. In this case network diagrams, which mainly illustrate the event order come into action [42]. For instance, if the starting and finishing activities of an erection company are simply thought about, the most uncertain periods belong to construction submission and material supply. WBS of an erection company can mainly be ordered as it follows:

1. Civil Handover
2. Delivered Materials /Delivery Dates
3. Preparation of Project Schedule
4. Erection Works
    a. Mechanical Works
    b. Piping Works
    c. Electrical Works
5. Project Completion

According to Kaplan 2014 [43], to achieve an efficient time management all the data such as equipment, human, material and budget should be used in a suitable way. From this point of view, data of two separate projects were examined by taking the time criterion in this study. Work scope of the installation company is summarized in the following WBS (Figure 5.1):

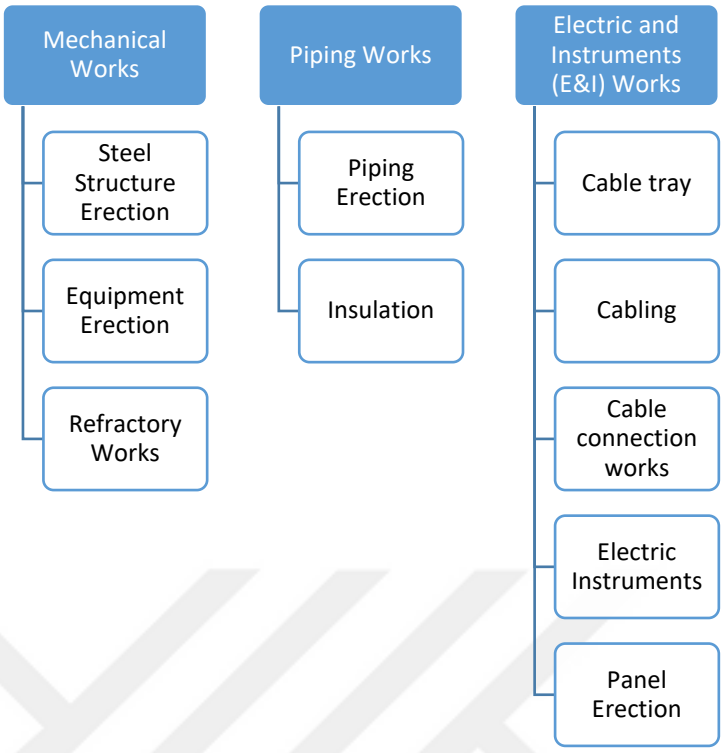


Figure 5.1 Work breakdown structure (WBS) of an erection company

As it is mentioned before the project is planned, under three different departments (1) mechanical works, (2) piping works and (3) electrical works. Steel construction assembly, equipment installation and refractory works form the mechanical works. Piping works consist of insulation works and pipe installation while electrical works include cable tray erection, cabling, cable connection works, instrument and panel erection. Although there are small technological differences and different technology companies are involved in the two projects, these projects are similar to each other in many aspects (Table 5.1).

Table 5.1 Differences and similarities between Project A and Project B

	Project A	**Project B**
Region	Mediterranean	Marmara
Lines	Erection Lines were PL&TCM, CCL, ARP, HDGL, ECL, BAF, Utility Plant, TM	Erection Lines were PL&TCM, CCL, ARP, HDGL, ECL, BAF, Utility Plant, TM
Duration	14 months	16 months
Number of max. employee	1427	516

Table 5.2 (continued): Differences and similarities between Project A and Project B

	Project A	**Project B**
Number of min. employee	64	58
Construction Area [km2]	122	80
Project Scope	• mechanical works • piping works • electrical works • Also, electrical works scope consists of Medium Voltage cabling	• mechanical works • piping works • electrical works
Encountered Problems	• Late delivery of materials • Late delivery of construction site	• Late delivery of materials • In sufficient soil survey • Equipment deficiency in one large line • Manufacturing deficiencies

5.1 Mechanical Works

Previously mentioned mounted lines are shown from Figure 2.4 to Figure 2.8. Equipment erection, steel structure erection, and refractory works of these lines constitute mechanical works.

Erection process only starts after a series of activities are completed. Namely, erection company takes over the projects, construction work of the hall where the line will be mounted is completed and submitted, and finally overhead cranes are handed over. Ground controls are consisted of sub activities such as ground level distances, compliance with the project, and control of anchor holes' accuracy. Additionally, for the application of equipment steel, benchmark positioning events are carried out which lasts no more than two days. In the submitted regions before starting to work, benchmarks are employed. First works are chipping and padding. The region where the equipment will be mounted in order to fixate tightly equipment with the grout material, a surface roughening activity is applied on this particular chipping area. Padding activity, on the other hand, is the process of fixating leveling shims according to the equipment and ground on concrete in order to support the firmness of the equipment and to meet the values in the project. It is applied around anchor holes, after

chipping where the surface is deformed. These activities are completed after the values meet the designated project values. Afterwards, the anchors are fixed to the holes and equipment is installed. By pouring grout material which is a kind of a concrete mixture into the holes, the first step of installation is completed. This activity is applied to all equipment which lays on the particular line. Then calibration activities start. After performing measurements according to the project values, last grout is poured and equipment is fixed entirely to the ground. The process of cold run starts, after the calibration processes end equipment are tested one by one. In order to realize cold run a major part mechanic, piping and electric works has to be completed. After cold run, the hot run process starts where the entire line is tested.

5.2 Piping Works

Piping works consist of lines such as hydraulic, cooling water, wastewater, steam, plastic pipe, compressed air, and combustion air. According to the project details for each individual line supports are produced and mounted. In the meantime, again according to the project the standard length of six meters are divided into designated dimensions and if bending is required the necessary production activities are conducted. Then installation of pipe lines starts. In pipe works plastic pipe, hydraulic, cooling water, combustion pipe material installations are conducted according to the desired quality. Test activities of each of these works requires different approaches. For instance, in hydraulic lines flushing activity is employed. Flushing process is the process of feeding the pipes with water at pressures varying according to pipe diameters. Thus, the lines are checked for crack and deficiencies and the detected problems are solved.

5.3 Electrical Works

First of all, cable trays are mounted. After cable tray installation proceeds according to the scope of the project; cabling, transformer erection, panel erection, conduit, grounding works, electrical instrument erection such as flow meter and thermocouple works are conducted. The amounts of cable, instrument, and panel for two companies are given in Table 2. Since the divisions are different, tracking the work can be handled in two ways. Firstly, amount of cables is analyzed according to man-hour values.

Secondly, based on the completion date of electric installation and depending on previous experiences an assumption table stating the degree of effects on project for each activity is prepared (Table 5.2).

Table 5.3 The amounts of cable, instrument, and panel for Project A and Project B

	Cable Tray (m)	**Panel (pcs)**	**Cabling (m)**	**Cable Connection (pcs)**	**Instrument (pcs)**
Project A	48,885	1,260	938,097	123,433	3,978
Project B	28,917	1,184	718,696	116,442	3,515

The respective assumptions may differ in each project. Progress of project is employed when creating the charts. Thus, discussion can be performed on total electric installation works. Namely, the amount of work done is multiplied by the project percentage and divided by the total project amount (Table 5.3).

Table 5.4 Assumptions related to the degree of effect for each activity on the total electrical project

Distribution of Total Project Percent	**Erection Works**	**Unit**
32%	Cable Tray	m
38%	Cabling	m
10%	Cable Connection	pcs
15%	Panel	pcs
5%	Instrument	pcs
100%	**Total**	

For example, assume that in Project A 20000 m cable tray is mounted, installation of 60 panels is completed and 40000 m cable is mounted then percentage of electric work progress is calculated as it follows:

$$=(20{,}000x0.32/48.885)+(60x0.15/1.260)+(40{,}000x0.38/938{,}097)= 15.43\%$$

In addition, mechanical, piping and electrical works are always checked by the quality control engineer whether the equipment is used properly or not, or if any irregularities are detected, the related work is done. Any quality problem in the region of mounting processes are conducted, instant precautions can be taken, and necessary arrangements can be performed.

5.4 The Project Time Analysis

Project A and Project B are compared to each other in this section. As the progress flow was previously mentioned, project activities is listed by timewise and in a logical order. While cold roll mill complex is planned to be installed, to understand more clearly the workflow, six plants PL&TCM, ARP, BAF, ECL, HDGL, CCL and Utilities Plant are categorized by three departments that are mechanical works, piping works and electrical works. Each plant has technological structure differences such as in equipment, drawings and electrical design, although they have similar orders of piping, electrical and mechanical works. Thus, the project can be analyzed explicitly. It enables us to conduct PERT analysis and report through the software of MS Project.

All lines can be installed at different times, because they don't have a commitment to assemble each other. Thus, the company starts to establish the lines where the construction areas are handed over by the employer company. According to the completion of the construction works, the assembly works may start at the same time or may start at different times on all lines. Although the starting times of the lines are different in these two projects, their data of the two finished projects will be utilized in this study. The same organization chart used in both of these projects and the related data is included in Appendix A. The summarized data of Project A and Project B is given in the following table (Table 5.4). Mounted lines, quantities of equipment erection, quantities of piping erection and quantities of cabling are shown with the related total hall areas for both Project A and Project B. The related data for each line separately is given in detail in Appendix B. It is explained that although there is a difference in the amount of installation, the production capacities of the production lines are the same.

Table 5.5 Data of Project A and Project B

	Total Halls Area		**Equipment Erection**		**Piping Erection**				**Cabling**	
A	122	km^2	12,860	ton	93,247	m	339,113	inch-m	938,097	m
B	80	km^2	12,261	ton	91,963	m	243,909	inch-m	718,696	m

In addition, exemplary plans, where every activities are going smoothly such as no delays in submissions of equipment and pipes, and civil works completion without

encountering any problems, is given in Appendix C and Appendix D. Appendix C includes also the differences of planned start times and actual start times. Each of two projects was planned similarly and given in Appendix D more detailed. It shows that complete duration of PL&TCM line is estimated to be nine months, ARP to be six months, HDGL to be seven months, TM to be six months, BAF to be five months, CCL to be six months, ECL to be five months and Utility to be nine months. As a result, that total process duration is estimated to be twelve months. The completion time of piping and mechanical works is estimated to be eleven months, and the duration of electrical works is estimated to be twelve months.

5.4.1 Time Analysis for Mechanical Works

Actual times are different from this scenario. Figure 5.2 and Figure 5.3 show how much assembly is performed each month in total mechanical assembly of all lines and how long it takes in these two separate projects. In addition, they display differences in tonnes between these projects and the differences between the numbers of personnel employed in mechanical works each month. While the average mechanical progress of Project A was 1.069 tons per a month, the average of Project B was 766 tons. While the total mechanical work in Project A lasted 14 months, it continued in Project B for 16 months. While the maximum number of personnel in mechanical works in Project A is maximum 291, minimum15 people per a month, in Project B, the maximum is 174 personnel, and the minimum is 22 personnel (Table 5.5).

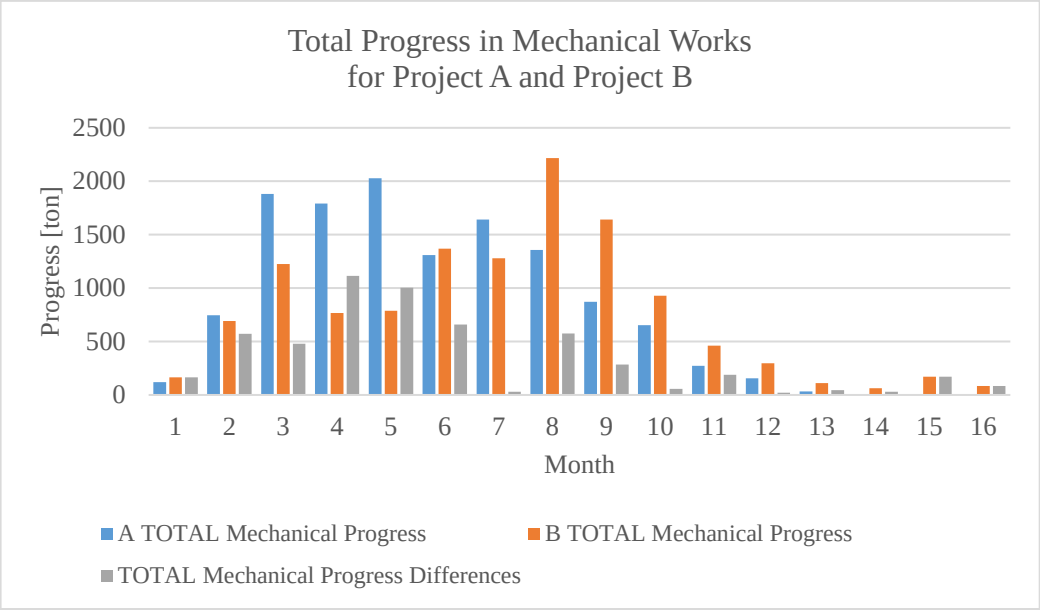


Figure 5.2 Total progress in mechanical works of Project A and Project B

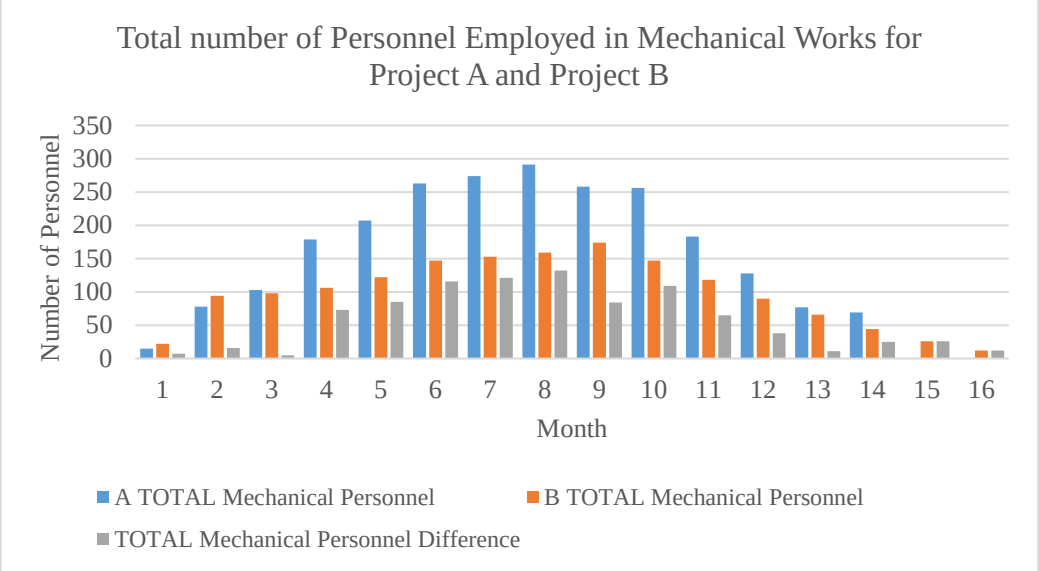


Figure 5.3 Total number of personnel employed in mechanical works for Project A and Project B

Table 5.6 Data of the personnel who work in mechanical works per month

Number of Personnel Employed in Mechanical Works per a month		
Project	**Max**	**Min**
A	291	15
B	174	22

5.4.2 Time Analysis for Piping Works

Figure 5.4 and Figure 5.5 show how much assembly is performed each month in total piping assembly of all lines and how long it takes in two separate projects. In addition, they display differences in meters between the two projects and the differences between the numbers of personnel employed in piping works per month. While the average piping progress of Project A was 7.771 m per a month, the average of Project B was 5.748 m. While the total piping work in Project A lasted 12 months, it continued in Project B for 16 months. The maximum number of mechanical works personnel in Project A is maximum 487, minimum 60. In Project B, a maximum of 216 personnel, minimum 10 personnel (Table 5.6).

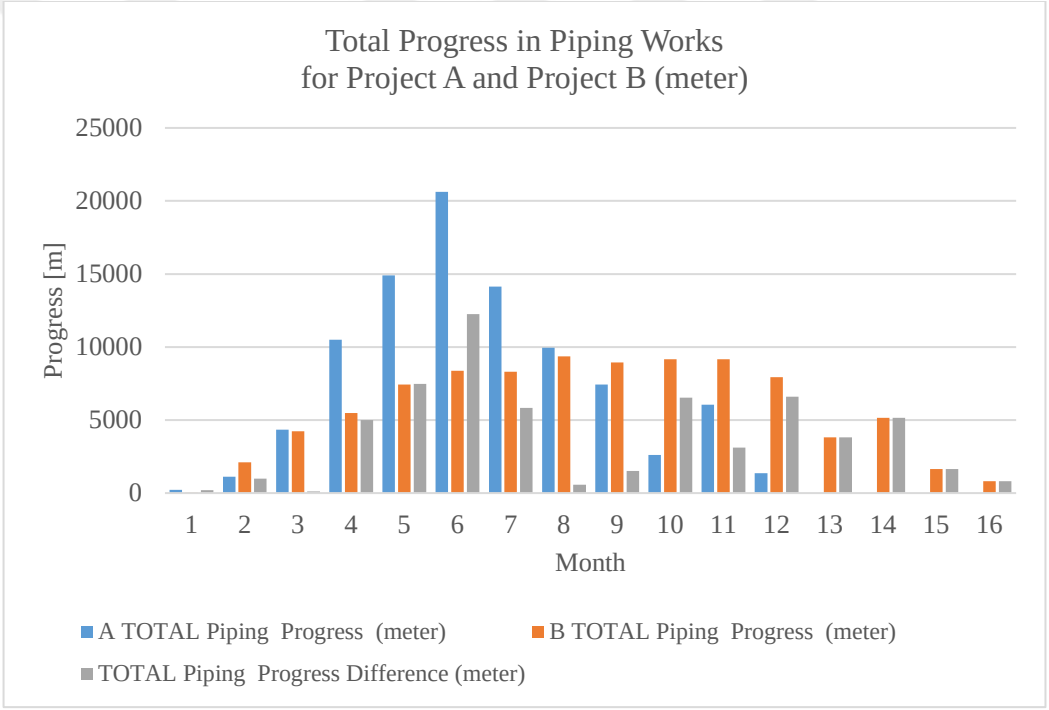


Figure 5.4 Total progress in piping works of Project A and Project B

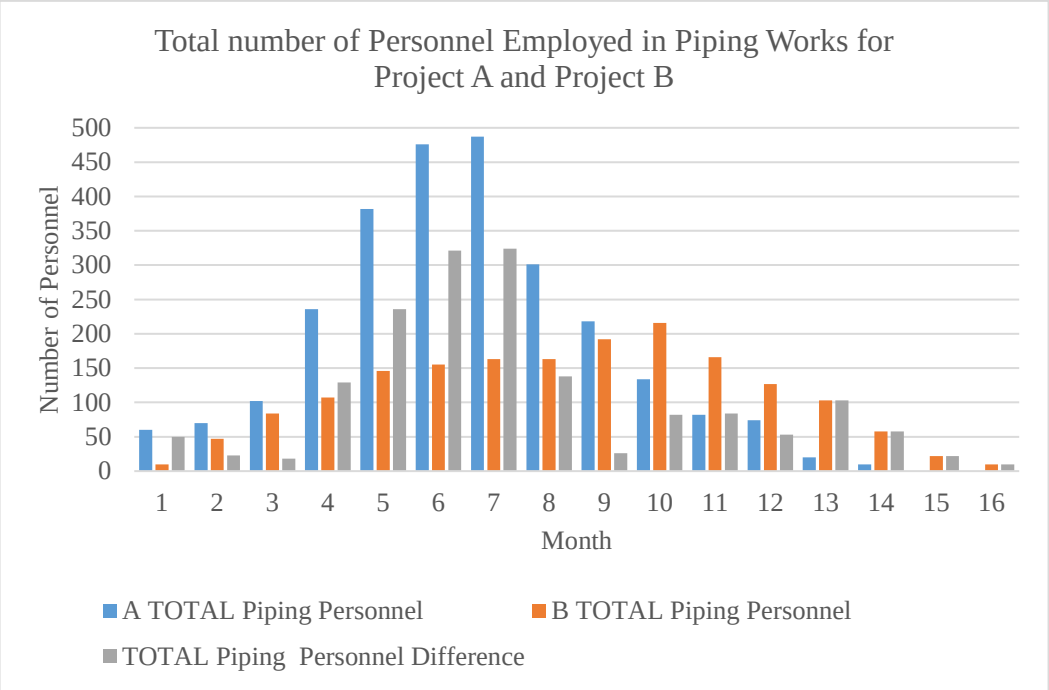


Figure 5.5 Total number of personnel employed in piping works for Project A and Project B

Table 5.7 Data of the personnel who work in piping works per month

Number of Personnel Employed in Piping Works per month		
Project	**Max.**	**Min**
A	487	10
B	216	10

5.4.3 Time Analysis for Electrical Works

Figure 5.6 and Figure 5.7 show how much assembly is performed each month in total cabling assembly of all lines and how long it takes in these two separate projects. In addition, they display differences in meters between the two projects and the differences between the numbers of personnel employed in mechanical works per month. While the average electrical progress of Project A was 7.771 m per a month, the average of Project B was 5.478 m. While the total electrical work in Project A lasted 14 months, it continued in Project B for 16 months. While the maximum number of piping works personnel in Project A is maximum 347 and minimum 10, in Project B a maximum of 75 personnel and the minimum 7 personnel (Table 5.7).

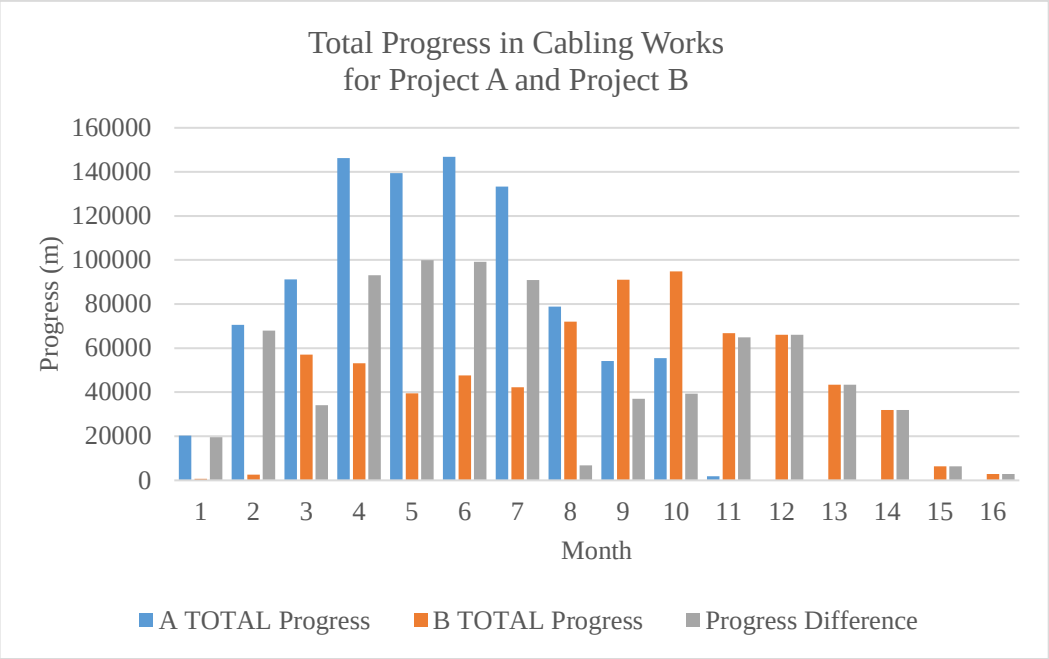


Figure 5.6 Total progress in electrical works of Project A and Project B

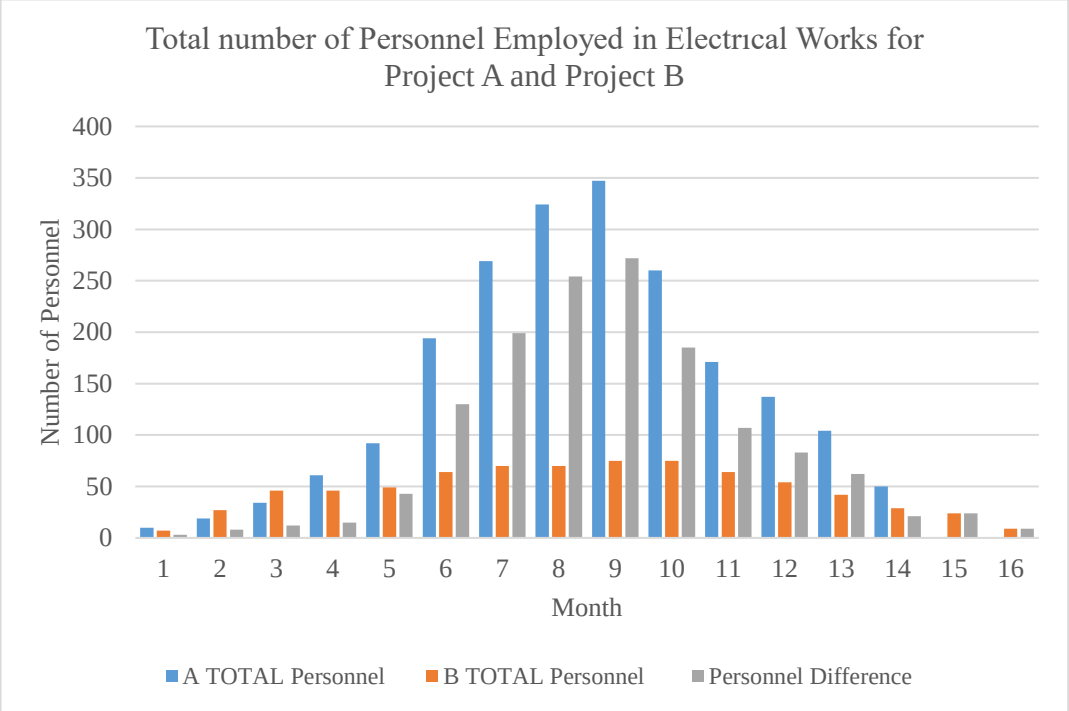


Figure 5.7 Total number of personnel employed in electrical works for Project A and Project B

Table 5.8 Data of the personnel who work in electrical works

Number of Personnel Employed in Electrical Works per a month		
Project	**Max.**	**Min**
A	347	10
B	75	7

5.5 PERT Analysis

In Table 5.9 optimistic, most likely and pessimistic durations of mechanical, piping and electrical progresses for each line is summarized. As it is mentioned before these durations are determined with the help of similar projects and previous experiences. Comparative progress tables for all lines are given in Appendix E.

Organization schema given in Appendix A summarizes working orders of the two projects. Each line progress is determined in three departments which are mechanical, piping and electrical erection. The time analysis of the progress of these three departments was done by estimating completion times of optimistic, pessimistic and most likely scenarios. Optimistic times defined by the employer company in the procurement processes and are always calculated if all goes according to plan. Most likely times are defined by two similar projects, in this case data of Project A and Project B are used (Appendix E). In pessimistic duration the worst-case scenarios of each project has taken into consideration. For instance, during Project B several problems are occurred such as construction problems and manufacturing defects in equipment, in result the project slowed down, and the solution process took four to five months. Pessimistic values involve all these negative effects on projects. In the following table problems that are not in the responsibility of assembly company, but the employer company should solve; are being categorized and total problem numbers and average solution times are added for the cases of Project A and Project B separately (Table 5.8).

Table 5.9 Total numbers of problems and average solution times of problems for Project A and Project B

	Project A		**Project B**	
To Mechanical Works	**Number of Data**	**Average Solution Time [day]**	**Number of Data**	**Average Solution Time [day]**
Missing Materials (duct, flange, shim etc.)	87	41	90	88
Construction Problems (non-completed areas, water leaked problems etc.)				
Missing Project Drawings				
Required revision works				
late-detection of materials with manufacturing problems and failure to solve the problem in time				
To Piping Works	**Number of Data**	**Average Solution Time [day]**	**Number of Data**	**Average Solution Time [day]**
Construction Problems (non-completed areas, water leaked problems etc.)	130	29	113	60
Missing Materials (pipe, fittings, valve etc.)				
Missing Project Drawings				
Delayed the works that the main firm must finish in the field				
Piping materials lists				
To Electrical Works	**Number of Data**	**Average Solution Time [day]**	**Number of Data**	**Average Solution Time [day]**
Construction Problems (non-completed areas, water leaked problems etc.)	12	36	21	47
Missing Project Drawings				
Missing Materials (cable plate and support etc.)				
Total	**229**		**224**	

After optimistic, pessimistic and most likely scenarios are determined, expected time is calculated according to the formulas (Formula 4.5) and the results are stated in PERT analysis (Table 5.9). Defined via expected time a schedule was created in MS Project and the critical path was calculated. The results can be found in detail in Figure 5.8

and Figure 5.9. Working schedule in MS Project was defined between 8:00 – 12:30 in the morning and 13:30 – 17:00 in the afternoon. The connections between electricity, pipe and mechanical are almost similar in all lines. After completion of mechanical work piping work starts and when piping is completed electrical works get started. The time period added to the connection between jobs was determined by PERT analysis: the difference between the minimum finish times is zero, usually 7 and the worst timing is 14 days. Thus, the relationship between the most expected times is 7 days. The effective data stated in the software includes the completion of the construction works in the area belonging to the work area by the main contractor, delivery of the related installation drawings and details, and finally the material delivery. This time being zero, is related to the events outside the assembly company, and the delay of the main contractor will affect the project. During the preparation of the software it is assumed that the main contractor complied with the deadlines specified in the tender. However, it should be kept in mind that this would not happen in real life. When PERT analysis was performed, the time of implementation of the two projects, the desired installation times in the tender and the mentioned delays were taken into consideration and the times were determined together with the assembly division chiefs.

Table 5.10 Time table of the project lines

No	Task	Optimistic (a)	Most Likely completion (m)	Pessimistic (b)	Expected (e)	Standard Deviation
1	**PL&TCM**					
1.1	**Mechanical**	7.0	9.0	14.0	9.5	1.17
1.2	**Piping**	7.0	9.5	14.0	9.8	1.17
1.3	**Electrical**	7.0	8.0	14.0	8.8	1.17
2	**ARP**					
2.1	**Mechanical**	5.0	6.0	7.0	6.0	0.33
2.2	**Piping**	4.0	5.0	5.7	4.9	0.28
2.3	**Electrical**	4.0	4.0	7.0	4.5	0.50

Table 5.10 (continued): Time table of the project lines

No	Task	Optimistic (a)	Most Likely completion (m)	Pessimistic (b)	Expected (e)	Standard Deviation
3	**HDGL**					
3.1	**Mechanical**	4.3	6.0	8.0	6.1	0.61
3.2	**Piping**	4.3	7.5	9.0	7.2	0.78
3.3	**Electrical**	4.3	6.0	10.0	6.4	0.94
4	**TM**					
4.1	**Mechanical**	3.0	4.0	5.0	4.0	0.33
4.2	**Piping**	3.0	4.8	5.7	4.7	0.44
4.3	**Electrical**	3.0	3.0	5.0	3.3	0.33
5	**BAF**					
5.1	**Mechanical**	2.5	3.0	4.0	3.1	0.25
5.2	**Piping**	3.0	4.0	4.7	3.9	0.28
5.3	**Electrical**	3.0	3.0	5.0	3.3	0.33
6	**CCL**					
6.1	**Mechanical**	4.0	6.0	7.0	5.8	0.50
6.2	**Piping**	4.0	6.0	7.0	5.8	0.50
6.3	**Electrical**	4.0	5.0	8.0	5.3	0.67
7	**ECL**					
7.1	**Mechanical**	3.0	4.0	5.0	4.0	0.33
7.2	**Piping**	3.0	3.3	4.0	3.4	0.17
7.3	**Electrical**	3.0	3.0	5.0	3.3	0.33
8	**UTILITY***	7*	11.5*	14*	11.167*	1.17*
8.1	**Mechanical***	1.0	1.5	2.5	1.6	0.25
8.2	**Piping***	7.0	11.3	13.3	10.9	1.06
8.3	**Electrical***	4.0	4.0	8.0	4.7	0.67

**Critical path*

The critical path calculated in the software is shown in Figure 5.8 and Figure 5.9. The sum of the red-highlighted tasks shown in the Figure 5.8 and Figure 5.9 is the critical

path. This path was calculated as the installation works of Utility. According to the critical path standard deviation and variance is calculated as it follows:

The total path standard deviation (Formula 4.6) is obtained follows:

$$\sigma_e = \frac{b-a}{6} = \frac{14-7}{6} \quad \textbf{(5.1)}$$

$$\sigma_{utility} = 1.17 \quad \textbf{(5.2)}$$

The total path variance (Formula 4.7) is determined fallows;

$$v = \sigma_{utility}^2 = 1.36 \quad \textbf{(5.3)}$$

Total Project is calculated (Formula 4.8) in GANT diagram which is included in the Figure 5.8. According to the results, the completion of this project in the range of 11.167 + 1.36 to 11.167-1.36 is very high [29].

$$K_i = \frac{T_i - T}{\sqrt{\sigma_{utility}^2}} = P(z \leq K_i) \quad \textbf{(5.4)}$$

$$K_i = \frac{13-11.167}{\sqrt{1.36}} = 1.567 \quad \textbf{(5.5)}$$

Kimlik	Görev Modu	Görev Adı	Süre	Başlangıç	Bitiş	Öncüller
0		**Proje1**	**335 gün**	**13.5**	**24.4**	
1		Effective Date	0 gün	13.5	13.5	
2		**PL&TCM**	**302 gün**	**13.5**	**20.3**	
3		Mechanical	285 gün	13.5	3.3	1
4		Piping	295 gün	13.5	13.3	3TT+7 gün;8TT
5		Electrical	265 gün	20.6	20.3	4TT+7 gün;9TT
6		**ARP**	**194 gün**	**13.5**	**29.11**	
7		Mechanical	180 gün	13.5	15.11	1
8		Piping	148 gün	22.6	22.11	7TT+7 gün
9		Electrical	135 gün	13.7	29.11	8TT+7 gün
10		**HDGL**	**224 gün**	**13.5**	**31.12**	
11		Mechanical	182 gün	13.5	17.11	1
12		Piping	217 gün	13.5	23.12	11TT+7 gün
13		Electrical	192 gün	15.6	31.12	12TT+7 gün
14		**TM**	**147 gün**	**13.5**	**12.10**	
15		Mechanical	120 gün	13.5	14.9	1
16		Piping	140 gün	13.5	4.10	15TT+7 gün
17		Electrical	100 gün	30.6	12.10	16TT+7 gün
18		**BAF**	**125 gün**	**13.5**	**19.9**	
19		Mechanical	93 gün	13.5	17.8	1
20		Piping	118 gün	13.5	12.9	19TT+7 gün
21		Electrical	100 gün	7.6	19.9	20TT+7 gün
22		**CCL**	**189 gün**	**13.5**	**24.11**	
23		Mechanical	175 gün	13.5	10.11	1
24		Piping	175 gün	20.5	17.11	23TT+7 gün
25		Electrical	160 gün	12.6	24.11	24TT+7 gün
26		**ECL**	**134 gün**	**13.5**	**28.9**	
27		Mechanical	120 gün	13.5	14.9	1
28		Piping	102 gün	7.6	21.9	27TT+7 gün
29		Electrical	100 gün	17.6	28.9	28TT+7 gün
30		**UTILITY**	**335 gün**	**13.5**	**24.4**	
31		Mechanical	48 gün	13.5	1.7	1
32		Piping	328 gün	13.5	16.4	4TT;8TT;12TT;16TT;20TT;24TT;28TT;31BB
33		Electrical	140 gün	1.12	24.4	32TT+7 gün;5TT;9TT;13TT;17TT;21TT;25TT;29TT;31BB

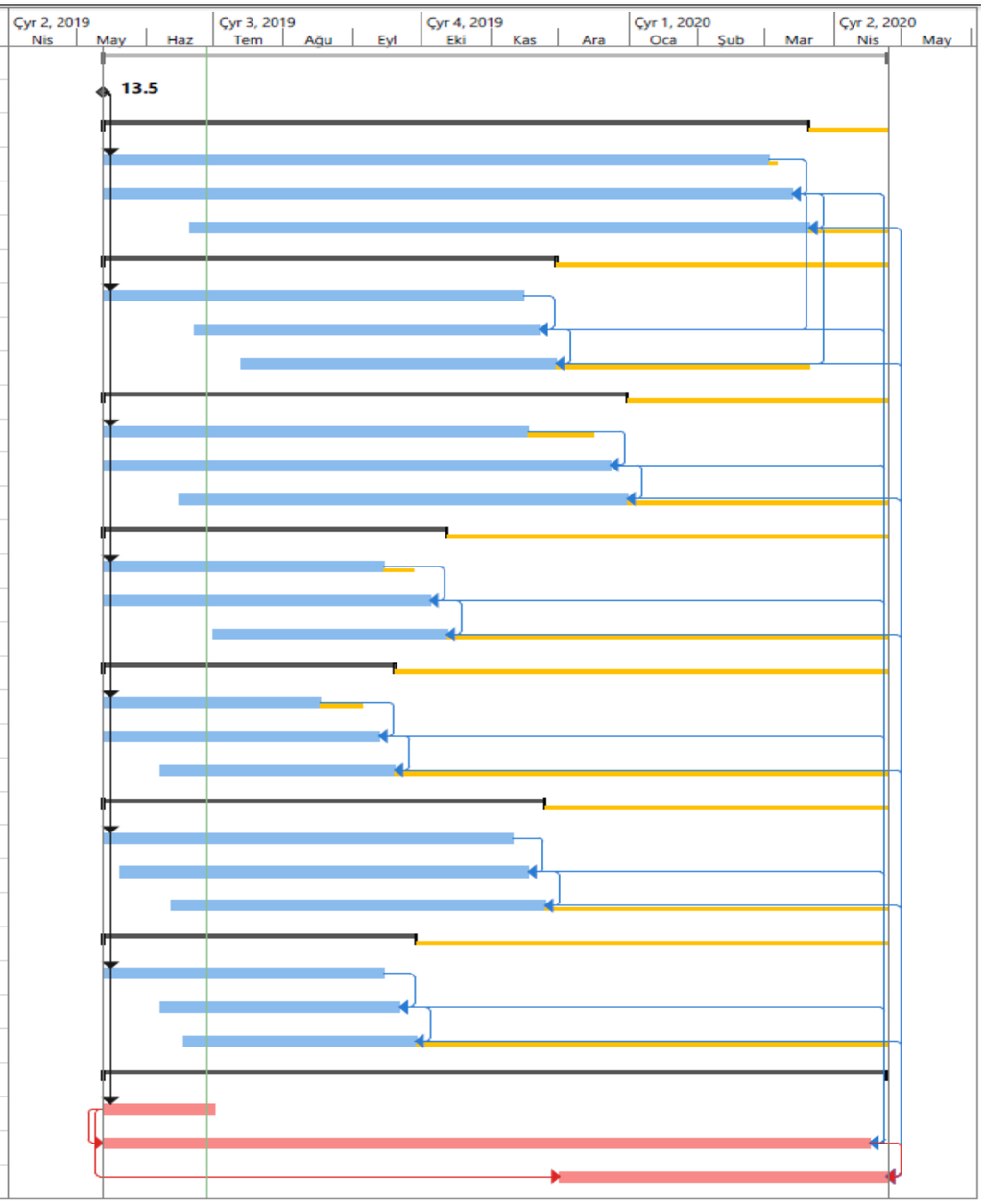


Figure 5.8 GANT diagram of PERT analysis results

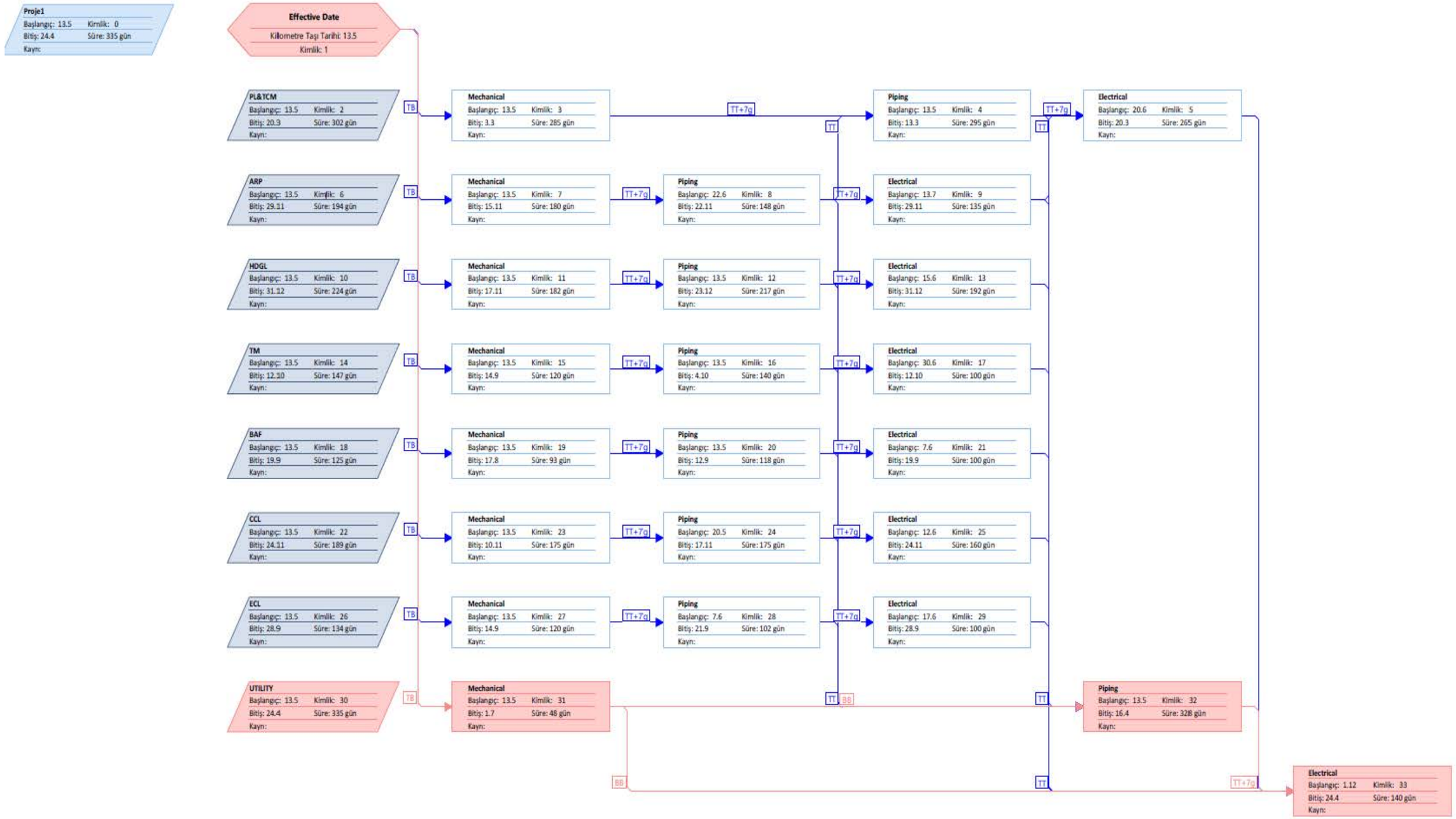
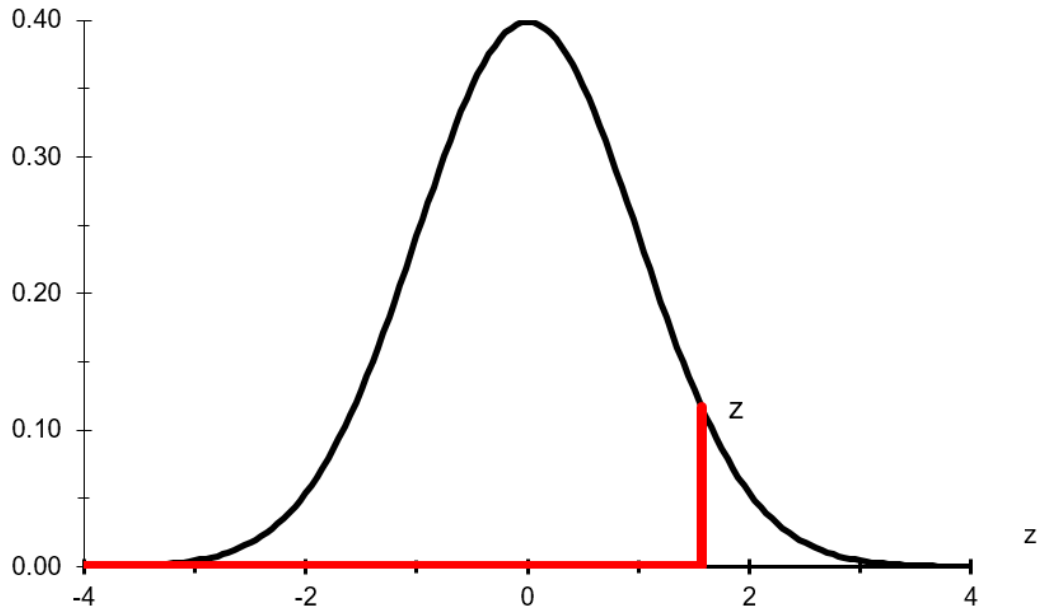


Figure 5.9 Network diagram of PERT analysis results

CHAPTER 6

6 RESULTS AND DISCUSSION

Figure 6.1 illustrates the standard normal distribution (z) and it indicates the K_i value calculated in the PERT analysis. The probability of project completion in 13 months is 94, 14%. In addition, it is observed that the lines have slack periods when looking at the diagram created on MS Project. Yellow lines indicate the slack times. For instance, the HDGL line was calculated to be completed within 224 days. Since the total project took 335 days to finish, it has a slack time of 111 days. That means, HDGL can start not together with all the other lines but after 111 days. Lines with slack time may have different assembly start times within the calculated time, or the installation time can be extended. Due to the amount of slack time, efficiency analysis of each line conducted in themselves where the main indicator is man-hour. The data of two projects was compared by using man-hour values to evaluate the progresses of the related projects. Man-hours show differences from the beginning towards the end of the construction site as it is illustrated in personnel graphs given in the Appendix E. While the number of personnel increases from the beginning to the middle, it decreases towards the end of the project. Thus, the analysis was conducted by total man-hour. Working hours employed in this study are based on labor law number 4857 and the progress was defined by the amount of assembly completion.



	z	f(z)	F(z)
z	1.57	0.116871	0.941443
	1.567	0	
	-4	0	

Figure 6.1 Standard normal distribution of the conducted PERT analysis

6.1 PL&TCM

For PL&TCM most appropriate data can be acquired by revealing the differences and similarities of the two projects.

6.1.1 Mechanical works of PL&TCM

While the progress of mechanical work in Project A is calculated as 0.03 ton/man-hour (Table 6.1), in Project B the number reached to 0.04 ton/man-hour.

Even if the mechanical work continued twelve months in both projects, in Project A the mechanical work went through a readjustment process for two months. Therefore, in the personnel diagram the work was defined as fourteen months (Appendix E). On the hand several problems were encountered in Project B. First of all, soil survey was not sufficiently conducted. Since the construction took place on a soft soil, it needed special attention. Secondly, one of the large equipment failed during the cold run, due to a manufacturing deficiency. Hence, the progress of assembly slowed down, and after assessing and fixing the problem the process continued in the normal order, but this costed the company almost extra four months. When the man-hour comparisons and project duration analysis is taken into consideration, it may well be argued that Project B is more efficiently conducted than Project A.

As result of PERT analysis in mechanical assembly of PL&TCM, while the expected time is calculated from Table 5.9 as nine and half months, the variance is 1.36. That means probability of work completion lays in between ±1.36 months to the expected time.

Table 6.1 PLTCM Mechanical Progress /Man-hour

PLTCM- TOTAL MECHANICAL WORKS		
	Progress (ton)	**Man-hour**
A	5,275.80	182,000
B	5,595.03	153,140

6.1.2 Piping works of PL&TCM

For piping works tracing is done by two units. While one of them indicates only the length of the line with the unit meter [m], the other shows pipe diameter and length with the unit of inch meter [inch-m]. In Table 6.2 the sum values of both projects are given for each unit. While the progress of piping work in Project A is calculated as 0.09 m/man-hour and 0.28 inch-m/man-hour, in Project B the number reached to 0.21 ton/man-hour and 0.53 inch-m/man-hour (Table 6.2). The fore-mentioned problems

affected also PL&TCM piping assembly time, since all departments are connected to each other by means of completing the project. Namely, piping works depend on mechanical progress and electrical works depend on both piping and mechanical progress.

Table 6.2 PLTCM Piping Progress/ Man-hour

PLTCM – TOTAL PIPING WORKS		
	Progress	**Man-hour**
A (m)	19,366.59	**218,400**
B (m)	26,631.33	**130,000**
A (inch-m)	61,658.89	218,400
B (inch-m)	67,053.15	**130,000**

Piping works for both Project A and Project B are completed in eleven months (Appendix E). In the meantime, when the personnel diagram is assessed for Project A one month of readjustment time was remained. Then again, in Project B piping works were conducted more efficiently, when the aforementioned statements are considered.

As result of PERT analysis in piping assembly of PL&TCM, while the expected time is calculated from Table 5.9 as 10 months, the variance is 1.36. That means probability of work completion lays in between ±1.36 months to the expected time.

6.1.3 Electrical works of PL&TCM

Electrical works will be assessed according to cabling progress (Table 6.3). While the progress of mechanical work in Project A is calculated as 1.69 m/man-hour, in Project B the number reached to 3.43 m/man-hour. The aforementioned problems encountered in both mechanical and piping works, affected also PL&TCM electrical assembly time. Additionally, the amount of cables in Project A is 77% higher than in Project B, due to design variation and requirements of employer company. While in Project A assembly time was nine months, the related process completed in Project B in ten months. However, in Project A readjustment process continued for a while (Appendix

E). Then again, in Project B was conducted more efficiently, when the fore-mentioned statements are considered.

Table 6.3 PLTCM Electrical Progress /Man-hour

PL&TCM – TOTAL ELECTRIC WORKS		
	Cabling (m)	**Man-hour**
A	394,077.00	233,220
B	222,321.00	64,740

As result of PERT analysis in electrical assembly of PL&TCM, while the expected time is calculated from Table 5.9 as nine months, the variance is 1.36. That means probability of work completion lays in between ±1.36 months to the expected time.

6.2 ARP

6.2.1 Mechanical works for ARP

For two projects total progress in mechanical works is 0.03 ton/man-hour (Table 6.4). While Project A is completed in six months, Project B lasted for seven months (Appendix E). The difference was related to the late hand-over of the construction site. Additionally, in Project B a late delivery in material supply caused a delay in project start. For both cases work efficiency are similar.

As result of PERT analysis in mechanical assembly of ARP, while the expected time is calculated from Table 5.9 as six months, the variance is 0.11. That means probability of work completion lays in between ±0.11 months to the expected time.

Table 6.4 ARP Mechanical Progress /Man-hour

ARP- TOTAL MECHANICAL WORKS		
	Progress (ton)	**Man-hour**
A	810.75	28,340
B	757.40	21,060

6.2.2 Piping Works for ARP

In Table 6.5 the sum values of both projects are given for each unit. While the progress of piping work in Project A is calculated as 0.14 m/man-hour and 0.43 inch-m/man-hour, in Project B the number reached to 0.57 ton/man-hour and 0.88 inch-m/man-hour. While Project A is completed in seven months, Project B lasted for six months (Appendix E). In Project elimination of construction deficiencies and late delivery of piping material caused a delay in piping progress. Even though, a late material delivery happened also in Project B, it was conducted more efficiently. As result of PERT analysis in piping assembly of ARP, while the expected time is calculated from Table 5.9 as five months, the variance is 0.08. That means probability of work completion lays in between ±0.08 months to the expected time.

Table 6.5 ARP Piping Progress /Man-hour

ARP – TOTAL PIPING WORKS		
	Progress	**Man-hour**
A (m)	2,388.41	17,160
B (m)	4.896.08	8,580
A (inch-m)	7,430.91	17,160
B (inch-m)	7,551.68	**8,580**

6.2.3 Electrical Works of ARP

While the progress of electrical work in Project A is calculated as 1.11 m/man-hour, in Project B the number reached to 2.94 m/man-hour (Table 6.6). Electrical work for both of the projects completed in similar times (Appendix E). However, because of the construction problems in Project A the assembly work was slowed down and readjustments were made. Then again, materials delivered late by the employer company and a delay was experienced in work completion. In Project B, a more efficient work process was observed. As result of PERT analysis in electrical assembly of ARP, while the expected time is calculated from Table 5.9 as four and half months,

the variance is 0.25. That means probability of work completion lays in between ±0.25 months to the expected time.

Table 6.6 ARP Electrical Progress /Man-hour

ARP- TOTAL ELECTRICAL WORKS		
	Cabling (m)	**Man-hour**
A	10,104.00	9,100
B	12,233.00	4,160

6.3 HDGL

6.3.1 Mechanical works of HDGL

For both projects total progress in mechanical works is 0.03 ton/man-hour (Table 6.7). While Project A is completed in nine months, Project B lasted for thirteen months (Appendix E). The reason why Project B lasted longer is because insufficient soil survey of the construction site resulting in water leakages and manufacturing deficiency in materials of steel structure which slowed down the mechanical assembly. Additionally, in Project B a delay in material supply was experienced that slowed down the progress. Even though all of these problems, it is observed that both of the projects have similar work efficiencies. As result of PERT analysis in mechanical assembly of HDGL, while the expected time is calculated from Table 5.9 as six months, the variance is 0.37. That means probability of work completion lays in between ±0.44 months to the expected time.

Table 6.7 HDGL Mechanical Progress /Man-hour

HDGL- TOTAL MECHANICAL WORKS		
	Progress (ton)	**Man-hour**
A	3,453.39	123,760
B	3,150.09	104,780

6.3.2 Piping Works of HDGL

In Table 6.8 the sum values of both projects are given for each unit. While the progress of piping work in Project A is calculated as 0.15 m/man-hour and 0.31 inch-m/man-hour, in Project B the number reached to 0.20 ton/man-hour and 0.31 inch-m/man-hour. While Project A is completed in six months, Project B lasted for ten months (Appendix E). The aforementioned problems mechanical work applies also for piping works. In Project B, a more efficient work process was observed. As result of PERT analysis in piping assembly of HDGL, while the expected time is calculated from Table 5.9 as seven months, the variance is 0.6. That means probability of work completion lays in between ±0.6 months to the expected time.

Table 6.8 HDGL Piping Progress /Man-hour

HDGL – TOTAL PIPING WORKS		
	Progress	**Man-hour**
A (m)	15.018,00	100.880
B (m)	15.934,61	80.340
A (inch-m)	31.636,22	100.880
B (inch-m)	25.299,05	80.340

6.3.3 Electrical Works of HDGL

While the progress of electrical work of HDGL in Project A is calculated as 1.17 m/man-hour, in Project B the number reached to 3.05 m/man-hour (Table 6.9). While Project A is completed in eight months, Project B lasted for twelve months (Appendix E). Delays in mechanical and piping works in Project B slowed down also the electrical progress. Even though all of these problems, in Project B, a more efficient work process was observed. As result of PERT analysis in electrical assembly of HDGL, while the expected time is calculated from Table 5.9 as six months, the variance is 0.89. That means probability of work completion lays in between ±0.89 months to the expected time.

Table 6.9 HDGL Electrical Progress /Man-hour

HDGL – TOTAL ELECTRICAL WORKS		
	Cabling (m)	**Man-hour**
A	156,829.00	100,100
B	145,707.50	47,840

6.4 TM

6.4.1 Mechanical Works of TM

While the progress of mechanical work of TM in Project A is calculated as 0.02 ton/man-hour, in Project B the number reached to 0.04 ton/man-hour (Table 6.10). While Project A is completed in nine months, Project B lasted for eight months (Appendix E). Due to general material deficiencies in Project B, the progress slowed down. The TM's employed in this two projects were different in term of technological structure, but the working capacity were the same. Therefore, varieties were encountered in tonnes and man-hours. When it is evaluated on man-hour values and working progress, it may well be argued that Project B showed a more efficient work process. As result of PERT analysis in mechanical assembly of TM, while the expected time is calculated from Table 5.9 as four months, the variance is 0.11. That means probability of work completion lays in between ±0.11 months to the expected time.

Table 6.10 TM Mechanical Progress /Man-hour

TM- TOTAL MECHANICAL WORKS		
	Progress (ton)	**Man-hour**
A	1,182.15	60,320
B	452,80	11,700

6.4.2 Piping Works of TM

In Table 6.11 the sum values of both projects in piping assembly are given for each unit. While the progress of piping work in Project A is calculated as 0.13 m/man-hour

and 0.33 inch-m/man-hour, in Project B the number reached to 0.16 ton/man-hour and 0.20 inch-m/man-hour. Both projects were completed in seven months (Appendix E). Even though, in Project A the work continued for readjustments, a more efficient work process was observed. As result of PERT analysis in piping assembly of TM, while the expected time is calculated from Table 5.9 as five months, the variance is 0.2. That means probability of work completion lays in between ±0.2 months to the expected time.

Table 6.11 TM Piping Progress /Man-hour

TM - TOTAL PIPING WORKS		
	Progress	**Man-hour**
A (m)	7,936.30	60,060
B (m)	4,432.84	27,300
A (inch-m)	19,537.37	60,060
B (inch-m)	5,438.23	27,300

6.4.3 Electrical Works of TM

While the progress of electrical work of TM in Project A is calculated as 1.60 m/man-hour, in Project B the number reached to 2.20 m/man-hour (Table 6.12). While Project A is completed in nine months, Project B lasted for five months (Appendix E). Differences in construction design and technological structure are the main reasons of the cabling amount. However, if man-hour taken into consideration, in Project B a more efficient work process was observed. As result of PERT analysis in electrical assembly of TM, while the expected time is calculated as three months, the variance is 0.11. That means probability of work completion lays in between ±0.11 months to the expected time.

Table 6.12 TM Electrical Progress /Man-hour

TM - TOTAL ELECTRICAL WORKS		
	Cabling (m)	**Man-hour**
A	110,544.00	68,900
B	25,183.00	11,440

6.5 BAF

6.5.1 Mechanical Works of BAF

While the progress of mechanical work of BAF in Project A is calculated as 0.03 ton/man-hour, in Project B the number became 0.02 ton/man-hour (Table 6.13). Mechanical work for both of the projects completed in similar times (Appendix E). The difference in tons is due to the alteration of construction design. Even though, in Project A a steel construction is used and in Project B a concrete construction was employed, in Project A a more efficient work process was observed. As result of PERT analysis in mechanical assembly of BAF, while the expected time is calculated from Table 5.9 as three months, the variance is 0.06. That means probability of work completion lays in between ±0.06 months to the expected time.

Table 6.13 BAF Mechanical Progress /Man-hour

BAF- TOTAL MECHANICAL WORKS		
	Progress (ton)	**Man-hour**
A	438,67	14.820
B	288,83	13.000

6.5.2 Piping Works of BAF

In Table 6.14 the sum values of both projects in piping assembly for BAF are given for each unit. While the progress of piping work in Project A is calculated as 0.12 m/man-hour and 0.27 inch-m/man-hour, in Project B the number reached to 0.19 ton/man-hour and 0.34 inch-m/man-hour. While Project A is completed in four

months, Project B lasted for seven months (Appendix E). The longer completion time of Project B is a result of insufficient soil survey. Even though slumps on ground and water leakages were occurred during assembly process, work performance of Project B was more efficient. As result of PERT analysis in piping assembly of BAF, while the expected time is calculated from Table 5.9 as four months, the variance is 0.08. That means probability of work completion lays in between ±0.08 months to the expected time.

Table 6.14 BAF Piping Progress /Man-hour

BAF - TOTAL PIPING WORKS		
	Progress	**Man-hour**
A (m)	2,951.80	24,180
B (m)	4,439.98	23,920
A (inch-m)	6,449.25	24,180
B (inch-m)	8,050.49	23,920

6.5.3 Electrical Works of BAF

While the progress of electrical work of BAF in Project A is calculated as 2.01 m/man-hour, in Project B the number reached to 2.11 m/man-hour (Table 6.15). Both of the projects completed in five months and work efficiency for both projects are similar (Appendix E). As result of PERT analysis in electrical assembly of BAF, while the expected time is calculated from Table 5.9 as three months, the variance is 0.11. That means probability of work completion lays in between ±0.11 months to the expected time.

Table 6.15 BAF Electrical Progress /Man-hour

BAF - TOTAL ELECTRIC WORKS		
	Cabling (m)	**Man-hour**
A	23,473.00	11,700
B	20,419.00	9,620

6.6 CCL

6.6.1 Mechanical Works of CCL

While the progress of mechanical work of CCL in Project A is calculated as 0.02 ton/man-hour, in Project B the number become 0.02 ton/man-hour (Table 6.16). While Project A is completed in six months, Project B lasted for nine months (Appendix E). Even though, elimination of construction deficiencies and late delivery of mechanical materials caused a delay in mechanical progress in Project B, it was conducted more efficiently.

As result of PERT analysis in mechanical assembly of CCL, while the expected time is calculated from Table 5.9 as six months, the variance is 0.25. That means probability of work completion lays in between ±0.25 months to the expected time.

Table 6.16 CCL Mechanical Progress /Man-hour

CCL- TOTAL MECHANICAL WORKS		
	Progress (ton)	**Man-hour**
A	1,125.40	52,520
B	1,551.75	59,800

6.6.2 Piping Works of CCL

In Table 6.17 the sum values of both projects in piping assembly for CCL are given for each unit. While the progress of piping work in Project A is calculated as 0.12 m/man-hour and 0.36 inch-m/man-hour, in Project B the number reached to 0.11 ton/man-hour and 0.38 inch-m/man-hour. While Project A is completed in five

months, Project B lasted for twelve months (Appendix E). The fore-mentioned problems affected also CCL piping assembly time, since all departments are connected to each other by means of completing the CCL. For both cases work efficiency are similar.

As result of PERT analysis in piping assembly of CCL, while the expected time is calculated from Table 5.9 as six months, the variance is 0.25. That means probability of work completion lays in between ±0.25 months to the expected time.

Table 6.17 CCL Piping Progress /Man-hour

CCL - TOTAL PIPING WORKS		
	Progress	**Man-hour**
A (m)	2,519.00	20,800
B (m)	5,837.25	51,480
A (inch-m)	7,453.78	20,800
B (inch-m)	14,444.06	51,480

6.6.3 Electrical Works of CCL

While the progress of electrical work of CCL in Project A is calculated as 1.64 m/man-hour, in Project B the number reached to 4.14 m/man-hour (Table 6.18). While Project A is completed in five months, Project B lasted for nine months (Appendix E). In Project A the mechanical work went through a readjustment process for three months. The aforementioned problems encountered in both mechanical and piping works, affected also CCL electrical assembly time. Despite all the troubles in Project B, it was conducted more efficiently.

As result of PERT analysis in electrical assembly of CCL, while the expected time is calculated from Table 5.9 as five months, the variance is 0.44. That means probability of work completion lays in between ±0.44 months to the expected time.

Table 6.18 CCL Electrical Progress /Man-hour

CCL - TOTAL ELECTRIC WORKS		
	Cabling (m)	**Man-hour**
A	89,612.50	54,600
B	92,648.50	22,360

6.7 ECL

6.7.1 Mechanical Works of ECL

While the progress of mechanical work of ECL in Project A is calculated as 0.03 ton/man-hour, in Project B the number become 0.02 ton/man-hour (Table 6.19). While Project A is completed in five months, Project B lasted for three months (Appendix E). In Project B, mechanical progress was stopped during two months because of late delivery of mechanical material. The difference in tons is due to different construction designs. For both cases work efficiency are similar.

As result of PERT analysis in electrical assembly of ECL, while the expected time is calculated from Table 5.9 as four months, the variance is 0.11. That means probability of work completion lays in between ±0.11 months to the expected time.

Table 6.19 ECL Mechanical Progress /Man-hour

ECL- TOTAL MECHANICAL WORKS		
	Progress (ton)	**Man-hour**
A	573,80	20,800
B	295,82	14,560

6.7.2 Piping Works of ECL

In Table 6.20 the sum values of both projects in piping assembly for ECL are given for each unit. While the progress of piping work in Project A is calculated as 0.15 m/man-hour and 0.31 inch-m/man-hour, in Project B the number reached to 0.17 ton/man-hour and 0.34 inch-m/man-hour. While Project A is completed in six months,

Project B lasted for seven months (Appendix E). The difference in meters and inch-meters is due to different construction design. In addition, the fore-mentioned problems in Project B affected also ECL piping assembly time, since all departments are connected to each other by means of completing ECL. For both cases work efficiency are similar.

As result of PERT analysis in piping assembly of ECL, while the expected time is calculated from Table 5.9 as three months, the variance is 0.03. That means probability of work completion lays in between ±0.03 months to the expected time.

Table 6.20 ECL Piping Progress /Man-hour

ECL - TOTAL PIPING WORKS		
	Progress	**Man-hour**
A (m)	6,238.96	41,860
B (m)	2,611.91	15,600
A (inch-m)	13,173.07	41,860
B (inch-m)	5,268.65	15,600

6.7.3 Electrical Work of ECL

While the progress of electrical work of ECL in Project A is calculated as 1.71 m/man-hour, in Project B the number reached to 1.81 m/man-hour (Table 6.21). While Project A is completed in six months, Project B lasted for seven months (Appendix E). The aforementioned problems encountered in both mechanical and piping works, affected also CCL electrical assembly time. Despite all the troubles in Project B, for both cases work efficiency are similar.

As result of PERT analysis in piping assembly of ECL, while the expected time is calculated from Table 5.9 as three months, the variance is 0.11. That means probability of work completion lays in between ±0.11 months to the expected time.

Table 6.21 ECL Electrical Progress /Man-hour

ECL - TOTAL ELECTRIC WORKS		
	Cabling (m)	**Man-hour**
A	38,693.00	22,620
B	12,249.00	6,760

6.8 UTILITY

6.8.1 Mechanical Works of Utility

While the progress of mechanical work of Utility in Project A is calculated as 0.08 ton/man-hour, in Project B the number become 0.16 ton/man-hour (Table 6.22). While Project A is completed in four months, Project B lasted for two months (Appendix E). For both cases work efficiency is similar.

As result of PERT analysis in mechanical assembly of utility, while the expected time is calculated from Table 5.9 as two months, the variance is 0.06. That means probability of work completion lays in between ±0.06 months to the expected time.

Table 6.22 Utility Mechanical Progress /Man-hour

UTILITY- TOTAL		
	Progress (ton)	**Man-hour**
A	763,00	9,360
B	169,49	1,040

6.8.2 Piping Works of Utility

In Table 6.23 the sum values of both projects in piping assembly for Utility are given for each unit. While the progress of piping work in Project A is calculated as 0.19 m/man-hour and 0.48 inch-m/man-hour, in Project B the number reached to 0.97 ton/man-hour and 1.96 inch-m/man-hour. While Project A is completed in nine months, Project B lasted for fifteen months (Appendix E). Due to late delivery in material supplied in the Project A, the assembly time was delayed. In Project B, the

fore-mentioned problems encountered in PL&TCM mechanical, piping and electrical works, affected also Utility piping assembly time. Even though all of these problems, in Project B, a more efficient work process was observed.

As result of PERT analysis in piping assembly of Utility, while the expected time is calculated from Table 5.9 as eleven months, the variance is 1.11. That means probability of work completion lays in between ±1.11 month to the expected time.

Table 6.23 Utility Piping Progress /Man-hour

UTILITY - TOTAL PIPING WORKS		
	Progress	**Man-hour**
A (m)	36,828.00	198,380
B (m)	27,178.81	56,420
A (inch-m)	191,773.80	198,380
B (inch-m)	110,803.51	56,420

6.8.3 Electrical Work of Utility

While the progress of electrical work of Utility in Project A is calculated as 2.98 m/man-hour, in Project B the number reached to 5.04 m/man-hour (Table 6.24). While Project A is completed in fifteen months, Project B lasted for nine months (Appendix E). The fore-mentioned problems encountered in both mechanical and piping works, affected also Utility electrical assembly time.

As result of PERT analysis in piping assembly of Utility, while the expected time is calculated from Table 5.9 as five months, the variance is 0.44. That means probability of work completion lays in between ±0.44 months to the expected time.

Table 6.24 Utility Electrical Progress /Man-hour

UTILITY - TOTAL ELECTRIC WORKS		
	Cabling (m)	**Man-hour**
A	114,764.00	38,480
B	117,934.50	23,400

CHAPTER 7

7 CONCLUSION

Since we are living in a developing country, in order to increase our development level in world economy, we need to increase our capacity of steel production. To achieve this governmental incentives are provided and, therefore investments in steel sector are encouraged. Especially to-day, investments focus mainly on cold mill semi manufactured products rather than liquid steel. Thus, required steel for sub-industry could be supplied within the country itself and reduce the external dependency.

On the other hand the efficiency of these cold mill complexes lacks of quality assessments. An efficiency study will enable us to provide a number of benefits in terms of time and economic gains. Accordingly, in this study the processes of cold rolling complex erection belonging to two separate companies (Project A and Project B) established in Turkey were evaluated using the time variable. In these two companies the erection processes were handled by a single company. Project A was completed in 14 months and two months later Project B started which covered a period of 16 months.

To achieve efficiency in such large and complex projects a good management of projects is essential. In order to manage a project, one has to have thorough knowledge of project management tools. This will affect the progress of the project positively. Since the most important tool for project management is planning progress, an efficiency study was conducted on the progress of erection processes.

Project planning is not a passive act that involves only in the beginning of the process, in contrary it is dynamic and has control over all the process. Namely, when the planned project starts to be implemented, its compliance with the plan should be continuously controlled.

Otherwise, the situation of the project going out of the plan may not be detected in time. The earliest intervention to problems may be possible by gathering regular

reports from division chiefs. In this regard, the time should be well understood and planned.

In the project planning, the time variable is an indicator in cost and quality assessment. A project manager who manages time and cost well, may exhibit a project with a good quality. Cost assessment is directly related to the management of time. This will enable the project to achieve a good level of efficiency. It does not necessarily indicate that when time reduced, the cost will do the same. It may face the risk of a decrease in the level of quality.

Likewise, the efficiency of the cold mill erection processes was analyzed by the time variable. PERT analysis was performed by using MS Project for time evaluation in accordance with several project management techniques. Thus, a network diagram was created, and a critical path was determined. In addition, slack times in the progresses of the installation stages are calculated (Figure 5.8 and Figure 5.9).

Mainly PERT analysis deals with uncertainty of time by estimating three different scenarios which includes optimistic, pessimistic and most likely completion times. These values are determined by previous experiences. Since the same project team was involved in Project A, more realistic estimations were achieved in Project B.

In MS project, the duration and connections of each line assembly were entered and the completion time of total project was estimated as 335 days or in other words, it can be completed in eleven months. The total critical path standard deviation was calculated as 1.17, the variance was 1.36. The probability of total project completion time was stated to be very high in 11.167 ± 1.36 periods [29]. An additional assessment was conducted in this study by comparing progress of assembled line in Project A and Project B in terms of time, progress, and manpower for each work.

Total data of the whole two projects:

- While the total mechanical progress of Project A was 12.859,96 tons and was completed by 495,300 man-hours, in Project B this value was 12.261,20 tons and it is completed by 410,280 man-hour. The mechanical progress was calculated as 0.026 ton/man-hour and 0.030 ton/man-hour respectively.

- While the total piping progress of Project A was 93.247,06 m with 339.113,06 inch-m and was completed by 681,720 man-hour, in Project B this value was 91,962.86 m with 243,908.81 inch-m and it is completed by 451,620 man-hour. The piping progress was calculated as 0.14 m/man-hour with 0.54 inch-m/man-hour and 0.20 m/man-hour with 0.54 inch-m/man-hour respectively.
- While the total electrical progress of Project A was 938,096.50 m cable and was completed by 538,720 man-hour, in Project B this value was 660,441.41 m cable and it is completed by 197,080 man-hour. The mechanical progress was calculated as 1.74 m/man-hour and 3.35 m/man-hour respectively.

Consequently:

1. The number of electrical and piping works varies in Project A and Project B due to construction design requirements of employer companies. These differences affected the duration.
2. The staff of Project B previously worked in the Project A. According to the results Project B achieved a more efficient progress as well as a more efficient workflow.
3. When two similar projects were considered, it was observed that the work was completed earlier in the Project A since the employer company was sensitive about the deadlines. Thus, continuous monitoring and conducting solution process without any delays accelerated the installation time.
4. On the other hand, the deadline sensitivity in Project A urged the employer company to involve more manpower. However, this did not contribute to the efficiency of the project as desired. For instance, while in Project A total mechanical progress was calculated as 1.74 m/man-hour, in Project B the number reached to 3.35 m/man-hour. Thus, it is observed that the number of employees does not necessarily increase the level of efficiency.
5. In Project B processing elimination of construction deficiencies with delays extended the project period.
6. Insufficient soil survey affected the progress of all works in Project B. This means that the assembly time was extended as well.
7. As the process Project B was observed, it was found more efficient than Project A in most cases, Project B represents a better example for future applications by using the values of Project B such as 0.03 ton/man-hour for mechanical

progress, 0.54 inch-m/man-hour for piping progress, and 3.35 m/man-hour for electrical progress. Thus, for the estimated time of 11 months the number of personnel can be identified. However, this number varies for each month and this should also be taken into consideration for future estimation.

8. Delays in supplying equipment and material for mechanical, piping and electrical works affect the assembly progress.
9. For potential manufacturing deficiencies of equipment and pipes, the employer company should conduct necessary examinations and should solve the problems as soon as possible.
10. Each delay in mechanical works has a direct effect on piping and electrical assembly progress. Similarly, delays in piping works affect electrical assembly progress.
11. The reason of employing both units of meters and inch-meters in progress calculation of piping works is because sometimes pipes with smaller diameters requires more assistance. For future plans it will be beneficial to use both units.
12. When employer company creates construction schedule, they should take into consideration slack times of lines in order to achieve an efficient process by assembly company.
13. The electrical and piping works vary with the construction design plans, using man-hour indicator will enable them to achieve a better project management.
14. Even though in Project B a more efficient process is managed, due to lack of personnel, delays in completion is experienced. For instance, when twelve thousand tons of mechanical work assembly is calculated with 0.03 ton/man-hour for 11 months of project period, the number of personnel is estimated to be more than 1,700. The actual number was 1578 in Project B. Note that this number is the total number of employees for each month. Thus, determining the right equipment and the right number of personnel is essential.
15. In both cases regular reports submitted by the division chiefs enable instant modifications on project management. The importance of documentation is underlined by this study. For instance when an erection company will continue with similar projects even though the staff will change with the help of the documentation the knowledge will be sustained.

For both cases several problems were encountered. Some of them resulted in time losses which can be counted in months. It will be very optimistic to expect a project to progress as it is planned to be. As long as problems are analyzed explicitly, are documented in detail and deductions are made, this will serve for future projects. When the growing demand of steel sector is considered this will serve the erection companies well.

Insight of these results, an assembly company by using the fore-mentioned values in a cold rolling mill complex can conduct a more efficient project. Employing the best practices discussed in this thesis will reduce the time invested in planning process.

REFERENCES

[1] DİSK Birleşik Metal İşçileri Sendikası. Demir Çelik Sektörü. İstanbul : Birleşik Metal – İş: Yazar. 2003.

[2] Sümer, G. Kreditörler Açısından Demir Çelik Sektör Değerlendirmesi. İşletme Araştırmaarı Dergisi, pp. 426-451. 2018.

[3] Türkiye Odalar ve Borsalar Birliği . Türkiye Demir ve Demir Dışı Metaller Meclisi Raporu. Ankara : TOBB. 2016.

[4] Kalkınma Bakanlığı. Demir - Çelik Çalışma Grubu Raporu. Ankara : Yazar. 2014.

[5] DMP Demir Profil Metal San. ve Tic. A.Ş. Haddeleme Tesisi Projesi. KOCAELİ : Barış Çevre ve Sistem Danışmanlığı İlaç İnşaat San. Tic. Ltd. Şti. 2014.

[6] YAŞAR, O. Türk İmalat Sanayinde Lokomotif Bir Sektör: Demir Çelik Sanayi. Marmara Coğrafya Dergisi, 20, pp. 42-78. 1303-2429. İstanbul : 2009,

[7] Project Management Institute. A Guide to the Project Management Body of Knowledge (PMBOK guide).(2000) USA / Pensilvania / Newton Square: 2000 Project Management Institute. 2001.

[8] DALYAN, İ. Türk İnşaat Sektöründe Proje Yönetimi ve Bilgisayar Destekli Planlama ile Verimlilik Analizi. Yayınlanmamış Yüksek Lisans Tezi, Yıldız Teknik Üniversitesi FBE İnşaat Mühendisliği Anabilim Dalı Yapı Programı Yüksek Lisans Tezi. 2010

[9] Ping , C., Qiang, M. and Ning Wan, J. Project Management in the Chinese Construction Industry: Six-Case Study. Journal of Construction Engineering and Management-asce - J CONSTR ENG MANAGE-ASCE, 135(10), pp. 1016-1026. 2009.

[10] Potts, K. Managing mega construction projects - learning from two case studies: London Underground’s Jubilee Line Extension and BAA’s Heathrow Terminal 5. Cape Town : 2007.

[11] Dood, J. & Langford, D. Construction management on one large project in London: A case study. Construction Management and Economics, 8 (4), pp. 385-398.: Routledge, 1990.

[12] Kumar A., & Ashok, K. Time / Cost Overrun in Construction of a Steel Plant in Asia: A Case Study. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 12 (5), p. 33. 2015.

[13] Nascimento, D., Sotelino, E., Pires Santoloni Lara, T., Caiado R., & Ivson, P. Constructability in Industrial Plant Construction: A BIM-Lean Approach Using the

Digital Obeya Room Framework. Journal of Civil Engineering and Management, 23 (8), pp. 1100-1108. 2017.

[14] Jacoby, H. S. Chemical Plant Construction. Industrial & Engineering Chemistry, 27 (9), pp. 999-1004. 1935.

[15] Edwards, D. J. & Holt, G. D. Construction plant and equipment management research: thematic review. Journal of Engineering Design and Technology, 7 (2), pp. 186-206. 2009.

[16] İSLAMOĞLU, A. Türkiye'de Faaliyet Gösteren İnşaat Proje Yönetimi Firmalarının Profillerinin Tespiti. Yayınlanmamış Yüksek Lisans Tezi, İstanbul Teknik Üniversitesi FBE İnşaat Mühendisliği Anabilim Dalı, Yapı İşletmesi Programı,. 2015.

[17] Kapakjian, S. & Schmid, S. R. Manufacturing Engineering and Techonology. (6th ed.). PEARSON. 2009.

[18] Rentz, O., Jochum R., & Schultmann, F. Report on Best Available Techniques (BAT) in the German Ferrous Metals Processing Industry FINAL DRAFT. On behalf of the German Federal Environmental Agency, Karlsruhe, 1999.

[19] SMS group GmbH Processing Lines and Furnace Technology. Strip Processing Lines. January, 2019 from https://www.sms-group.com/sms-group/downloads/. 2017

[20] Hassel, A. W. Bruder, K., Denoose, V., Hennion, A., Vanden Eynde, X., Fiorucci, M., et all. New approaches in electrolytic cleaning of cold rolled steel sheet. European Union. 2011.

[21] RAD-CON. What is Bell Annealing. January 2, 2019 from http://www.rad-con.com/strip_processors/HAS.html. 2005.

[22] Mishra, N. Presentation on Electrical and automation system of Cold Roll Mill Plant of JSW. January 2, 2019 from https://www.slideshare.net/neerajmishra56/presentation-on-electrical-and-automation-system-of-cgl-plant-crm2-jsw-kr?qid=21684b2e-7da1-4eee-ba75-6b57f393f407&v=&b=&from_search=1. 2015

[23] Parate, S. P. Study of Various Processes in CCL Plant at JSW Steel Coated Products Ltd. Unpublished master’s thesis, Mumbai University Dr. V.N. Bedekar Institute of Management Studies, Thane. 2015-2017.

[24] Karadeniz, Ö. C. PERT-CPM ile Proje Planlama, Değerlendirme ve Bir İşletme Uygulaması. Yayınlanmamış Yüksek Lisans tezi, Marmara Üniversitesi Sosyal Bilimler Enstitüsü Ekonometri Anabilim Dalı, Yöneylem Araştırması Bilim Dalı, İstanbul. 2007.

[25] Harvard Business School Publishing Corporation. Harvard Business Review on Managing Projects. Harvard Business School Press. 2005.

[26] Coşkun, O. Proje Yönetim Teknikleri ve Uygulamalı İncelenmesi. Yayınlanmamış Yüksek Lisans tezi, İstanbul Ticaret Üniversitesi, Fen Bilimleri Enstitüsü, Endüstri Mühendisliği. İstanbul, 2012.

[27] Kerzner, H. Project Management: A System Approach to Planning, Scheduling and Controlling. (9th ed.). John Wiley & Sons,Inc.. 2006.

[28] Greene J., &Stellman A.. Head First PMP. (3rd ed.) (M.,F., Türkmen, Trans.). İstanbul: Yakın Plan Yayınları. 2014. (Original work published 2014.)

[29] Albayrak, B.. Proje Yönetimi ve Analizi. (1st ed.). Ankara: Nobel Yayın Dağıtım Tic. Ltd. Şti.. 2009.

[30] Ekmekçi, İ. & Coşkun, O. Bir İnşaat Projesinin Evreleri ile Zaman ve Maliyet Analizinin Proje Yönetim Teknikleri Vasıtasıyla İncelenmesi. İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi, pp. s.39-53. 2012.

[31] Lester, A. Project Management, Planning and Control Managing Engineering, Construciton and Manufacturing Projects to PMI, APM and BSI Standards. (6th ed.). Cambridge, United States: Elsiver Ltd. 2014.

[32] Dikbaş, A. Scheduling Guide for Project Managers. ITU Project Management Center. p.20. May 2001.

[33] Wilson, J. Handbook of textile design. Cambridge, England: Woodhead Publising Limited in association with The Textile Instute. 2001.

[34] Burkeholder, V. R. Cost Reduction Program Through the Use of The Gant Chart. Int. J. Hospitaility Management, pp. 153-155. 1983.

[35] Martino, R. L. Proje İdaresi ve kontrolü: Kritik Yolun Bulunması. (1) (C.C. Yalgın, Çev.). Ankara: Bayındırlı Bakanlığı, 1967.

[36] Tenova. Electrolytic Cleaning Line. January 2, 2019 from https://www.tenova.com/product/electrolytic-cleaning-line/. 2019

[37] Gavas, M., Yaşar, M., Aydın M., & Y. Altunpak. Üretim Yöntemleri ve İmalat Teknolojileri. (3 ed.). Ankara: Seçkin Yayıncılık. 2013.

[38] Industries, Dassnagar Precision. Dassnagar. January 2, 2019 from https://www.dassnagar.com/dpe_products.html.

[39] Schey, J. A. Introductiın to Manufacturing Process. (2nd Ed). McGraw-Hill. 1987.

[40] T. Kuami and T. Kikkawa, *New PL-TCM (Pickling and Tandem Cold Strip Mill) in Vietnam.* January 2, 2019 from https://steelplantech.com/wp-content/uploads/2014/07/New-PL-TCM-in-Vietnam-T.Kikkawa-AISTech-2014-The-Iron-Steel-Technology-Conferance-and-Exposition-Pickling-Lines.pdf. 2014

[41] Varol, G. E. Defects Of Hot Rolled And Cold Rolled Flat Steels Due To Hot Dip Galvanizing Process And Their Prevention Methods. Unpublished master's thesis, Istanbul Technical University Graduate School Of Science Engineering And Technology. 2018.

[42] Uğur, L. O. and Baykan, U. N. Türk İnşaat Firmalarının Proje Planlama Uygulamaları Konusunda Bir Alan Çalışması. New World Sciences Academy. pp. 418-423. 2008.

[43] B. Kaplan, Genetik Algoritma ve Monte Carlo Simülasyonu ile Bir İnşaat Projesinde Alt Yüklenizi Seçimine İlişkin Süre Maliyet Kalite Optimizasyonu ve Risk Değerlendirilmesi, İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü İnşaat Mühendisliği Anabilim Dalı Yapı İşletmesi Programı Yüksek Lisans Tezi, 2014.

Appendix A Cold Rolling Mill Complex Project Organization Chart

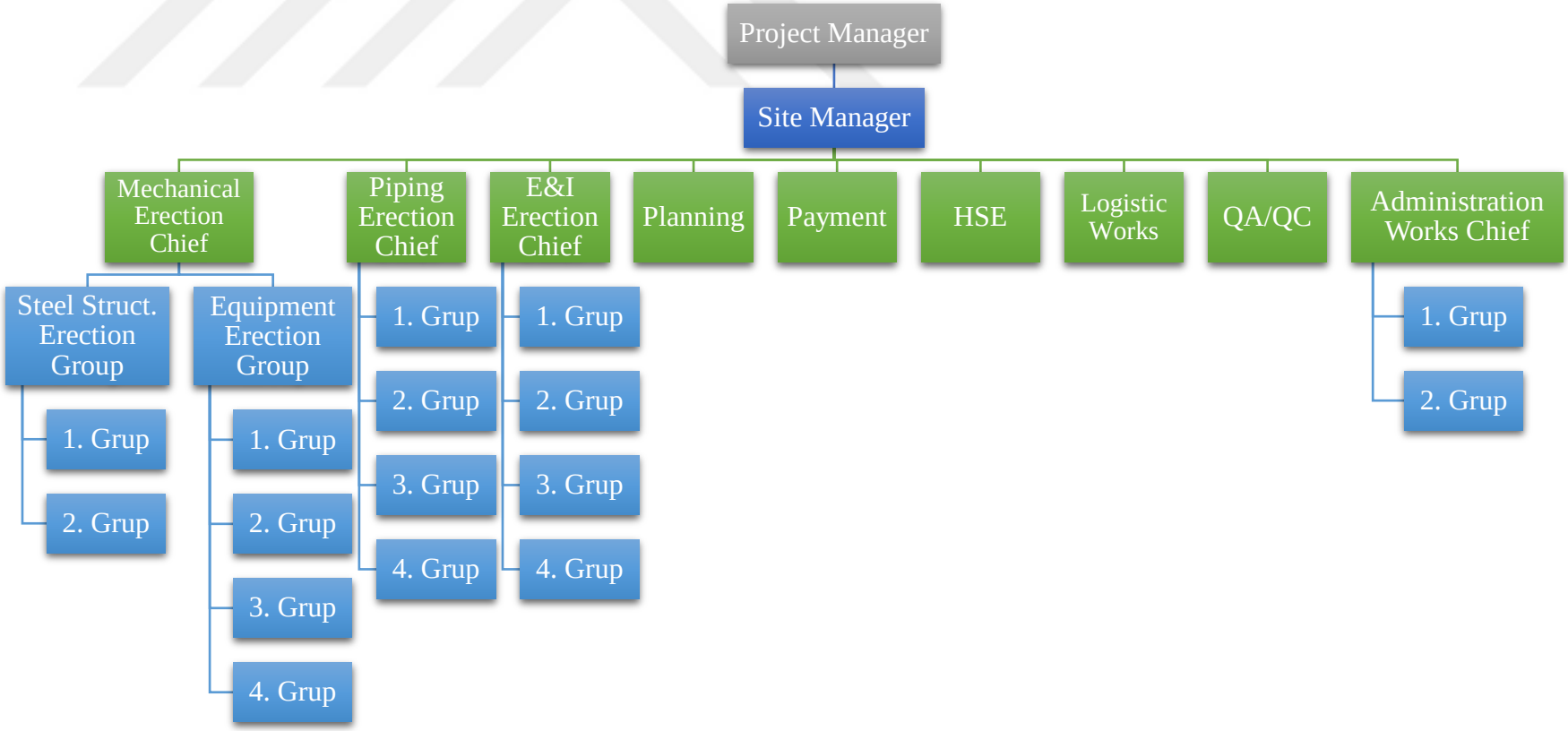


Figure A.1 Organization chart of installation company

Appendix B Data of Mounted Lines

Table B.1 Data of mounted lines

Line	Production Capacity	Project	Equipment Erection		Piping Erection				Cabling Erection	
CCL	150.000 ton / year	A	1,125	ton	2,519	m	7,454	inch-m	89,613	m
		B	1,552	ton	5,837	m	14,444	inch-m	92,649	m
ECL	250.000 ton / year	A	574	ton	6,239	m	13,173	inch-m	38,693	m
		B	296	ton	2,612	m	5,269	inch-m	12,249	m
DCR / TM	450.000 ton / year	A	1,182	ton	7,936	m	19,537	inch-m	110,544	m
		B	453	ton	4,433	m	5,438	inch-m	25,183	m
HDGL	350.000 ton / year	A	3,453	ton	15,018	m	31,636	inch-m	156,829	m
		B	3,150	ton	15,935	m	25,299	inch-m	145,708	m
PL&TCM	1.000.000 ton / year	A	5,276	ton	19,367	m	61,659	inch-m	394,077	m
		B	5,595	ton	26,631	m	67,053	inch-m	222,321	m
BAF	250.000 ton / year	A	439	ton	2,952	m	6,449	inch-m	23,473	m
		B	289	ton	4,440	m	8,050	inch-m	20,419	m
ARP		A	811	ton	2,388	m	7,431	inch-m	inch-m	m
		B	757	ton	4,896	m	7,552	inch-m	12,233	m
UTILITY		A	-	ton	36,828	m	191,774	inch-m	114,764	m
		B	169	ton	27,179	m	110,804	inch-m	187,935	m
TOTAL		A	12,860	ton	93,247	m	339,113	inch-m	938,097	m
		B	12,261	ton	91,963	m	243,909	inch-m	718,696	m

Appendix C GANT Chart of Project A

Project A Schedule

No	Task		Completion (%)	Duration (Date)	Start	End	Duration Differ / Estimating End Date Differ
	Project A Schedule						
1	**PL&TCM**						
	Erection Works	Plan		158	29.2	5.8	39
		Actual	19%	197	7.3	20.9	46
2	**ECL**						
	Erection Works	Plan		91	1.7	30.9	0
		Actual		91	1.7	30.9	0
3	**BAF**						
	Erection Works	Plan		60	1.9	31.10	0
		Actual		60	1.9	31.10	0
4	**TM**						
	Erection Works	Plan		121	1.4	31.7	1
		Actual	1%	122	1.5	31.8	31
5	**HDGL**						
	Erection Works	Plan		152	1.6	31.10	-4
		Actual		148	30.6	25.11	25
6	**CCL**						
	Erection Works	Plan		62	14.6	15.8	58
		Actual	0%	120	2.5	30.8	15

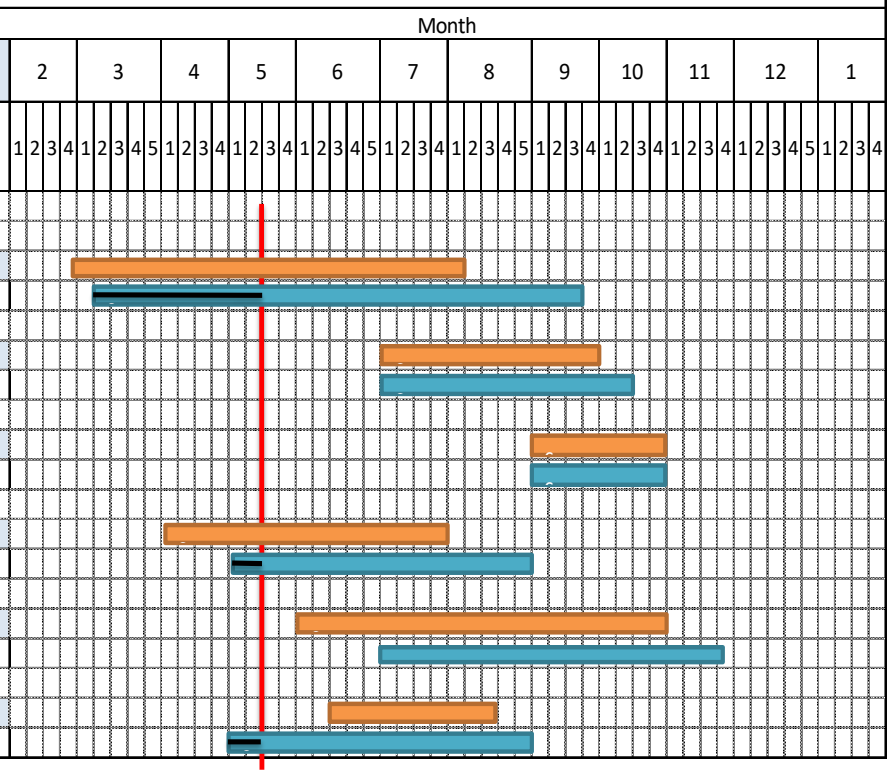


Figure C.1 Gant chart of Project A

Appendix D GANT Chart of Project B

PROJECT B PLAN SCHEDULE															
TASK		MONTH	1	2	3	4	5	6	7	8	9	10	11	12	13	14
MECHANICAL WORKS																
ESTIMATING PROGRESSING																
PL&TCM	100%					2%	10%	20%	24%	20%	12%	7%	5%			
ARP	100%							5%	20%	30%	30%	15%				
HDGL	100%			2%	15%	25%	25%	20%	10%	3%						
TM	100%			5%	40%	30%	25%									
BAF	100%			23%	40%	32%	5%									
CCL	100%		10%	25%	35%	25%	5%									
ECL	100%			15%	35%	30%	20%									
Utility	100%		5%	90%	5%											
PIPING WORKS																
ESTIMATING PROGRESSING																
PL&TCM	100%					1%	4%	15%	20%	25%	20%	10%	5%			
ARP	100%							5%	15%	20%	25%	25%	10%			
HDGL	100%				2%	5%	15%	25%	35%	10%	8%					
TM	100%				10%	25%	35%	30%								
BAF	100%			20%	35%	40%	5%									
CCL	100%		2%	35%	40%	16%	7%									
ECL	100%				20%	30%	30%	20%								
Utility	100%			1%	5%	10%	22%	25%	20%	15%	2%					
ELECTRICAL WORKS																
ESTIMATING PROGRESSING																
PL&TCM	100%							5%	15%	15%	15%	25%	22%	3%		
ARP	100%								15%	30%	30%	20%	5%			
HDGL	100%				2%	20%	20%	20%	30%	8%						
TM	100%				10%	30%	35%	21%	4%							
BAF	100%			2%	33%	30%	25%	10%								
CCL	100%		2%	10%	35%	30%	18%	5%								
ECL	100%				15%	30%	30%	20%	5%							
Utility	100%			1%	13%	15%	15%	20%	20%	10%	6%					

Figure D.1 Gant chart of Project B

Appendix E - Comparisons of Mounted Lines

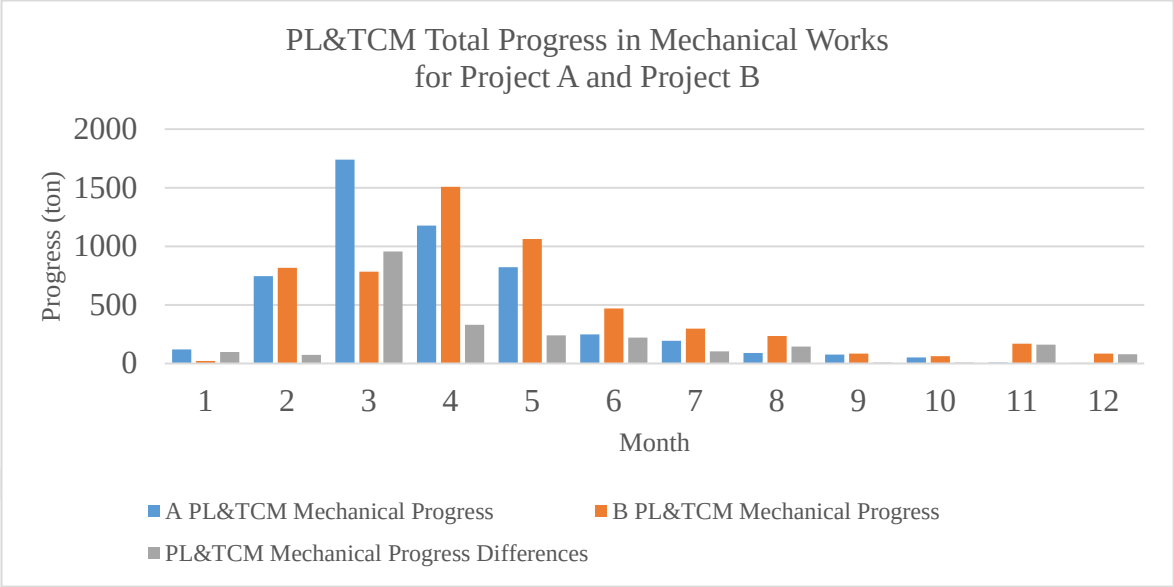


Figure E.1 PL&TCM Total progress in mechanical works of Project A and Project B

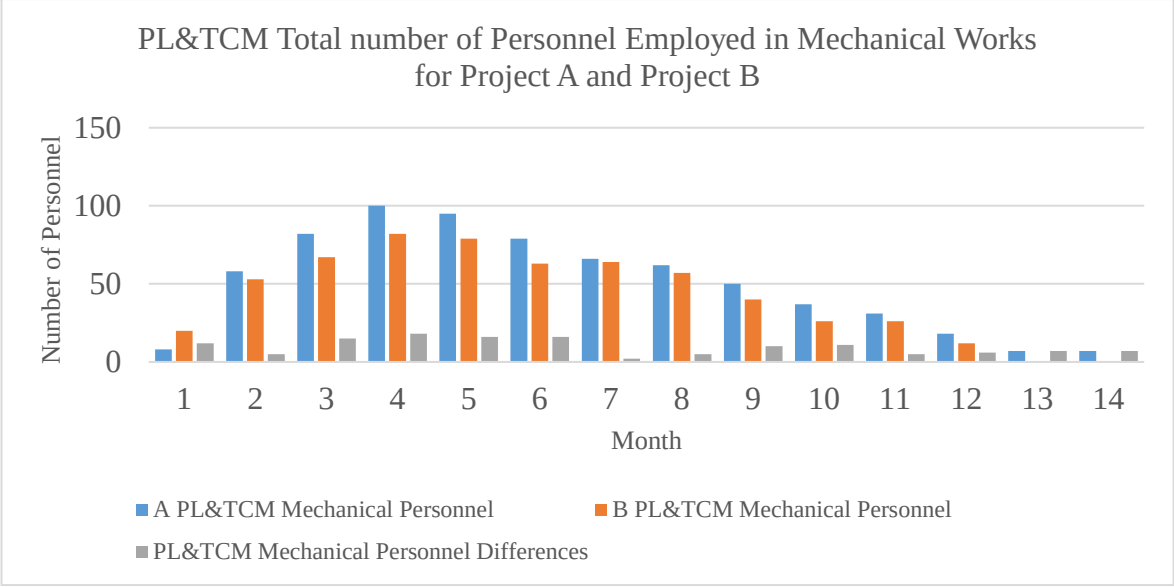


Figure E.2 PL&TCM Total number of personnel employed in mechanical works for Project A and Project B

Table E.1 Data of the personnel who work in PL&TCM mechanical works per month

Number of Personnel Employed in Mechanical Works per a month		
Project	**Max.**	**Min**
A	100	7
B	82	12

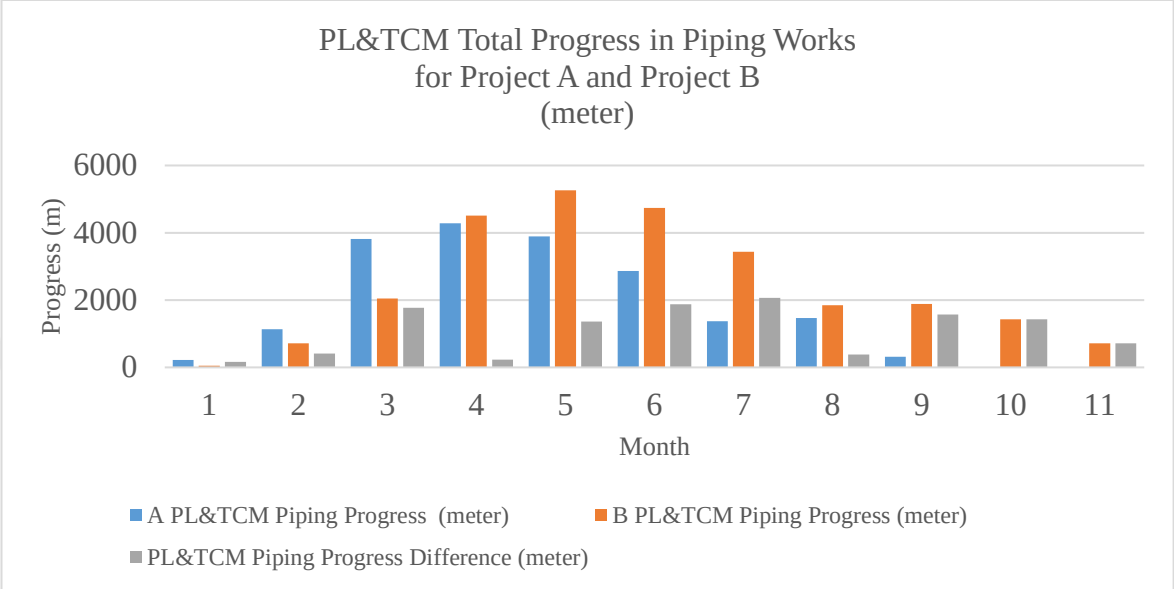


Figure E.3 PL&TCM Total progress in piping works of Project A and Project B

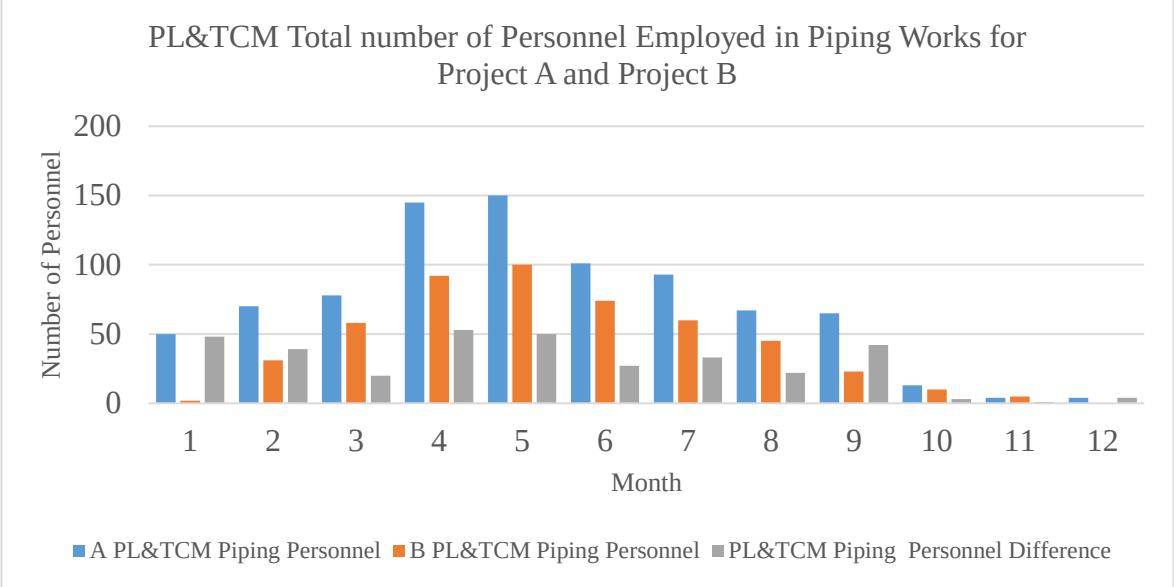


Figure E.4 PL&TCM Total number of personnel employed in piping works for Project A and Project B

Table E.2 Data of the personnel who work in PL&TCM piping works per month

Number of Personnel Employed in Piping Works per a month		
Project	**Max.**	**Min**
A	150	4
B	100	2

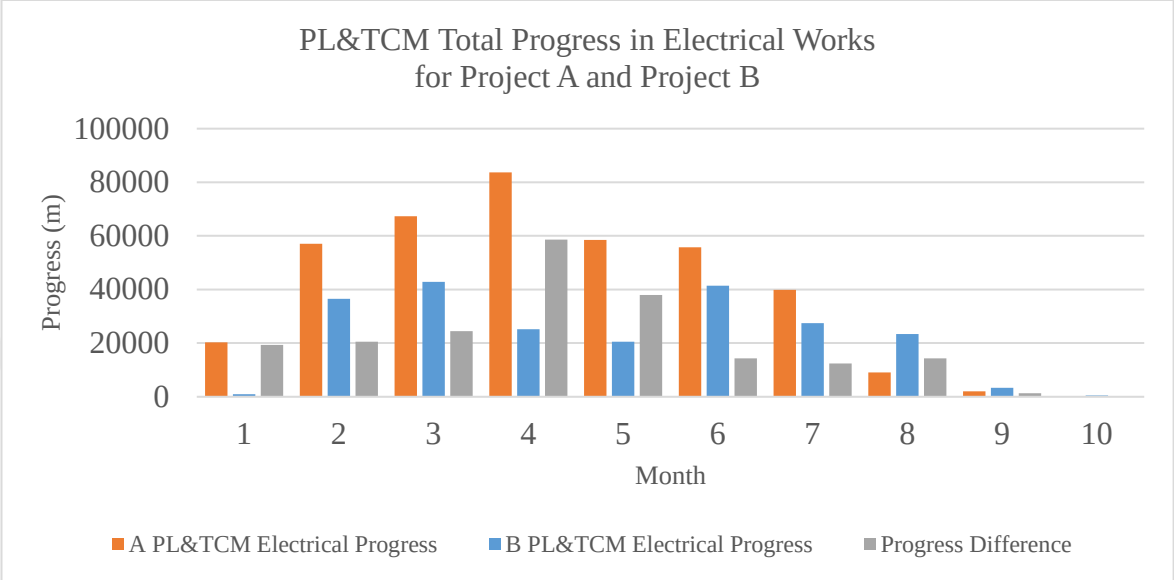


Figure E.5 PL&TCM Total progress in electrical works of Project A and Project B

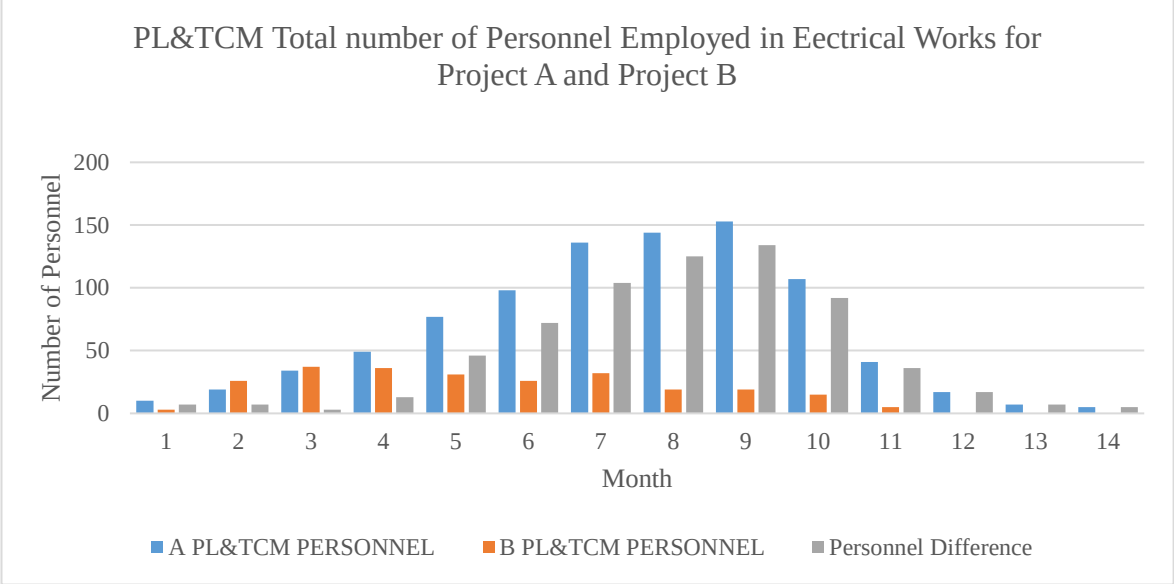


Figure E.6 PL&TCM Total number of personnel employed in electrical works for Project A and Project B

Table E.3 Data of the personnel who work in PL&TCM electrical works per month

Number of Personnel Employed in Electrical Works per a month		
Project	**Max.**	**Min**
A	153	5
B	37	3

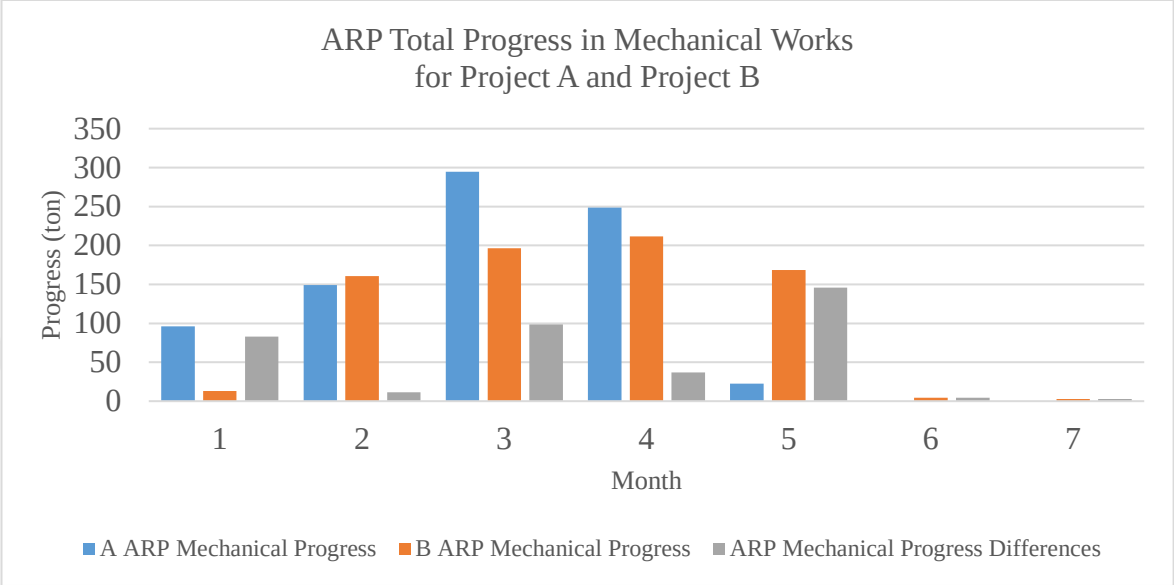


Figure E.7 ARP Total progress in mechanical works of Project A and Project B

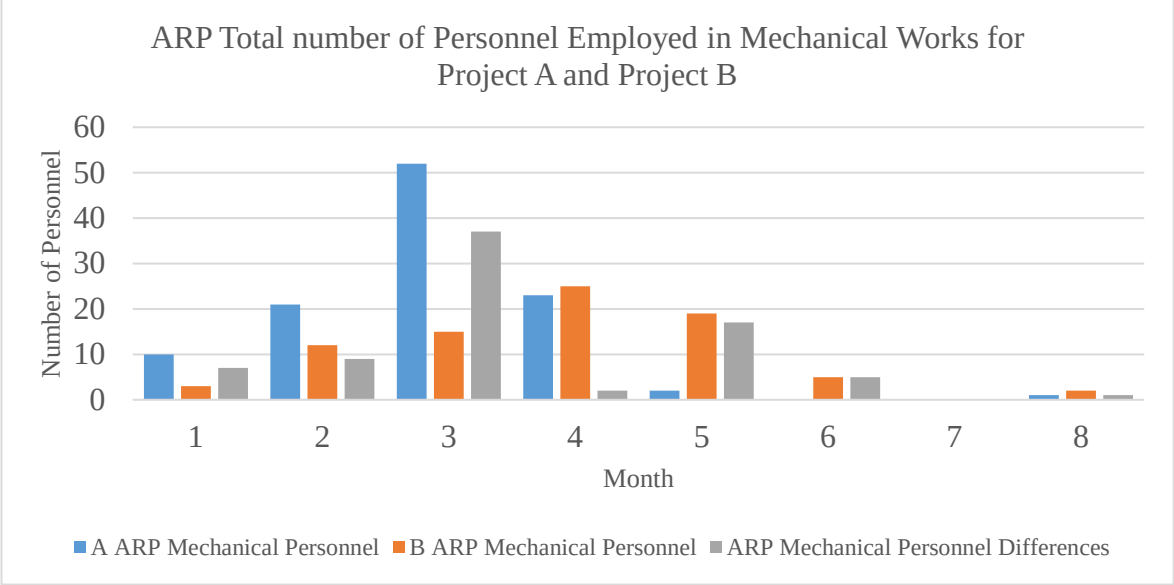


Figure E.8 ARP Total number of personnel employed in mechanical works for Project A and Project B

Table E.4 Data of the personnel who work in ARP mechanical works per month

Number of Personnel Employed in Mechanical Works per a month		
Project	**Max.**	**Min**
A	52	1
B	25	2

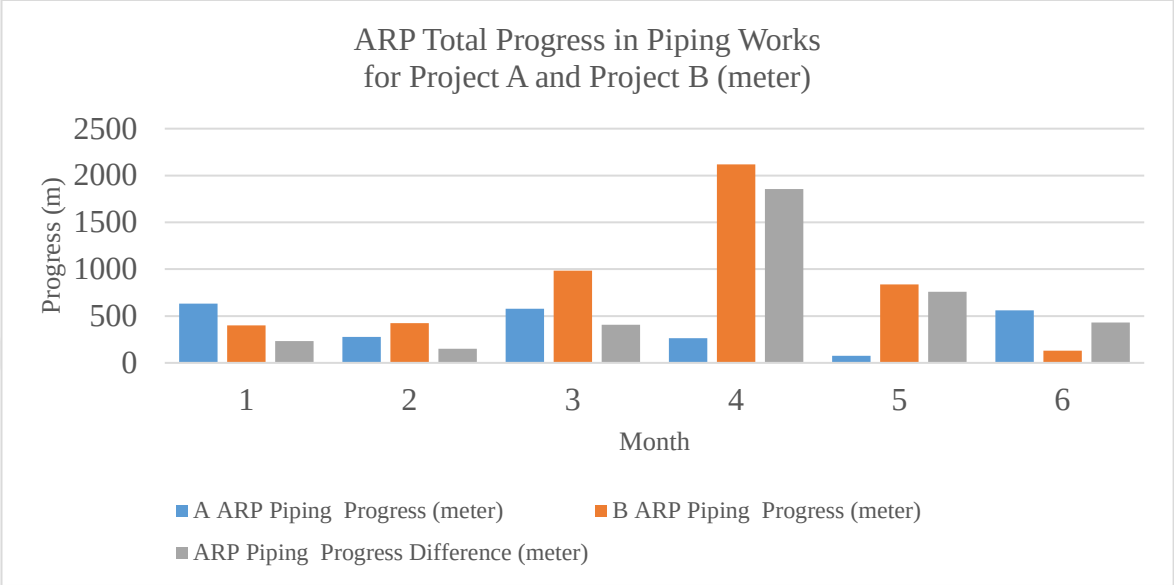


Figure E.9 ARP Total progress in piping works of Project A and Project B

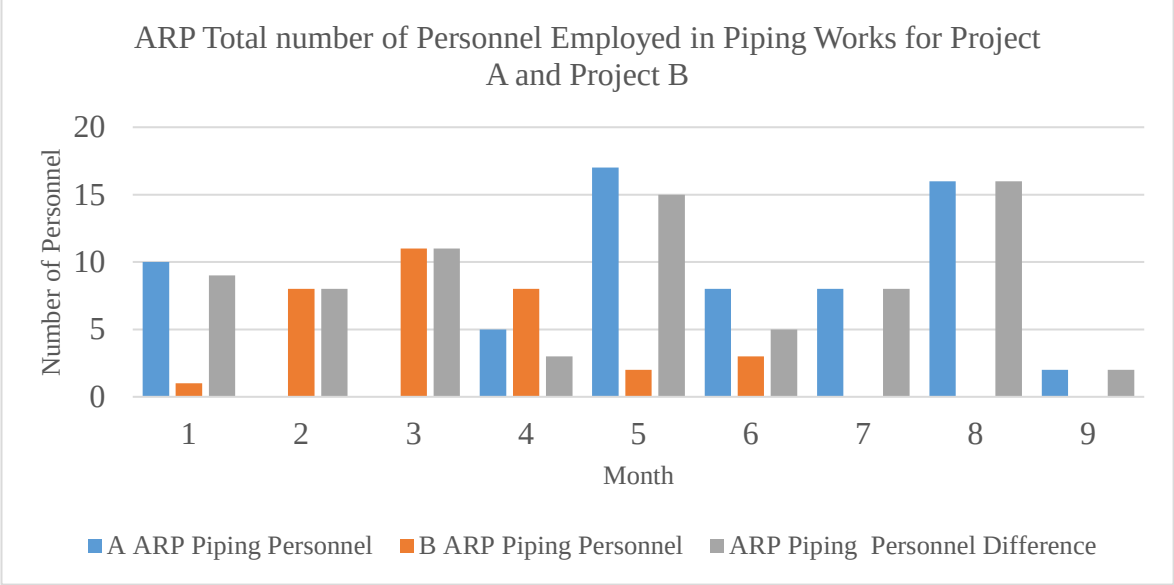


Figure E.10 ARP Total number of personnel employed in piping works for Project A and Project B

Table E.5 Data of the personnel who work in ARP piping works per month

Number of Personnel Employed in Piping Works per a month		
Project	**Max.**	**Min**
A	17	2
B	11	1

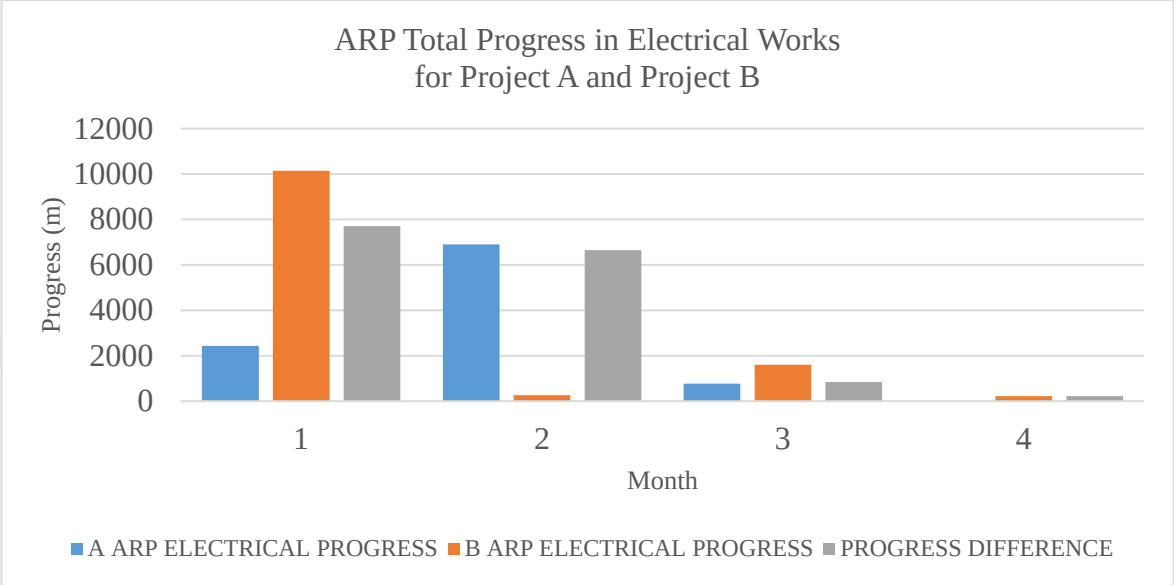


Figure E.11 ARP Total progress in electrical works of Project A and Project B

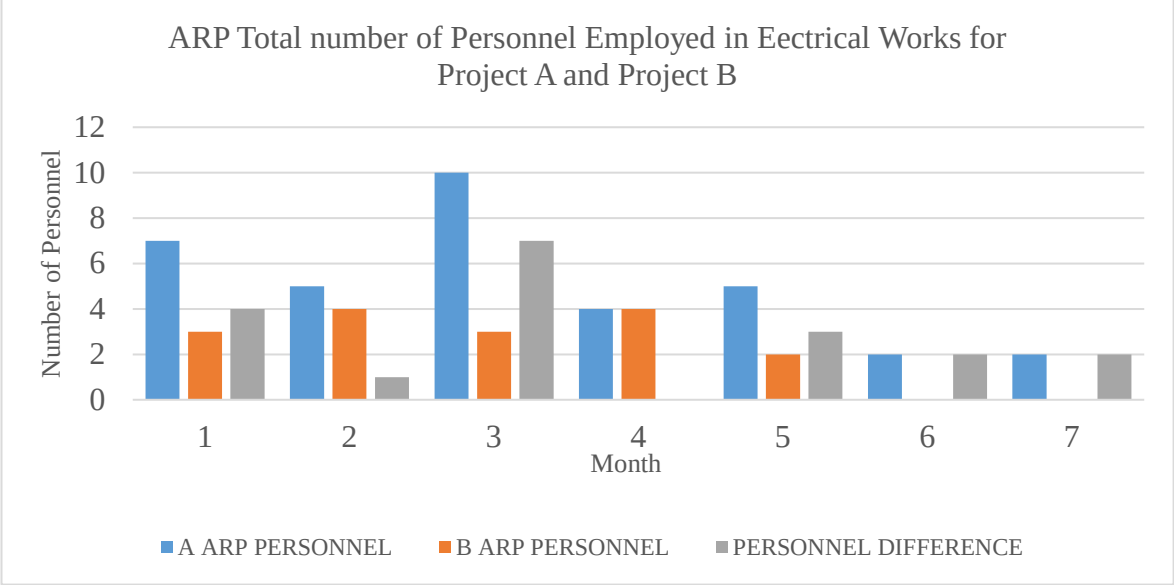


Figure E.12 ARP Total number of personnel employed in electrical works for Project A and Project B

Table E.6 Data of the personnel who work in ARP electrical works per month

Number of Personnel Employed in Electrical Works per a month		
Project	**Max.**	**Min**
A	10	2
B	4	2

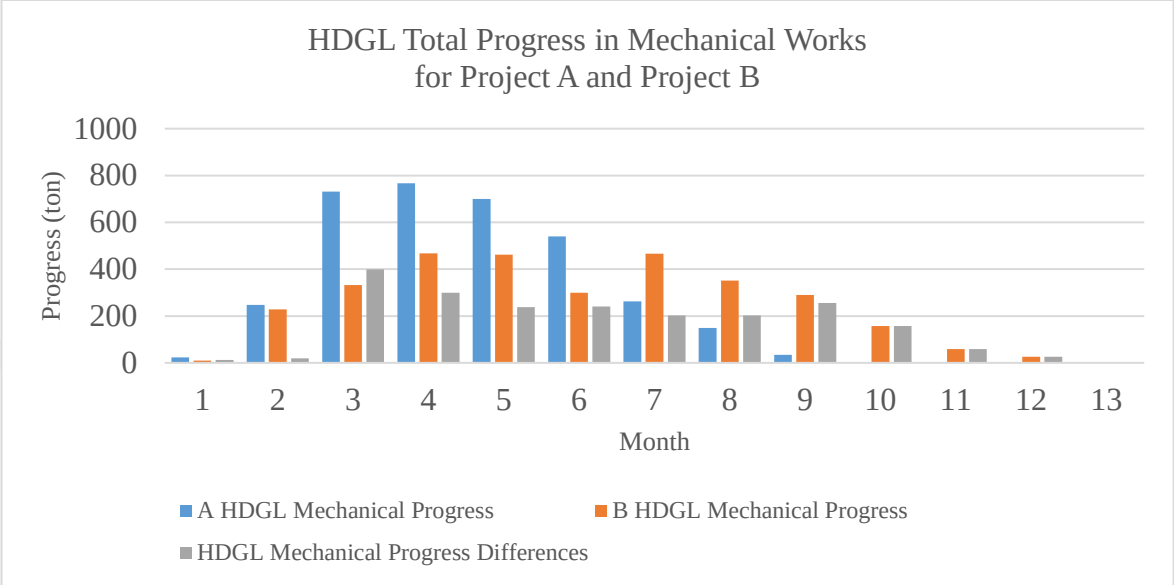


Figure E.13 HDGL Total progress in mechanical works of Project A and Project B

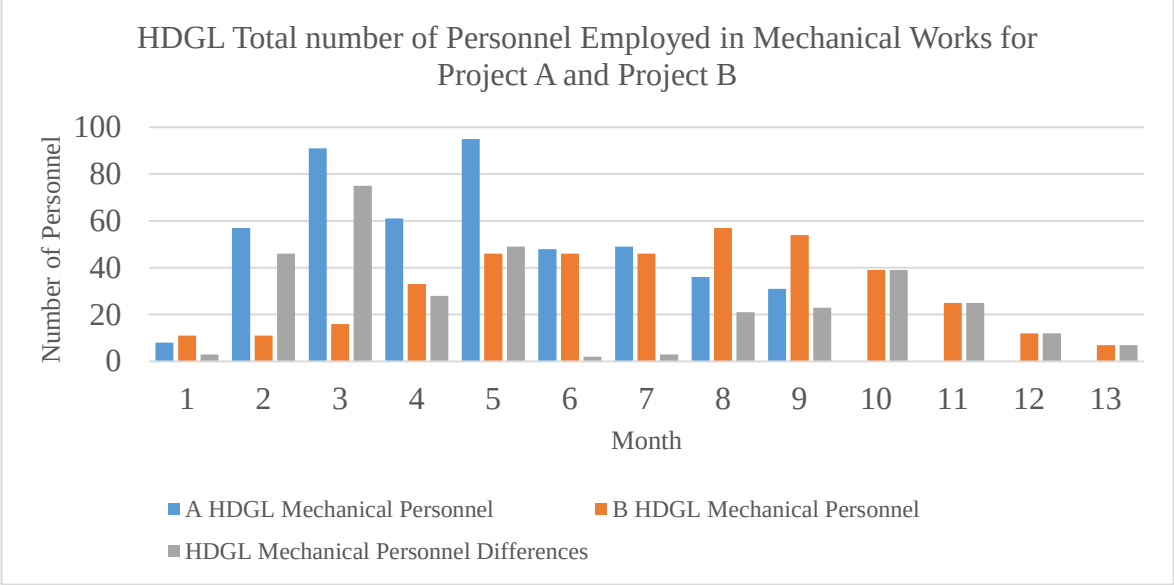


Figure E.14 HDGL Total number of personnel employed in mechanical works for Project A and Project B

Table E.7 Data of the personnel who work in HGDL mechanical works per month

Number of Personnel Employed in Mechanical Works per a month		
Project	**Max.**	**Min**
A	95	8
B	57	7

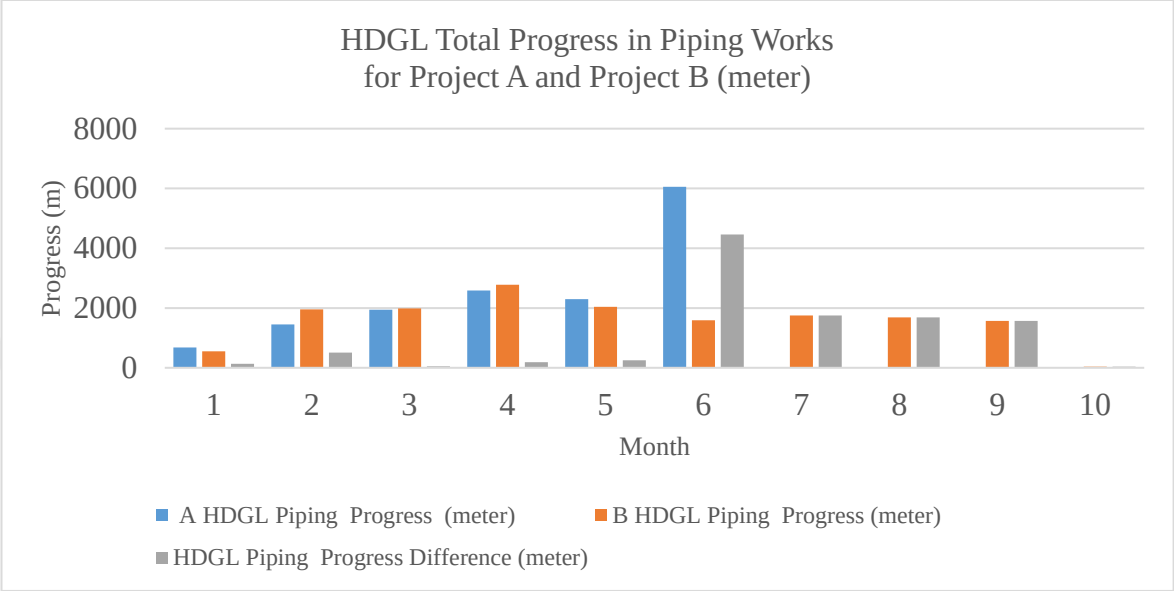


Figure E.15 HDGL Total progress in piping works of Project A and Project B

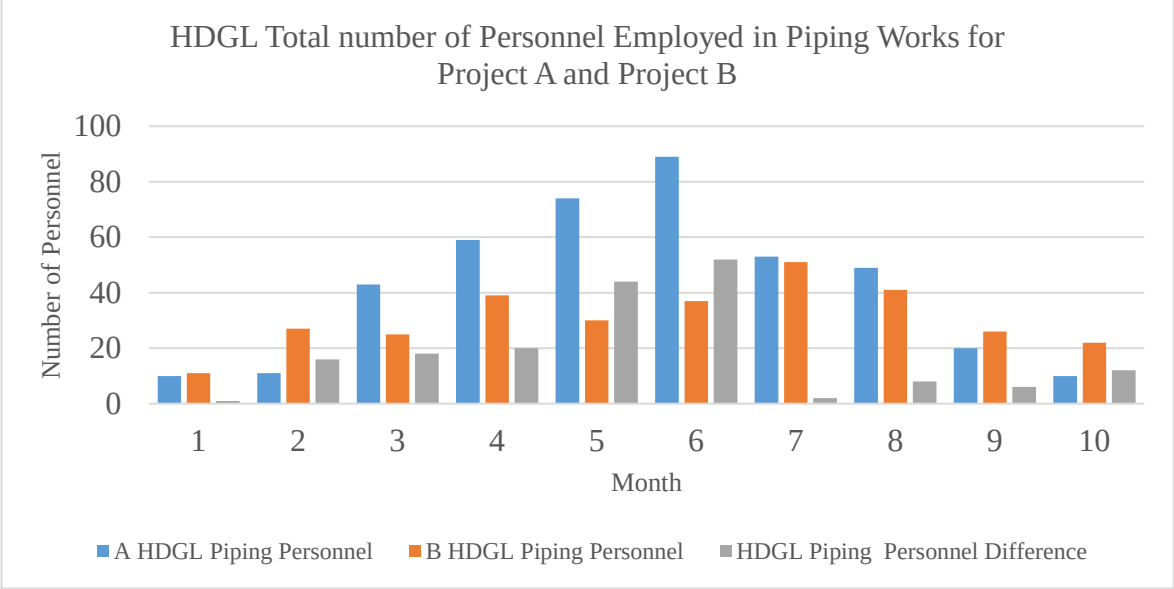


Figure E.16 HDGL Total number of personnel employed in piping works for Project A and Project B

Table E.8 Data of the personnel who work in HGDL piping works per month

Number of Personnel Employed in Piping Works per a month		
Project	**Max.**	**Min**
A	89	10
B	51	11

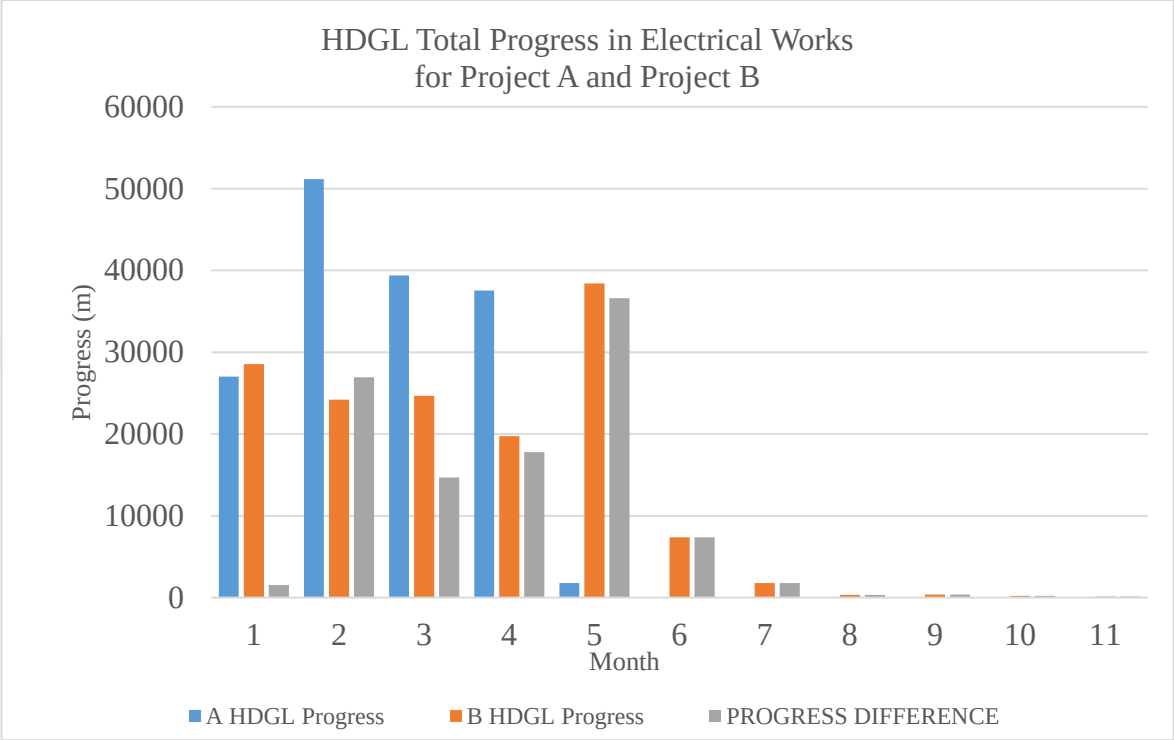


Figure E.17 HDGL Total progress in electrical works of Project A and Project B

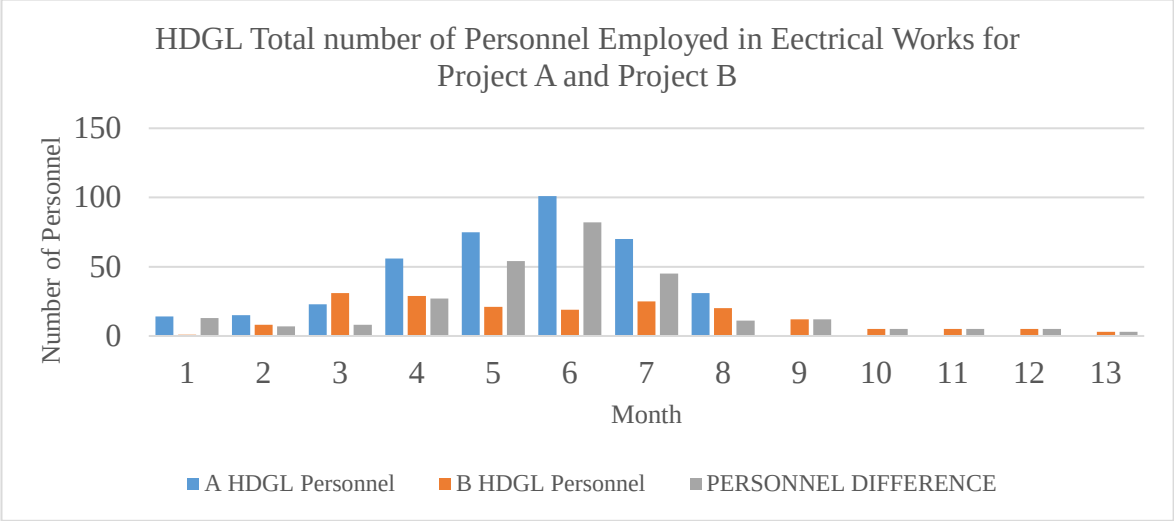


Figure E.18 HDGL Total number of personnel employed in electrical works for Project A and Project B

Table E.9 Data of the personnel who work in HGDL electrical works per month

Number of Personnel Employed in Electrical Works per a month		
Project	**Max.**	**Min**
A	101	14
B	31	1

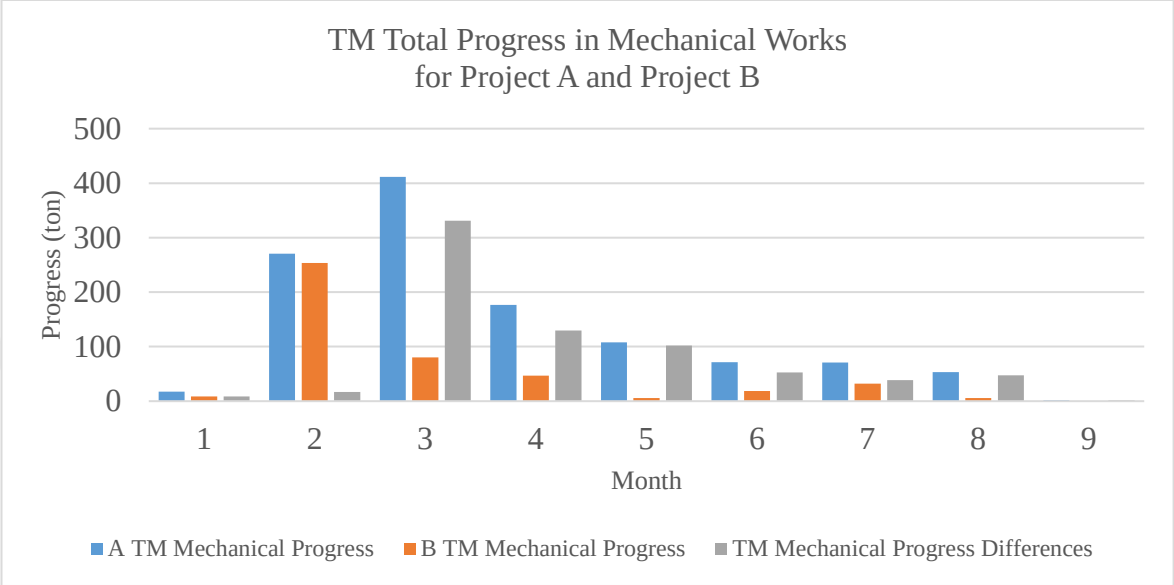


Figure E.19 TM Total progress in mechanical works of Project A and Project B

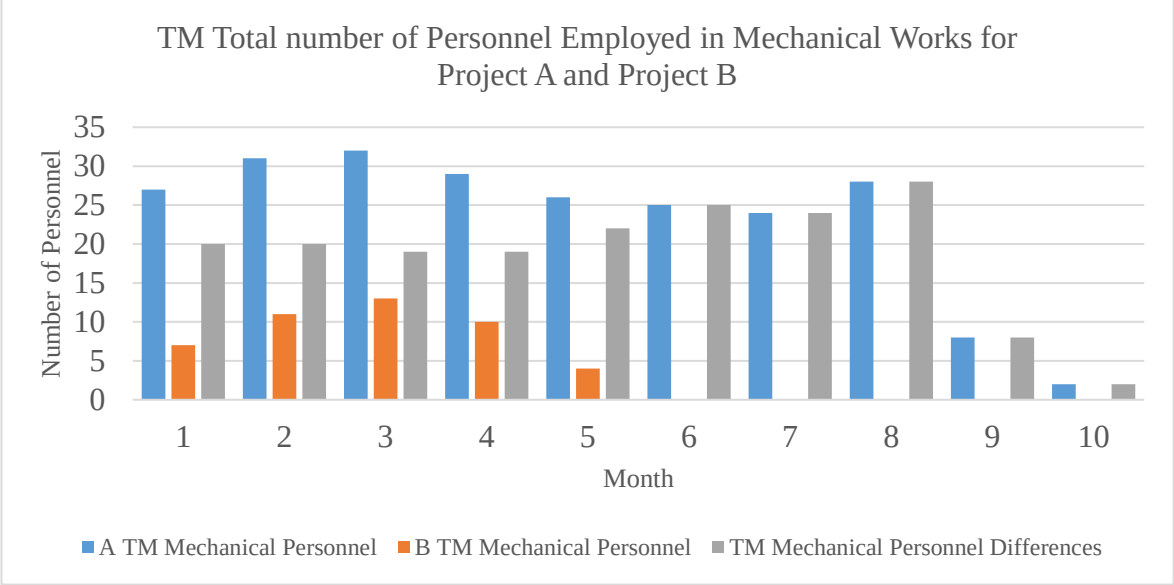


Figure E.20 TM Total number of personnel employed in mechanical works for Project A and Project B

Table E.10 Data of the personnel who work in TM mechanical works per month

Number of Personnel Employed in Mechanical Works per a month		
Project	**Max.**	**Min**
A	32	2
B	13	4

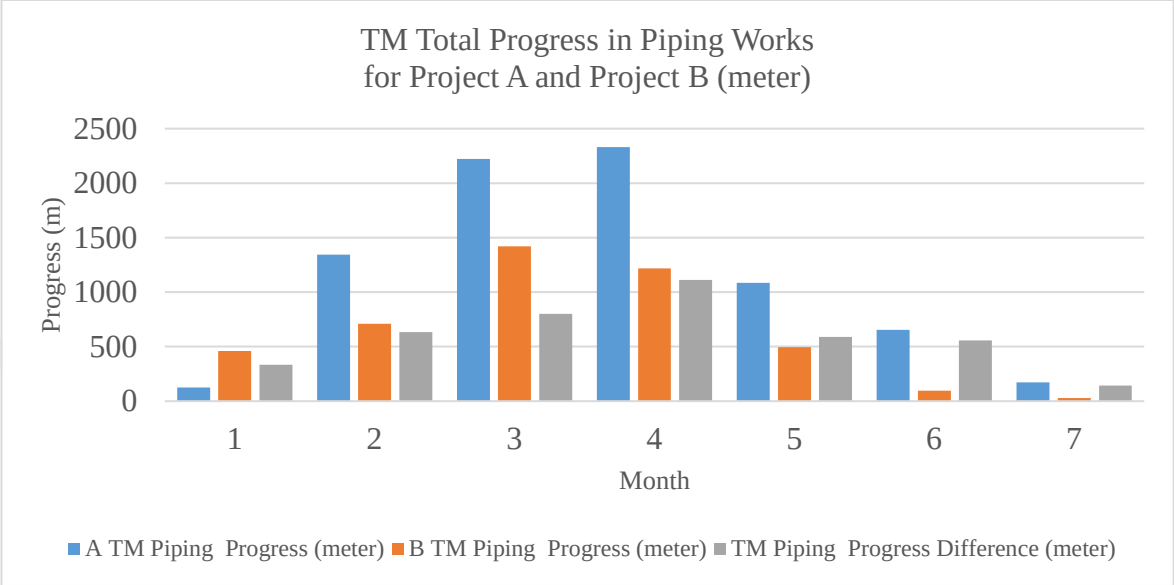


Figure E.21 TM Total progress in piping works of Project A and Project B

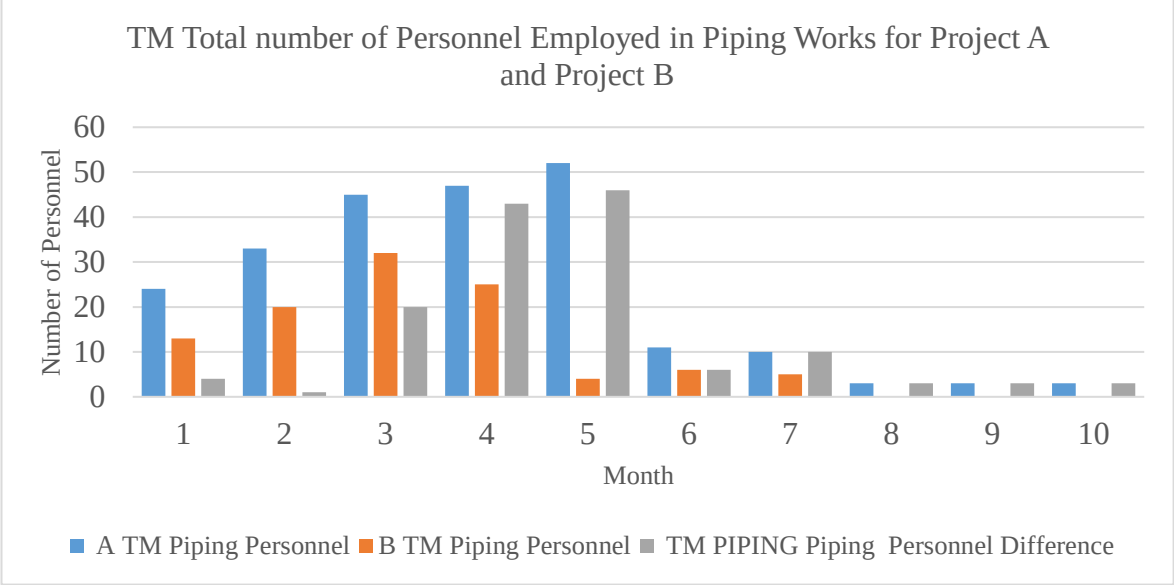


Figure E.22 Total number of personnel employed in piping works for Project A and Project B

Table E.11 Data of the personnel who work in TM piping works per month

Number of Personnel Employed in Piping Works per a month		
Project	**Max.**	**Min**
A	52	3
B	32	4

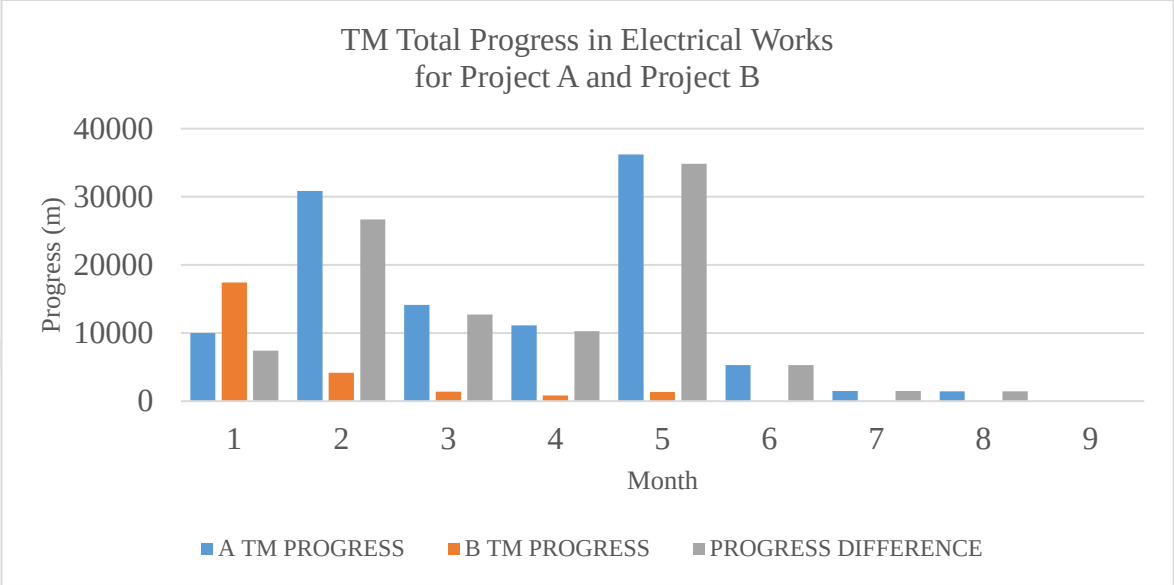


Figure E.23 TM Total progress in electrical works of Project A and Project B

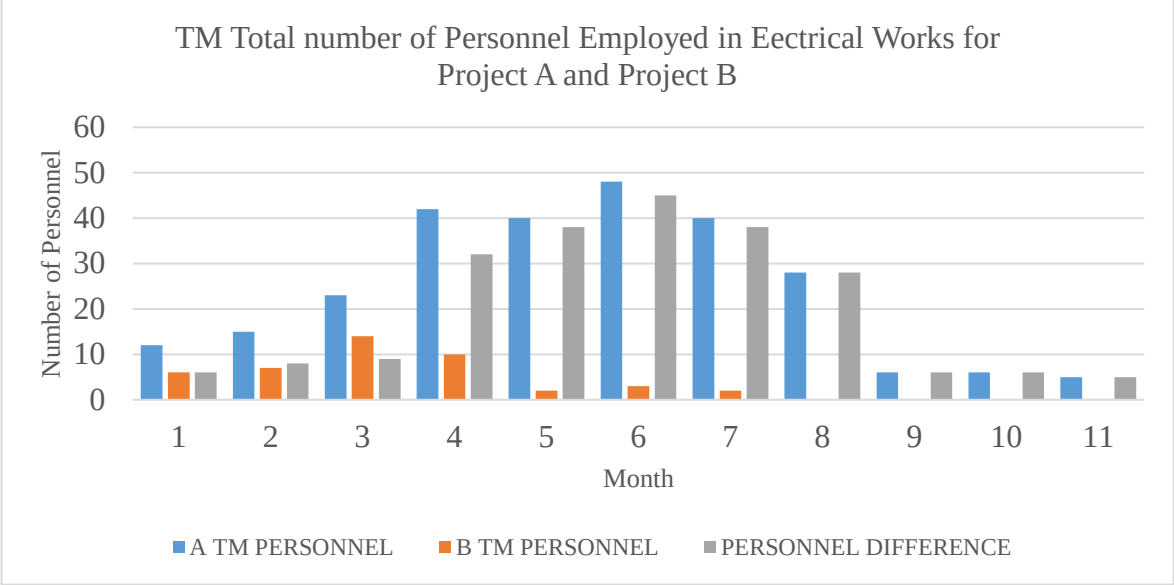


Figure E.24 TM Total number of personnel employed in electrical works for Project A and Project B

Table E.12 Data of the personnel who work in TM electrical works per month

Number of Personnel Employed in Electrical Works per a month		
Project	**Max.**	**Min**
A	48	5
B	14	1

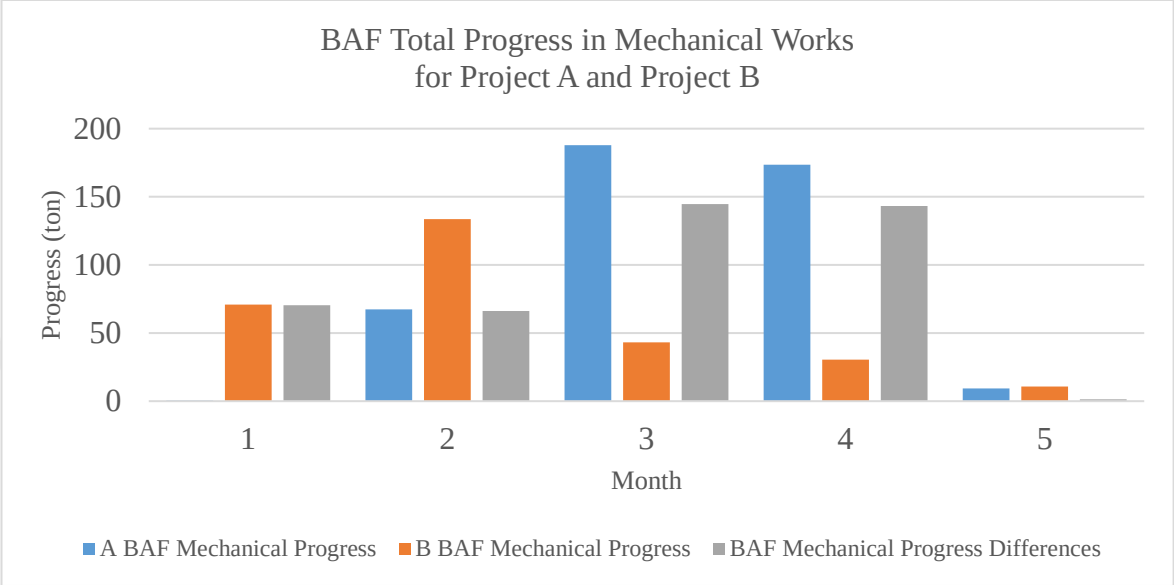


Figure E.25 BAF Total progress in mechanical works of Project A and Project B

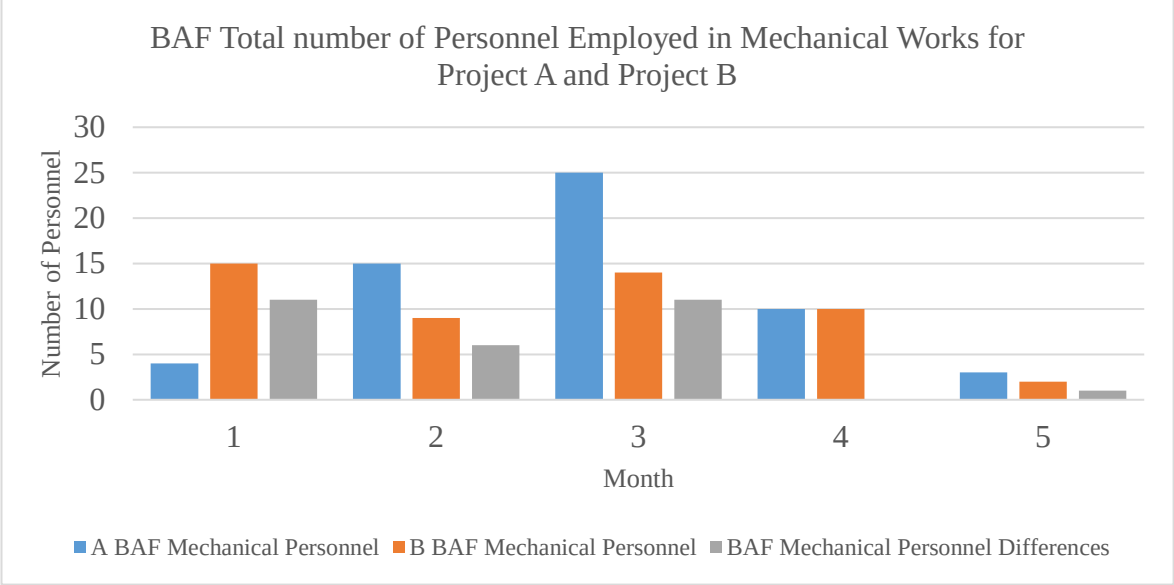


Figure E.26 BAF Total number of personnel employed in mechanical works for Project A and Project B

Table E.13 Data of the personnel who work in BAF mechanical works per month

Number of Personnel Employed in Mechanical Works per a month		
Project	**Max.**	**Min**
A	25	3
B	15	2

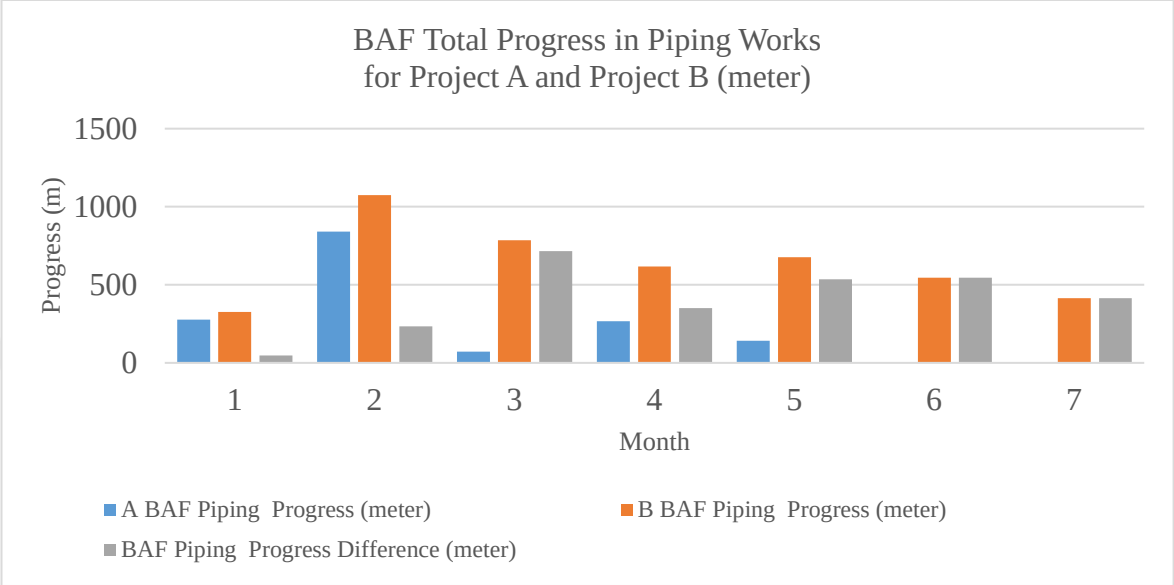


Figure E.27 BAF Total progress in piping works of Project A and Project B

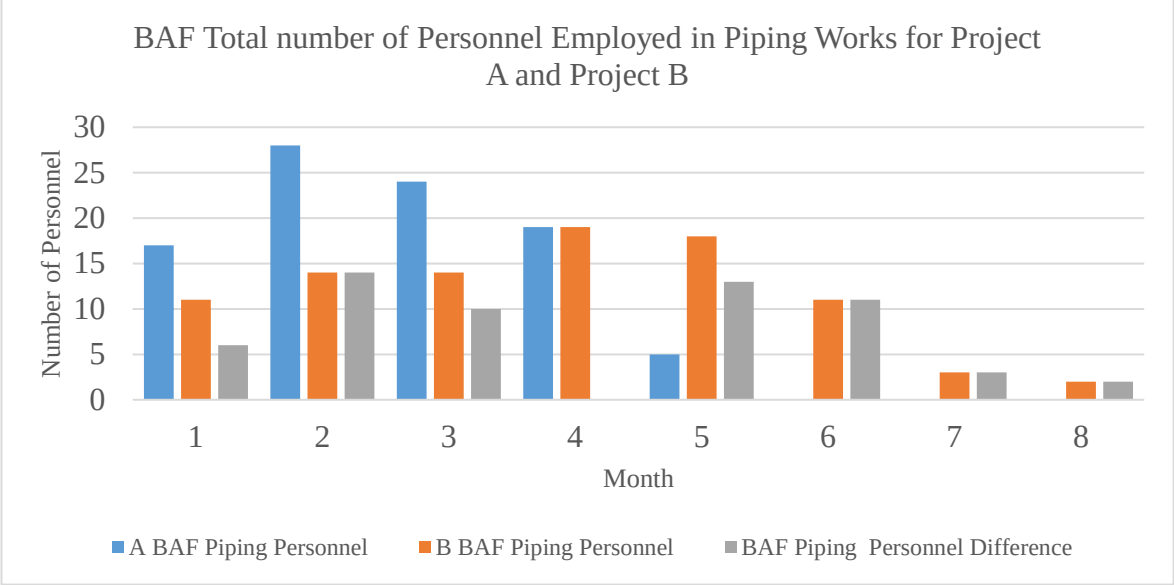


Figure E.28 BAF Total number of personnel employed in piping works for Project A and Project B

Table E.14 Data of the personnel who work in BAF piping works per month

Number of Personnel Employed in Piping Works per a month		
Project	**Max.**	**Min**
A	28	5
B	19	2

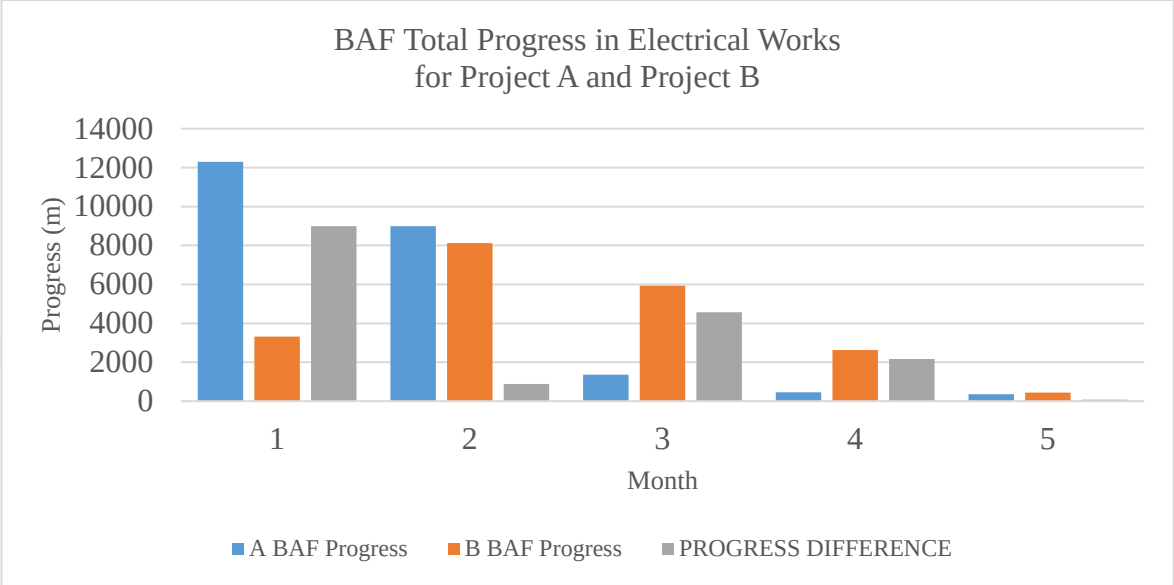


Figure E.29 BAF Total progress in electrical works of Project A and Project B

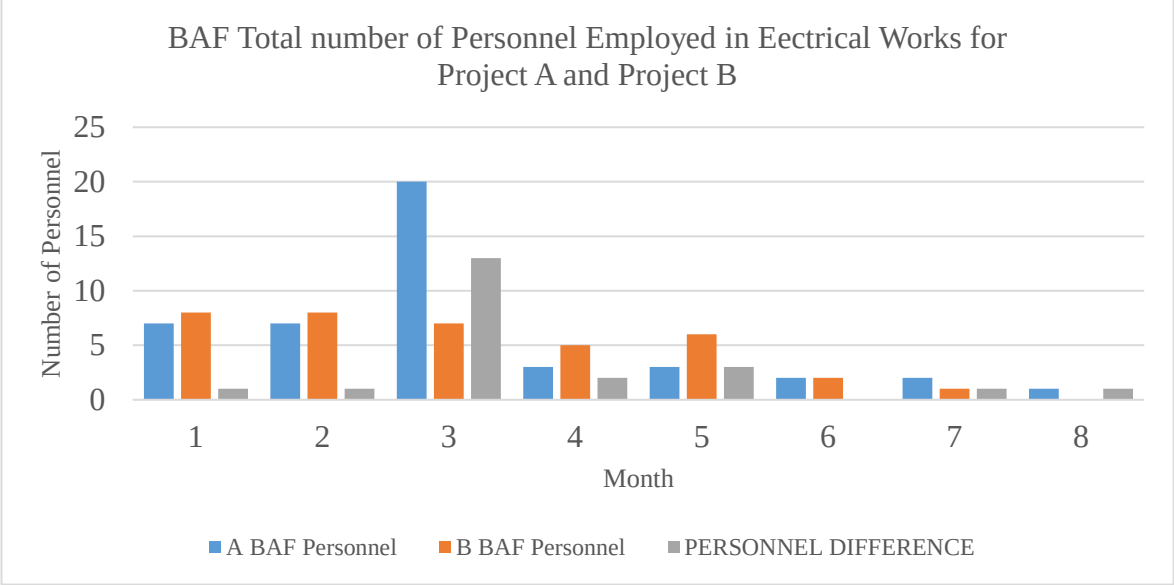


Figure E.30 BAF Total number of personnel employed in electrical works for Project A and Project B

Table E.15 Data of the personnel who work in BAF electrical works per month

Number of Personnel Employed in Electrical Works per a month		
Project	**Max.**	**Min**
A	20	1
B	8	1

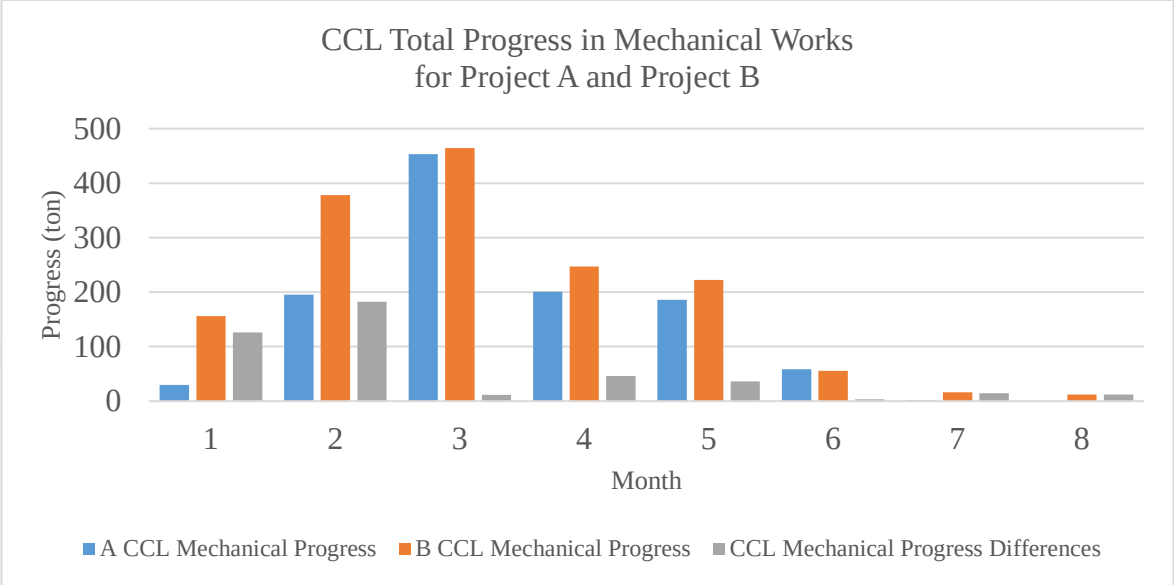


Figure E.31 CCL Total progress in mechanical works of Project A and Project B

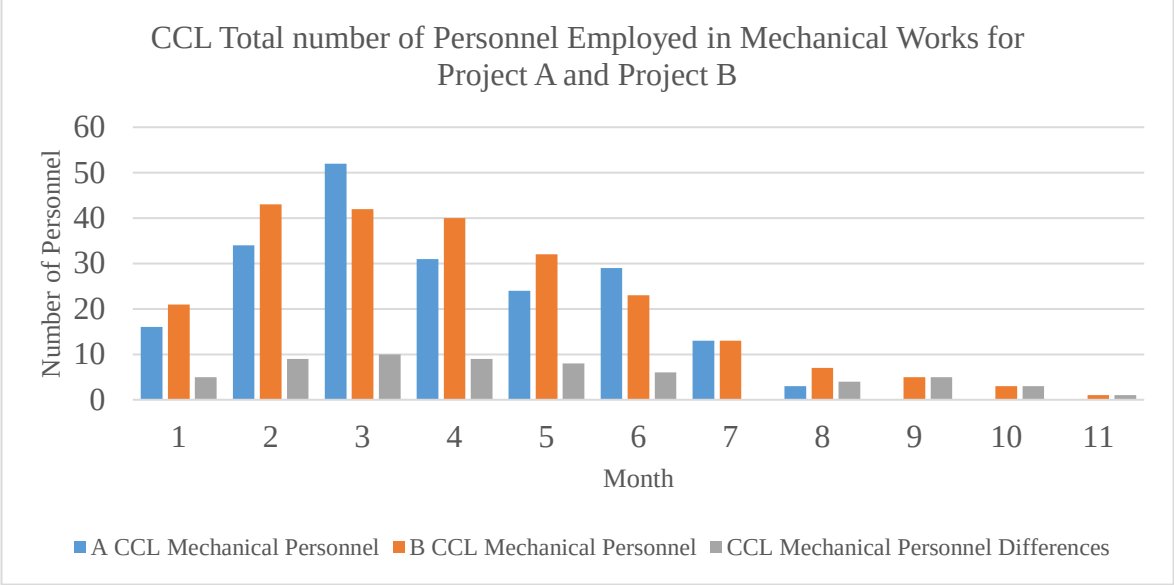


Figure E.32 CCL Total number of personnel employed in mechanical works for Project A and Project B

Table E.16 Data of the personnel who work in CCL mechanical works per month

Number of Personnel Employed in Mechanical Works per a month		
Project	**Max.**	**Min**
A	52	3
B	43	1

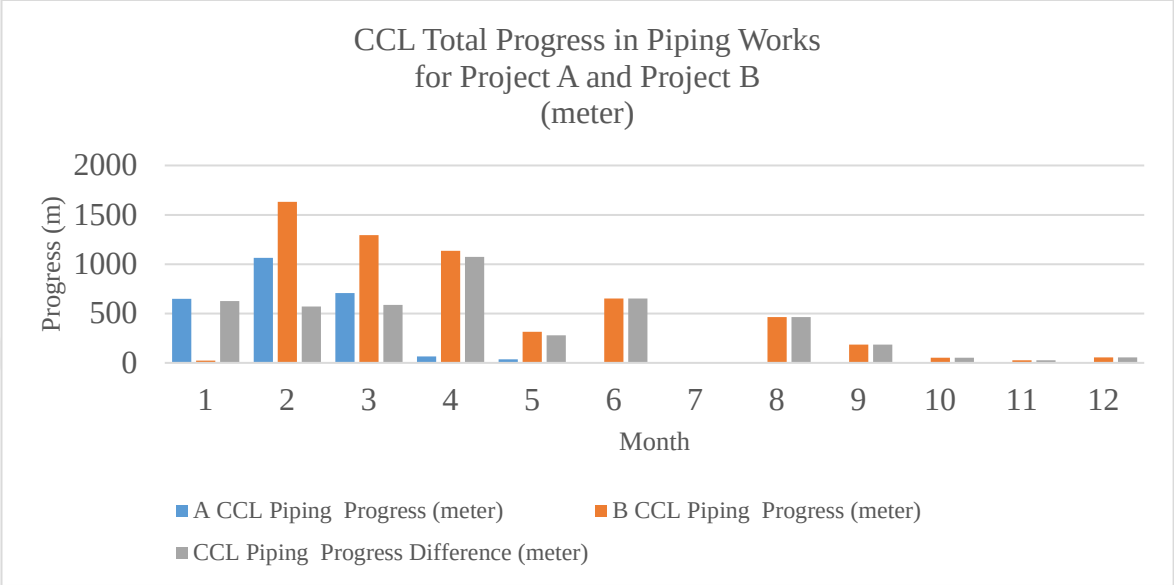


Figure E.33 CCL Total progress in piping works of Project A and Project B

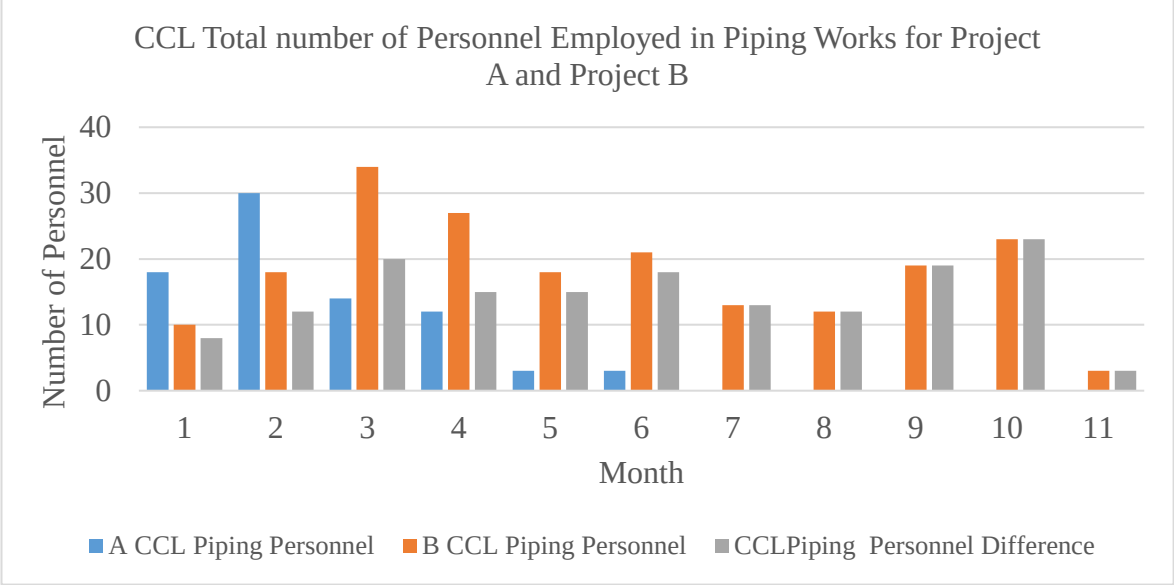


Figure E. 34 CCL Total number of personnel employed in piping works for Project A and Project B

Table E.17 Data of the personnel who work in CCL piping works per month

Number of Personnel Employed in Piping Works per a month		
Project	**Max.**	**Min**
A	30	3
B	34	3

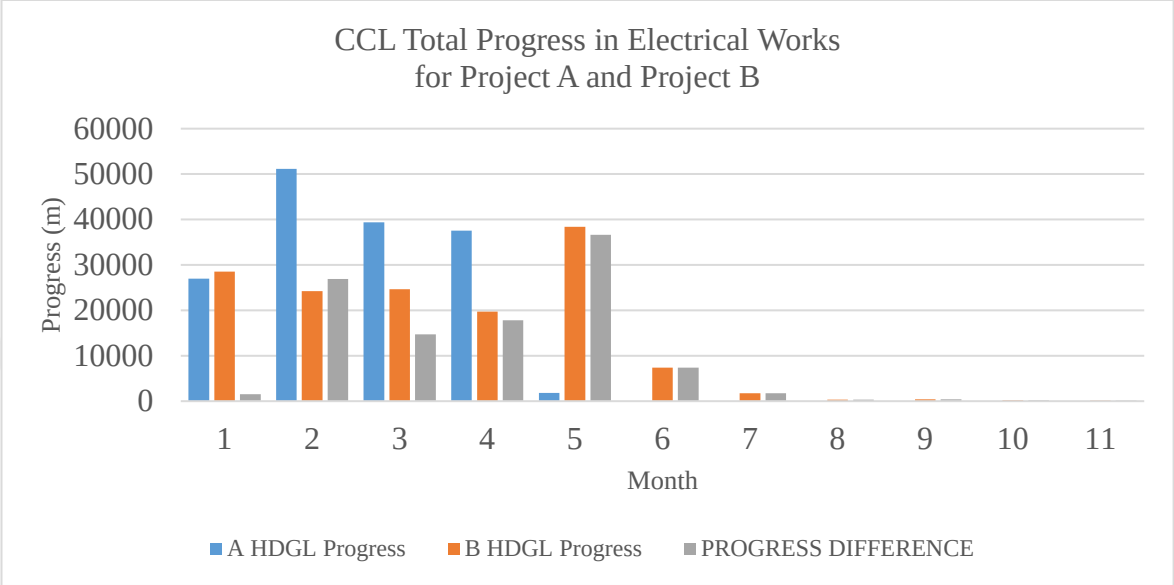


Figure E.35 CCL Total progress in electrical works of Project A and Project B

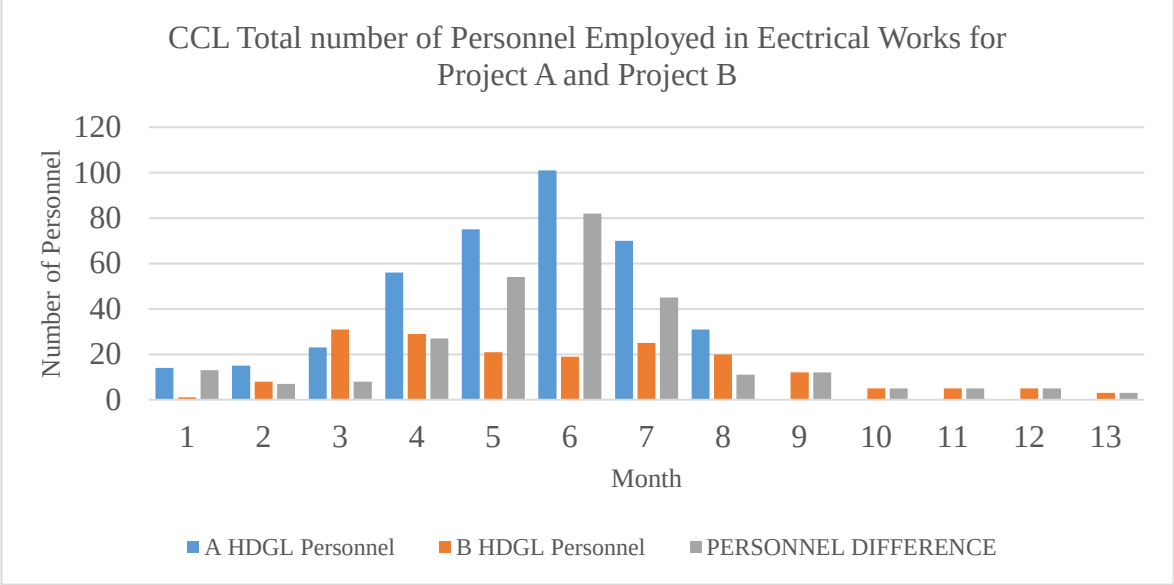


Figure E.36 CCL Total number of personnel employed in electrical works for Project A and Project B

Table E.18 Data of the personnel who work in CCL electrical works per month

Number of Personnel Employed in Electrical Works per a month		
Project	**Max.**	**Min**
A	73	5
B	19	1

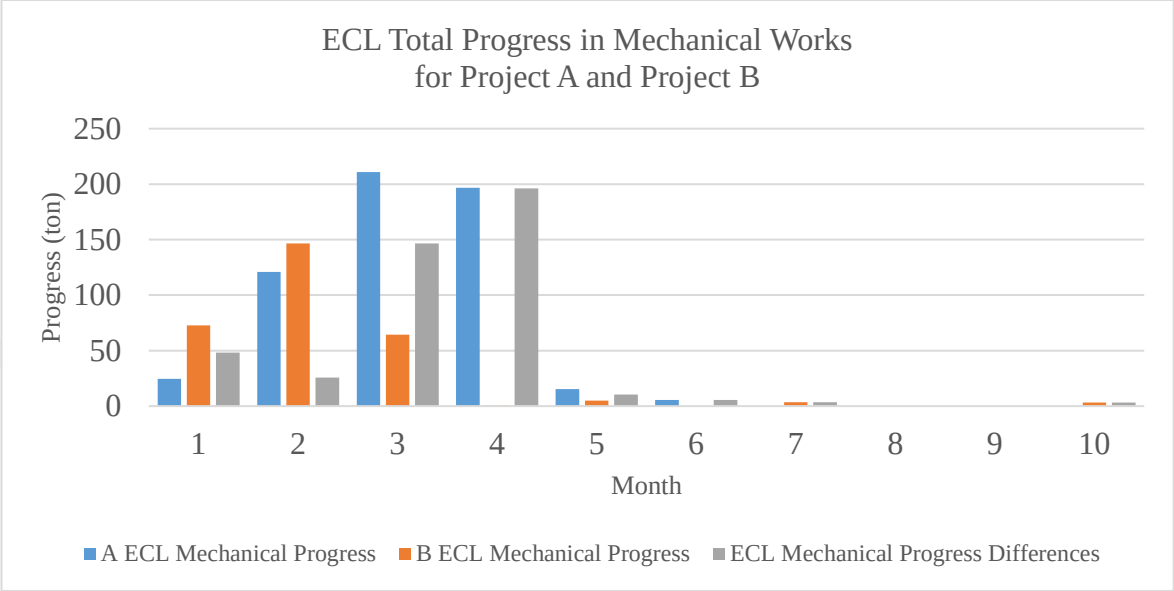


Figure E.37 ECL Total progress in mechanical works of Project A and Project B

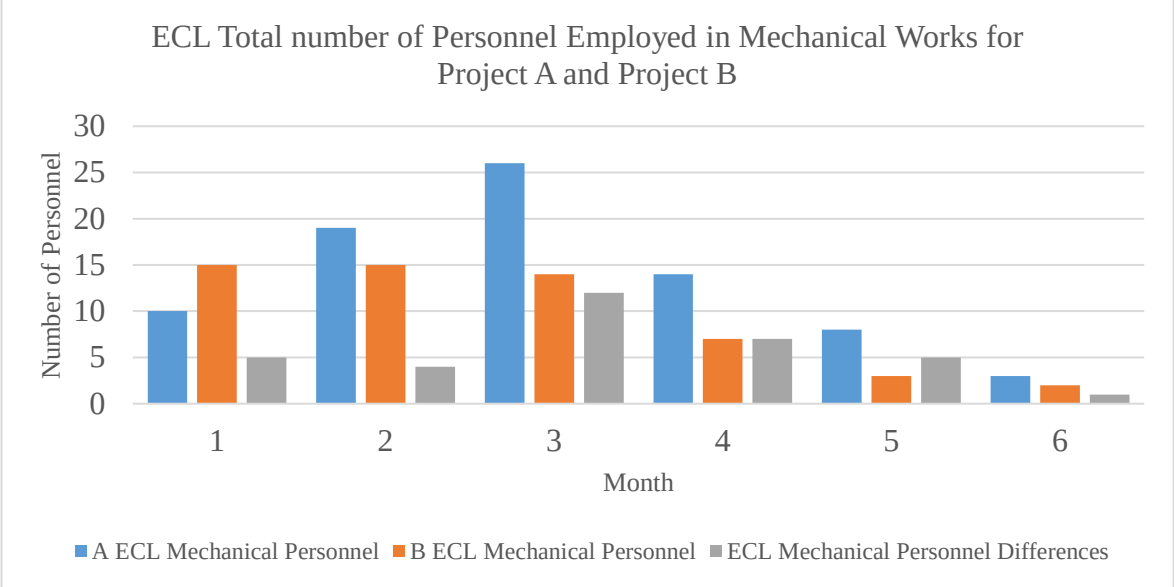


Figure E.38 ECL Total number of personnel employed in mechanical works for Project A and Project B

Table E.19 Data of the personnel who work in ECL mechanical works per month

Number of Personnel Employed in Mechanical Works per a month		
Project	**Max.**	**Min**
A	26	3
B	15	2

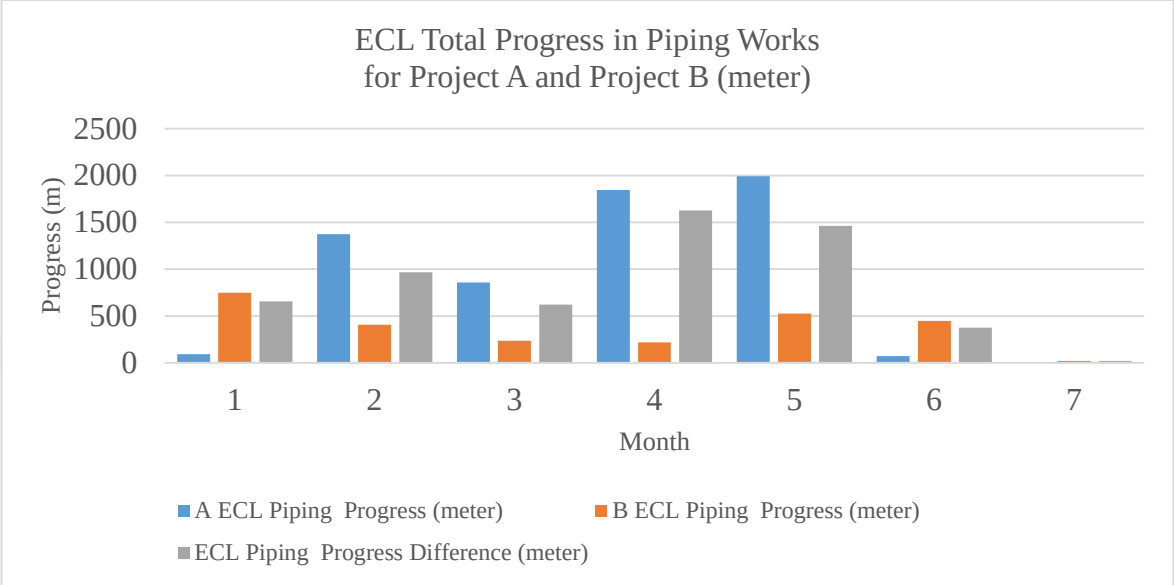


Figure E.39 ECL Total progress in piping works of Project A and Project B

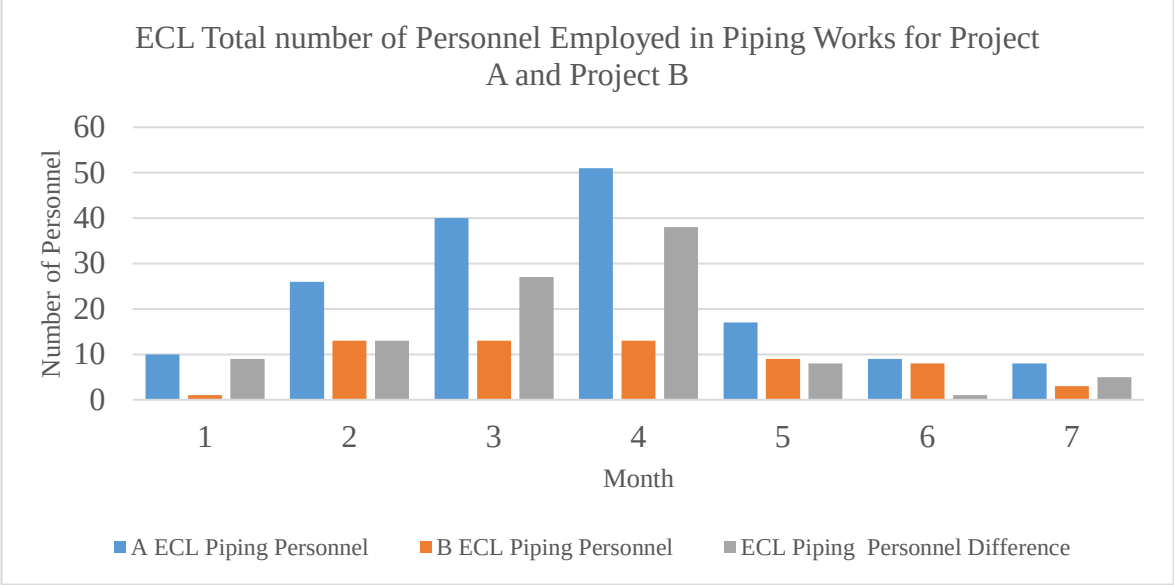


Figure E.40 Total number of personnel employed in piping works for Project A and Project B

Table E.20 Data of the personnel who work in ECL piping works per month

Number of Personnel Employed in Piping Works per a month		
Project	**Max.**	**Min**
A	51	8
B	13	1

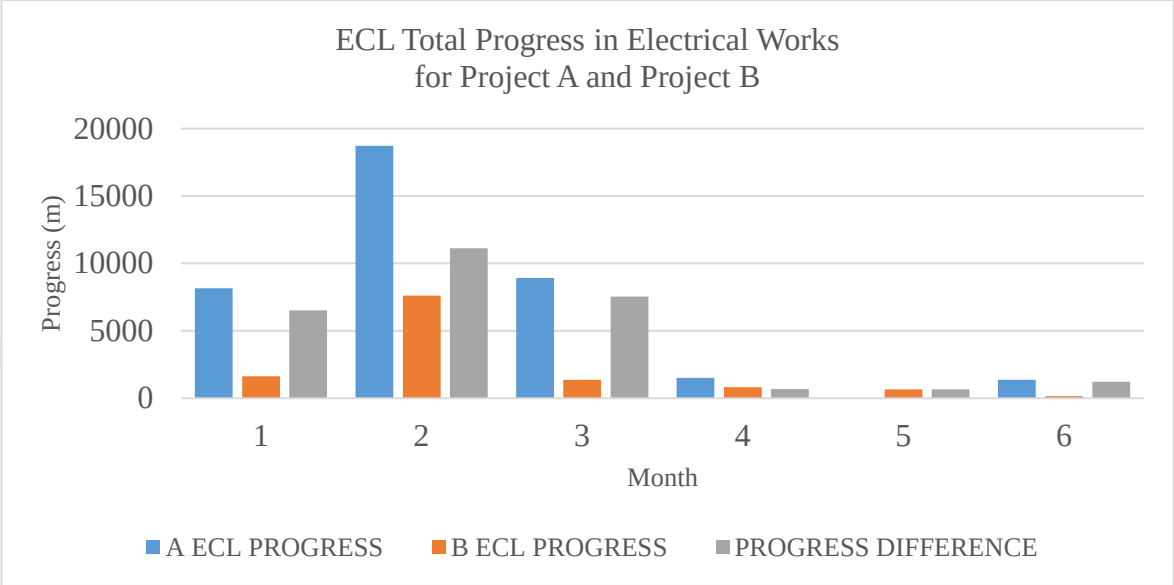


Figure E.41 ECL Total progress in electrical works of Project A and Project B

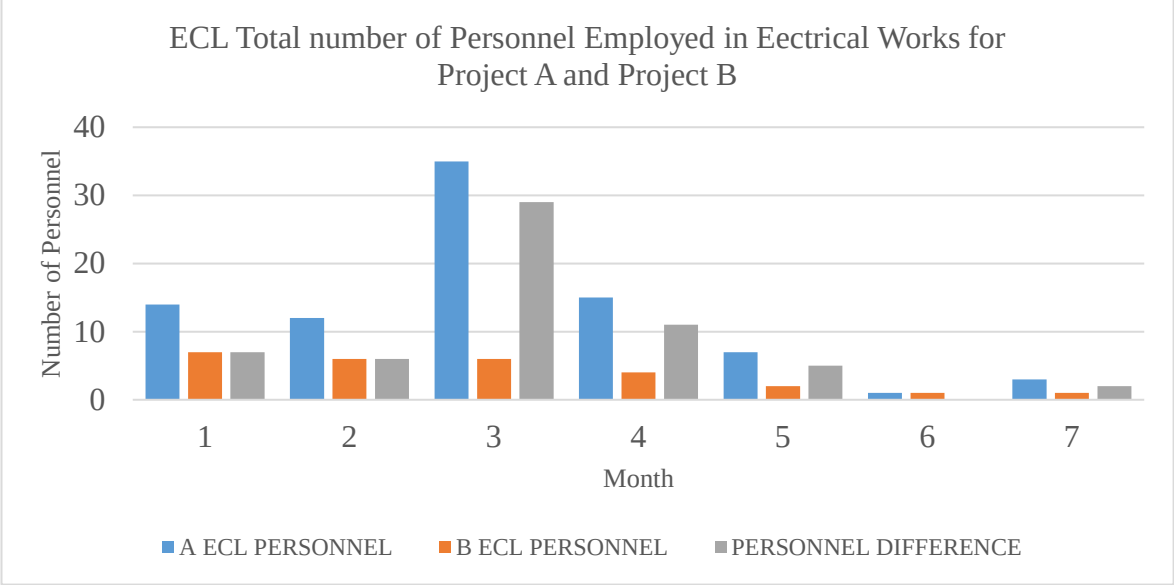


Figure E.42 ECL Total number of personnel employed in electrical works for Project A and Project B

Table E.21 Data of the personnel who work in ECL electrical works per month

Number of Personnel Employed in Electrical Works per a month		
Project	**Max.**	**Min**
A	35	1
B	7	1

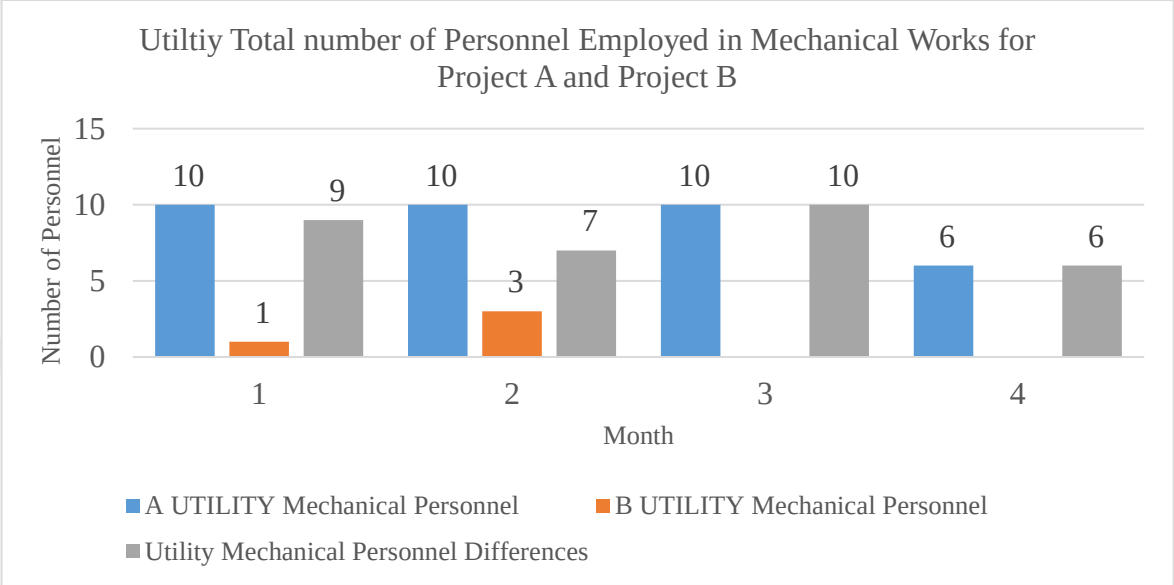


Figure E.43 Utility Total number of personnel employed in mechanical works for Project A and Project B

Table E.22 Data of the personnel who work in Utility mechanical works per month

Number of Personnel Employed in Mechanical Works per a month		
Project	**Max.**	**Min**
A	10	6
B	3	1

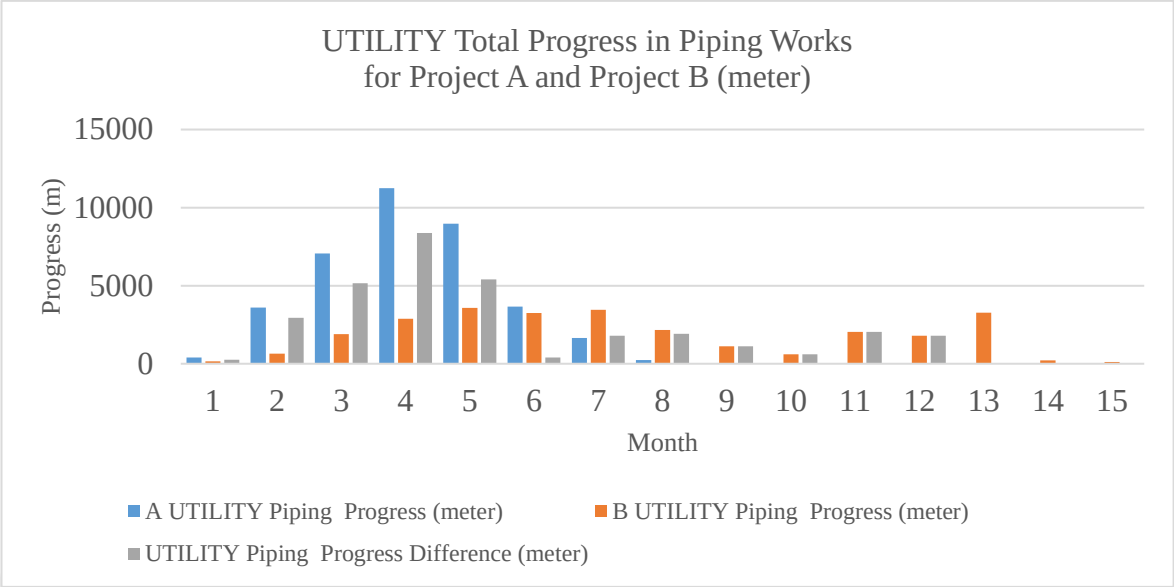


Figure E.44 Utility Total progress in piping works of Project A and Project B

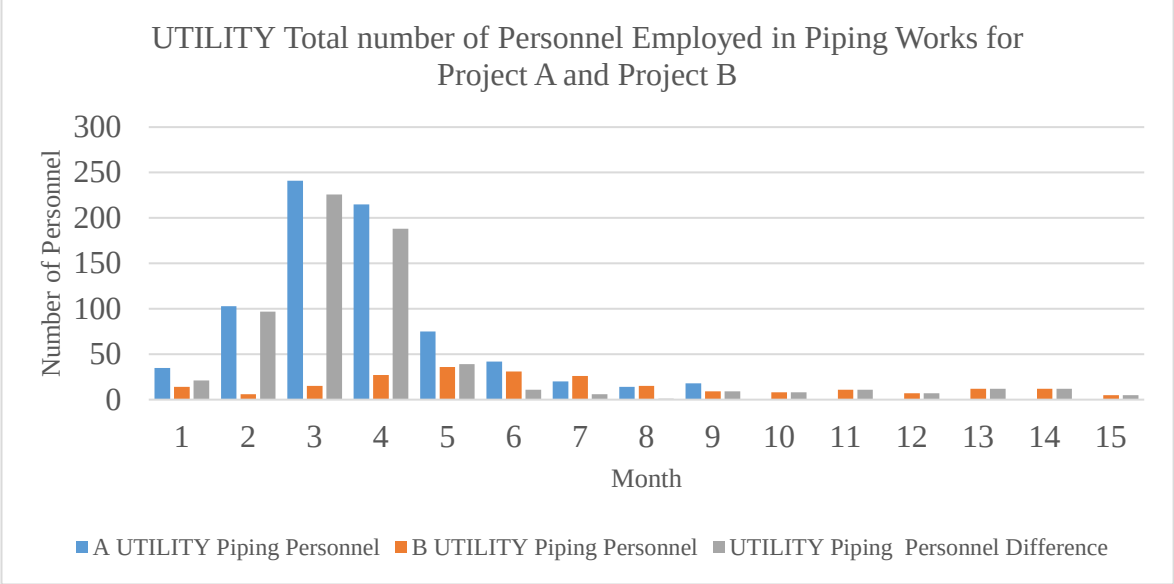


Figure E.45 Total number of personnel employed in piping works for Project A and Project B

Table E.23 Data of the personnel who work in Utility piping works per month

Number of Personnel Employed in Piping Works per a month		
Project	**Max.**	**Min**
A	241	14
B	36	6

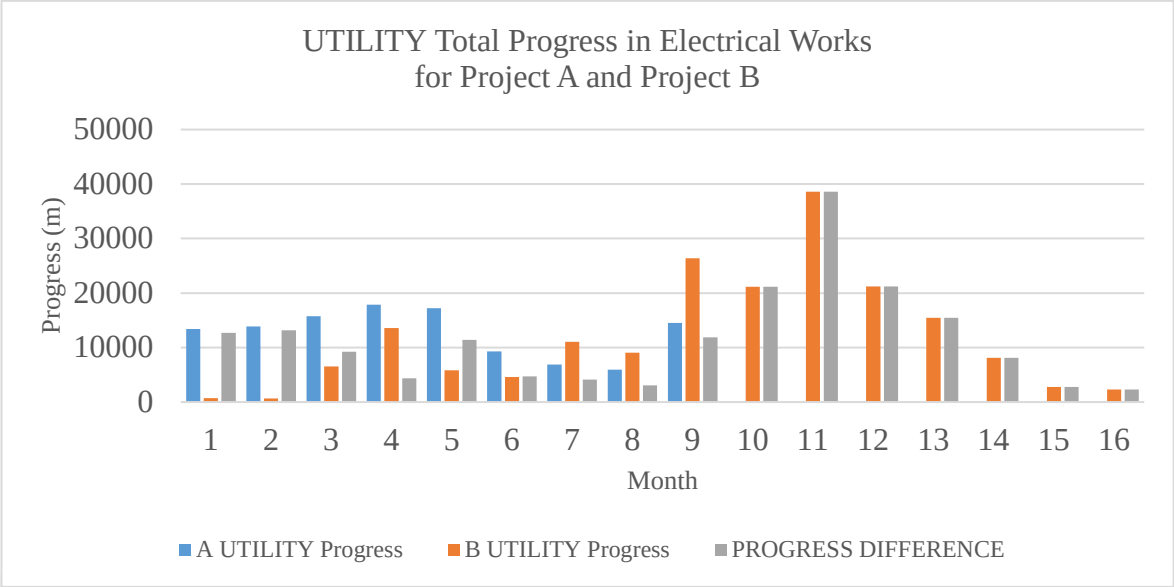


Figure E.46 Utility Total progress in electrical works of Project A and Project B

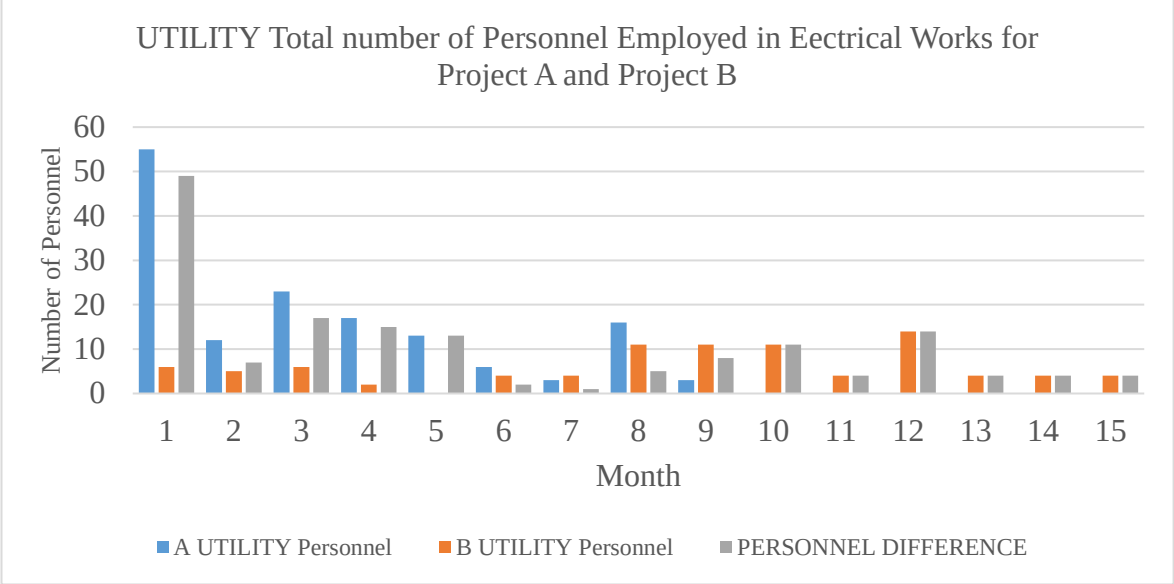


Figure E.47 Utility Total number of personnel employed in electrical works for Project A and Project B

Table E.24 Data of the personnel who work in Utility electrical works per month

Number of Personnel Employed in Electrical Works per a month		
Project	**Max.**	**Min**
A	55	3
B	14	2

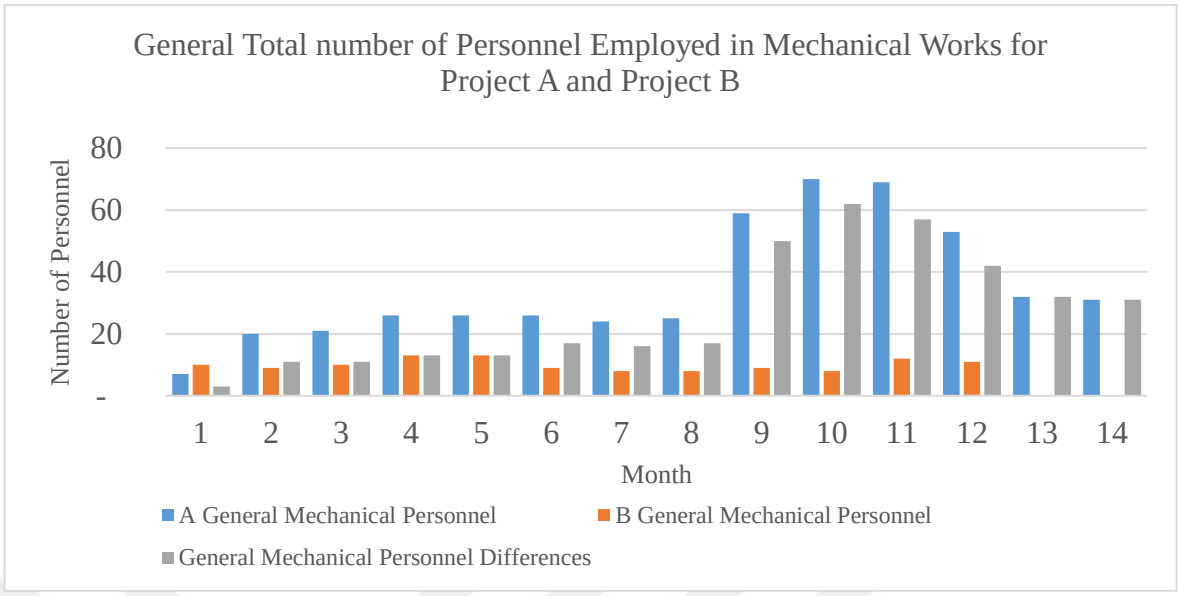


Figure E.48 General Total number of personnel employed in mechanical works for Project A and Project B

CURRICULUM VITAE



PERSONAL INFORMATION

Name Surname : Hatice Çetin

Date of Birth :24.01.1989

E-mail : 125103106@ybu.edu.tr

EDUCATION

High School : 2007 – Özel Ankara Aziziye Lisesi

Bachelor : 2012 – Erciyes Üniversitesi

Master Degree : 2019 – Yıldırım Beyazıt Universitesi

TOPICS OF INTEREST

- Project Management
- Mechanical Vibration