PROCESS CAPABILITY ANALYSIS (PCA) OF TENDER EVALUATION PROCESS IN PUBLIC AGENCIES

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ABSTRACT

PROCESS CAPABILITY ANALYSIS (PCA) OF TENDER EVALUATION PROCESS IN PUBLIC AGENCIES

Public is the largest client in many countries. Public agencies acquire good, service and constructed facilities through the procurement. Most of the public procurements are completed later than the estimated times or even canceled due to the various reasons. Public procurement processes can be improved by using statistical or non-statistical process improvement methods. A review of the construction management literature reveals that process improvement methods are commonly focused on construction operations. Various process improvements have been proposed to improve effectiveness and efficiency of construction operations. Yet improving the tender evaluation process of construction projects is an unexplored research area in the construction management literature. The objective of this study is to analyze the tender evaluation process of public agencies and measure and in turn evaluate the adequacy of this process by using the process improvement methods. The study presented in thesis is based on two process improvement methodologies: (1) Define-Measure-Analyze-Improve-Control (DMAIC) and Process Capability Analysis (PCA). Public procurement processes performed by public agencies (i.e., state universities) are investigated. Tender evaluation processes of public agencies are studied based on criteria: (1) number of participants and (2) estimated construction cost. The research findings reveals that (1) the most time-consuming stage in the tendering process is the tender evaluation stage, (2) the tenders having higher estimated construction cost and more participants have longer tender duration and (3) the process capabilities of public agencies based on number of tenderers and estimated construction cost appear to be poor. The poor capability indices of public agencies suggest that immediate managerial actions should be taken to improve tender evaluation process in public agencies.

ÖZET

KAMU KURUMLARINDA İHALE DEĞERLENDİRME SÜRECİNİN SÜREÇ YETERLİLİK ANALİZİ (SYA)

Kamu birçok ülkede en büyük müşteridir. Kamu kurumları ihale yoluyla ürün, hizmet ve inşa edilmiş tesisler edinir. Kamu alımlarının çoğu tahmin edilen sürelerden daha sonra tamamlanmakta ve hatta çeşitli nedenlerden dolayı iptal edilmektedir. Kamu alım süreçleri, istatistiksel veya istatistiksel olmayan süreç iyileştirme yöntemleri kullanılarak iyileştirilebilir. İnşaat yönetimi literatürü araştırması, süreç iyileştirme yöntemlerinin genellikle inşaat faaliyetlerine odaklandığını ortaya koymaktadır. İnşaat operasyonlarının etkinliğini ve verimliliğini artırmak için çeşitli süreç iyileştirmeleri önerilmiştir. Ancak inşaat projelerinin teklif değerlendirme sürecinin iyileştirilmesi, inşaat yönetimi literatüründe keşfedilmemiş bir araştırma alanıdır. Bu çalışmanın amacı kamu kurumlarının teklif değerlendirme sürecini analiz etmek ve bu süreci kullanarak sürec yeterliliğini ölçmek ve değerlendirmektir. Tezde sunulan çalışma iki süreç iyileştirme metodolojisine dayanmaktadır: (1) Tanımla-Ölç-Analiz-İyileştir-Kontrol Et (DMAIC) ve Süreç Yeterlilik Analizi (PCA). Kamu kurumları (devlet üniversiteleri) tarafından gerçekleştirilen kamu alım süreçleri incelenmektedir. Kamu kurumlarının teklif değerlendirme süreçleri şu kriterlere göre incelenmiştir: (1) katılımcı sayısı ve (2) tahmini inşaat maliyeti. Araştırma bulguları, (1) ihale sürecinde en fazla zaman alan aşamanın teklif değerlendirme aşaması olduğu, (2) daha yüksek tahmini inşaat maliyeti ve daha fazla katılımcısı olan ihalelerin ihale süresinin daha uzun olduğu ve (3) kamu kurumlarının isteklilerin sayısına ve tahmini inşaat maliyetlerine dayanan süreç yeterliliklerinin düşük olduğu görülmektedir. Kamu kurumlarının zayıf yetenek endeksleri, kamu kurumlarında teklif değerlendirme sürecini iyileştirmek için acil yönetim önlemlerinin alınması gerektiğini göstermektedir.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Public is the largest client in many countries. Governments have to make various investments, goods and service procurement in order to provide better service to their citizens and to meet the needs of the citizens. Public agencies acquire good, service and constructed facilities through the procurement. Public procurement process is carried out by the procurement laws. Most of the public procurements are completed later than the estimated times or even canceled due to the various reasons. These delays and cancellations in public procurement have negative impact on the efficient and effective use of public resources (e.g., human, financial and physical capital). For this reason, it is very important to explore the factors that can lead delay and disruptions in public investment and in turn to improve the effectiveness and efficiency of public procurement process.

It is widely known that the stage in which process delays occurred in public procurement is the “tender evaluation process” which starts with the receipt of tenders and ends with the announcement of the contractor who won the tender. Public Procurement Law does not specify a time limit to complete the tender evaluation process. This study focuses on time required to complete a tender evaluation process in the context of public procurement.

Previous research studies in the construction management literature applied process improvement methods such as Six Sigma, DMAIC, Lean and Lean-Six-Sigma methods to the design and construction phase of construction projects. These studies focus on (1) the defects and wastes that occurred during the design and construction phases and (2) explore the reasons adversely affect the performance of design and construction processes. It appears that the application of process improvement methods is limited to the design and construction stage of projects and a promising research area is to apply process improvement methods to the other stages of construction project namely tender evaluation process. This study differs from previous process improvement based research studies conducted in the construction management literature on the count that it focuses on the tender process of the construction projects. This study builds (1) Define-Measure-Analyze-Improve-Control (DMAIC) and Process Capability Analysis (PCA), (2) explores the tender evaluation process in public agencies, and in turn fills an important the gap in the literature.

1.2 Objectives of the Study

The main objectives of the study are follows:

- To **D**efine the tender evaluation process in public agencies
- To **M**easure the process capability of tender evaluation process in public agencies.
- To **A**nalyze the process capability of tender evaluation process in public agencies.

1.3 Scope and Structure of the Study

The scope of thesis presented herein, like any other research studies is defined by the above-mentioned objectives of the research. This thesis explores the tender evaluation process performed under the Public Procurement Law 4734 by “public agencies”. The theoretical framework of the study builds on Process Capability Analysis (PCA) and **D**efine-**M**easure-**A**nalyze **(DMA**IC) methodology and uses the first three steps of the DMAIC method are used. The Improve and Control steps of DMAIC method are beyond the scope of this thesis.

This study, which aims to Define, Measure and Analyze the tender evaluation process in public agencies, consists of 6 chapters. In the first chapter the stage is set by presenting (1) the motivating factors, (2) the objectives and (3) scope of the study. In the second chapter, the concept of public procurement and public procurement law, which is the source of public procurement, are introduced. The articles of Public Procurement Law related to the tender evaluation process, in which our research is focused, are explained. In addition to this a literature review is presented for gaining in insights on tender evaluation process in public agencies. In the third chapter, the concept of process improvement is explained, process improvement methods are classified, process improvement methods used in the service industry are discussed and the applications of process improvement methods in the construction industry are reviewed. In the fourth chapter, research design (i.e., sampling, data preparation and statistical analysis) followed in this thesis are presented. The fifth chapter presented the results of process capability analysis (PCA) of tender evaluation process and discusses the key research findings and interpretation of the results. In the last chapter, the main results of the study are summarized and recommendations for future studies are presented.

CHAPTER 2

TENDER EVALUATION PROCESS

2.1 Introduction

In this chapter, the concept of public procurement, The Public Procurement Law used in Turkey, tender processes, and traditional procurement methods are briefly discussed.

2.2 Public Procurement

The government has to make some investments in order to increase the welfare of its citizens and to provide better and more effective services to its citizens. It is one of the most important tasks of the government to make efficient spending in accordance with the law in public procurement. Procurement is the process of assessing, buying and receiving goods, works, and services. Procurement process can be studied at two different sectors: (1) public sector and (2) private sector. Procurement in public sector is performed by public agencies or organizations (Sabine Adotévi, 2004).

The main rationale in public procurement is "buying" can be more efficient and effective than "making" due to the operation market forces - "competition of the sellers or buyers". In the process of investing public resources, efficiency and fairness of the procurement system is important.

Public investment, with varying over the years, constitutes a large part of government expenditures. Public expenses have a large share in the national income of countries. Public procurement is an important function that requires close attention as procurement officials in public entities are governed by regulations, policies, and procedures (Dzuke and Naude, 2015).

In Turkey, the State Tender Law numbered 2884, which was enacted in 1983, lagged behind developments in time and is unable to keep up with the changes. The government has searched for a new system to ensure that budget is used more efficiently, resulting in the Public Procurement Law numbered 4734. The purpose of this law is to establish the principles and procedures to be applied in any procurement held by public authorities and institutions governed by public law or under public control or using public funds.

Public Procurement Law 4734 defines the procurement as follow: procurement means the proceedings which involve the award of a goods, services or works contract to the tenderer selected in accordance with the procedures and conditions laid down, and which is completed by signing of the contract following the approval of the contracting officer that has been defined in the procurement law (Public Procurement Law, 2012).

Authorities amenable to Public Procurement Law 4734 carry out procurement of goods, services and construction works under a certain discipline within the framework of this law in order to meet their needs on time, in a timely manner, to determine the most advantageous price in all bidders and to use their financial resources efficiently. Authorities shall make all the procurements in a competitive environment in accordance with the principles of transparency, equality, reliability, confidentiality, and openness to public scrutiny.

Public procurement is not an event on contrary it is a process that entails many sub-processes. The public procurement process is represented by a set of rules, policies, and procedures that specify how government procurement activities are supposed to be carried out. Public Procurement Law 4734 in Turkey describes this process, rules, and policies in detail. Public Procurement is a process consisting of three basic steps. These steps are procurement planning, procurement process, and contract management. According to Public Procurement Law 4734, the steps of the public procurement process is explained as follows;

- Preparations before the tender
- Preparation of the tender document
- Tender notice and announcement process procedures
- Tender procedures (receipt of bids, 1st and 2nd session procedures)
- Decision making and appeal processes
- Invitation to contract and contract
- Implementation of the contract

The public procurement process starts with the emergence of need. After defining the needs, the necessary works to be done is determined. Technical specification is prepared. If the technical specification is appropriate, all kinds of price survey are carried out for the approximate cost estimation. The approximate cost is determined with the exception of value added tax and shown on a chart of accounts. The tender procedure is decided. If financial resources is available and secured, the tender approval certificate will be prepared and presented to tender authority for approval. Following the approval of tender by authority, tender documents are prepared via Electronic Public Procurement Platform (EPPP *namely EKAP in Turkish*) and sent to the Public Procurement Authority (PPA *namely KIK in Turkish)* for control. If the tender notice is appropriate, the payment notice of tender will be sent to the relevant person. As soon as the tender announcement fee reaches the system, a receipt is sent to the PPA. When the tender is published in the public procurement bulletin, tender document is added to the tender folder. At the same time, cover letter with publication date is sent to the Press Publication Association. The official gazette is added to the tender folder. By adding all the documents, preparation of the tender folder is completed. And the tender commission is appointed. Tender documents are given to the members of the commission. The tender documents are sold to the tenderers. If there is no objection to the tender notice or documents, the delivery of the tender envelopes is beginning. At the place and time of the procurement, the list of buyers of documents from EPPP is taken and the tender starts. The tender envelopes are examined in detail and the tender evaluation process is carried out. The tender commission decides on which tenderer is to be awarded. The tender commission decision is presented to authority for approval. The tender decision finalized with the approval of the decision by authority is announced to all tenderers. If the tender authority does not approve the decision, the tender is canceled. The appeals against the decision are taken into consideration and then, the tenderer is invited to the contract. With the completion of all documents and settling by mutual consent, the contract is signing. After the contract, the result announcement is made.

2.3 Tender Procedure

Tender is defined as “the price offer with the document and/or information submitted by a tenderer to a contracting authority for the procurement carried out pursuant to the provisions according to the Public Procurement Law 4734” (Kamu İhale Kurumu, 2012).

The tendering is a procurement procedure where potential suppliers are invited to bid according to contract terms (Lysons and Farrington, 2005). Tendering can be defined as the process of assessing competitive bids and comparing them with each other in the framework of tender rules. In other words, tendering means the process of making an offer, bid or proposal in response to an invitation or request for tender. The purpose of the tendering is to ensure that the product or service is available in the right conditions, with the right quality, quantity, price and time (Munyaka, 2015).

Different procedures are followed for the procurement of good, work and service. These procedures are grouped into three major headings: (1) open tendering, (2) negotiated tendering and (3) restricted tendering.

According to the explanation of Public Procurement Law 4734,

- Open tendering is “a procedure whereby any tenderer may submit a tender.”
- Restricted tendering is “a procedure whereby only tenderers invited following a prequalification evaluation by the contracting authority may submit a tender.”
- Negotiated tendering is “a procedure which can be used in cases specified in law and conducted in two stages, whereby the contracting authority negotiates with the tenderers about the technical details, implementation methods and, in certain cases, the price.”

For public projects, often open tendering is recommended and preferred because the open tendering allow accountability for how to use public funds against possible accusations (Chinyio, 2011). In open tendering, any contractor can submit a tender to work. This increases the competitive environment because each contractor tries to make the lowest bid and provide fair participation. The most important disadvantage of open tendering is that all tenders must be controlled technically and financially. This obligation causes a considerable to be spent the amount of time and effort in the construction industry (Tang, Lu, and Chan, 2003).

2.4 Traditional Procurement Method: Design-Bid-Build

The success of any project is directly affected by the cost, quality and duration of the project. The performance of the project may vary depending on the procurement methods that have chosen for the project. Therefore, the most suitable procurement method should be selected for project success.

Public agencies aim to obtain the best price with a competitive bidding process to use taxpayers' money most effectively. This process requires that the cost of the project be calculated and known before the contracting. Public agencies are obliged to establish a fair and competitive environment and to follow the principles of impartiality to facilitate the procurement process. Design-Bid-Build (DBB) method is a primary process that fulfills these requirements. Many constructions projects have been successfully completed with this method (CSI, 2011).

Design-Bid-Build (DBB), known as the 'traditional procurement system', has become the main method of procuring construction projects. Construction works have been based on a traditional relationship between the designer, owner, and contractor. According to this traditional relationship, owner appoints the designer at the beginning of the process and the designer prepares all contract and design documents. After preparing all the design and project specifications by the designer, he/she selects the contractor who will be responsible for the construction, independently of the designer. The contractor also carried out the construction work according to the contract and design documents. In this way, the design and construction phases are separated. The contractor does not participate in the design phase of the project, but the designer and engineers serve throughout the project as representatives of the owner. The owner has a contractual relationship with all parties. Owner contracts with the designer and the contractor separately. It provides for the highly desirable direct professional relationship between the owner/user and the architect-engineers for the project. However, there is no contractual relationship between the contractor and the design team. Figure 2.1. shows the basic organization of a typical Design-Bid-Build project.

DDB easily meets all procurement requirements and does not contain conflicts. As a project delivery method, DBB advances a project from the concept stage to completion. According to this method, design-bid and construction process is a successive linear activity sequence. Figure 2.2. The stages of Design-Bid-Build method shows mentioned linear activities of Design-Bid-Build method. As the name implies, design-bid-build has three main phases; design, bid, build.

- Design (drafting, schematic design, design development, preparing the tender and construction document)
- Open tender
- Build

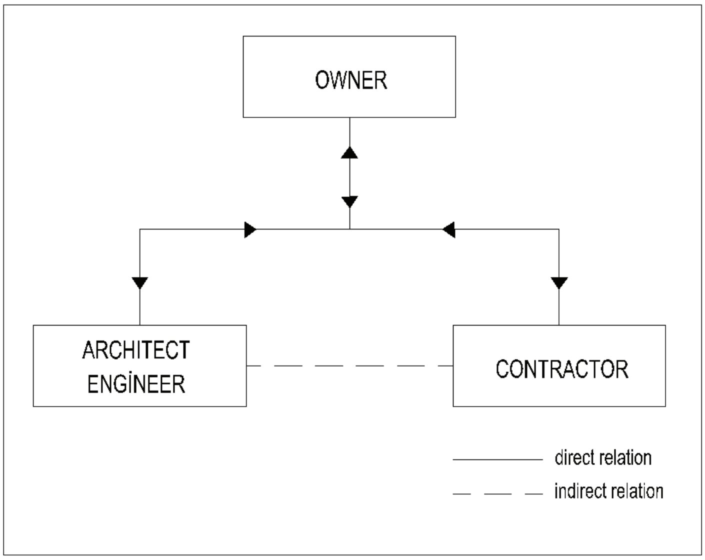


Figure 2.1. Design- Bid- Build procurement method relationship

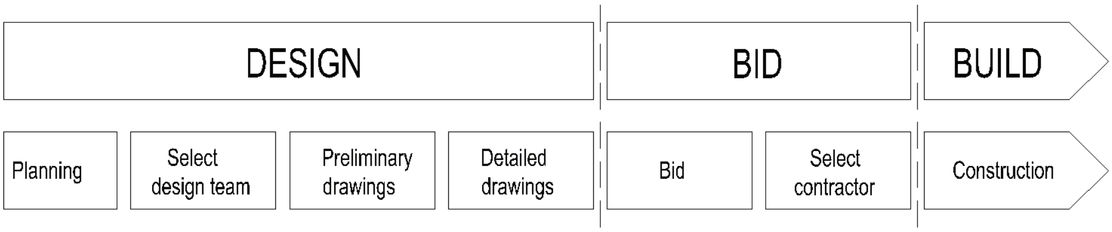


Figure 2.2. The stages of Design-Bid-Build method

In the first stage, owner contracts with a design specialist who develops project drawings and technical specifications. In order to move to the second stage 'bid', the design process must be completed completely. At the completion of the design, the project moves into the second phase known as 'Bid' In this phase, construction bids are solicited from general contractors and the project is awarded to a bidder on a competitive basis.

In the second phase, competitive bidding is being done to obtain the lowest cost. As stated in the law, public institutions select contractors with competitive bidding. However, in some cases, not only the cost but also parameters such as technical competence, experience are taken into account. The lowest price is not always the only criterion used to reward the contract.

The third phase is the actual construction of the project by the general contractor. After the tender is concluded, the contract is signed between the contractor and owner. This takes the most time and uses the most money but also produces tangible results.

2.5 Tender Process in Public Procurement Law 4734

2.5.1 Threshold Values

The threshold value is the monetary limit determined by considering the approximate cost of the project, which regulates the tender notice period and participation rules of the procurement. According to the Law, the tender notice must be given firstly. Considering the threshold values is necessary to determinate the duration of tender notice.

Table 2.1. Threshold values over the years

YEAR	4734 - 8/a *(TL)*	4734 - 8/b *(TL)*	4734 - 8/c *(TL)*
2002	300.000	500.000	11.000.000
2003	350.031	583.385	12.834.470
2004	398.685	664.475	14.618.461
2005	453.863	756.438	16.641.656
2006	474.468	790.780	17.397.187
2007	529.411	882.352	19.411.781
2008	560.858	934.763	20.564.840
2009	606.343	1.010.572	22.232.648
2010	642.299	1.070.498	23.551.044
2011	699.270	1.165.451	25.640.021
2012	792.482	1.320.805	29.057.835
2013	811.897	1.353.164	29.769.751
2014	868.486	1.447.479	31.844.702
2015	923.721	1.539.538	33.870.025
2016	976.465	1.627.445	35.804.003
2017	1.073.525	1.789.213	39.362.920
2018	1.239.599	2.066.004	45.452.363
2019	1.656.600	2.761.007	60.742.537

Threshold values are stated in Public Procurement Law 4734 published 2002 years, as follow:

“Article 8- Taking into consideration the estimated cost, the threshold values that shall be applicable for the implementation of Articles 13 and 63 of this Law are as follows:

a) three hundred billion Turkish Liras for procurement of goods and services by the contracting authorities operating under the general or the annexed budget (six hundred and ninety-nine thousand two hundred and seventy Turkish Liras)

b) five hundred billion Turkish Liras for procurement of goods and services by other contracting authorities within the scope of the PPL (one million one hundred and sixty-five thousand four hundred and fifty-one Turkish Liras)

c) eleven trillion Turkish Liras for the works contracts by any of contacting authorities covered by this Law (twenty-five million six hundred and forty thousand twenty-one)”

Thresholds and monetary limits are updated each year considering the rate of annual change of domestic producer price index which is released by Turkey Statistical Institutions. Table 2.1 shows the change of threshold values over the years.

2.5.2 Tender Notice Periods and Rules and Prior Notice

Article 13- Giving sufficient time for all tenderers to prepare their tenders;

a) Tenders with an estimated cost equal to or exceeding the threshold values stated in Article 8;

1) Notice of procurements to be conducted by open procedure shall be published at least forty days before the tender date,

2) Pre-qualification notice of procurements to be conducted by restricted procedure shall be published at least fourteen days before the date of the tender,

3) Notice of procurement to be conducted by negotiated procedure shall be published at least twenty-five days before the date of the tender,

It shall be published at least once in the Public Procurement Bulletin.

It is obligatory that an invitation letter shall be sent at least forty days before the tender day to candidates who are qualified as a result of the prequalification evaluation in the tenders to be made between certain tenderers whose costs are equal to or exceeding the threshold values.

b) Tenders for which the approximate cost is less than the threshold value stated in Article 8;

1) The procurement of goods or services with an estimated cost of up to 30.000 Turkish Liras and construction works up to 60.000 Turkish Liras billion shall be made at least seven days before the date of the tender and at least two of the newspaper being issued,

2) The procurement of goods or services between the amount of 30.000 Turkish liras and 60.000 Turkish liras and construction works between 60.000 Turkish liras and 500.000 billion Turkish liras at cost of at least fourteen days before the date of tender and at least two of the newspaper being issued,

3) The procurement of goods or services with an estimated cost of more 60.000 Turkish liras and below the threshold value and construction works whose value is below the threshold value of 500.000 Turkish liras shall be made at least twenty-one days before the date of the tender and at least two of the newspaper being issued.

It shall be announced by published at least one.

The thresholds values for tender notice period mentioned above belong to Public Procurement Law published 2002 years. These values are updated every year. Threshold values for tender notice over years are shown in Table 2.2.

Table 2.2. Threshold values for tender notice period

YEAR	4734 – 13/b (1) (TL)	4734 – 13/b (2) (TL)	4734 – 13/b (3) (TL)
2002	30.000	60.000	500.000
2003	38.191	76.382	636.524
2004	43.499	86.999	725.000
2005	49.519	99.039	825.340
2006	51.767	103.535	862.810
2007	57.761	115.524	962.723
2008	61.192	122.386	1.019.908
2009	66.154	132.311	1.102.622
2010	70.076	140.157	1.168.007
2011	76.291	152.588	1.271.609

(cont. on next page)

Table 2.2. (cont.)

2012	86.460	172.927	1.441.114
2013	88.578	177.163	1.476.421
2014	94.751	189.511	1.579.327
2015	100.777	201.563	1.679.772
2016	106.531	213.072	1.775.686
2017	117.120	234.251	1.952.189
2018	135.238	270.489	2.254.192
2019	180.732	361.481	3.012.502

2.5.3 Tender Evaluation

The evaluation of the tenders is a process defined by the evaluation of biddings and the comparison with each other in the context of the tender specification. It is a critical stage of the procurement process. It is the last chance for the public agency to influence the efficient and effective use of public resources and verify that the lowest responsible tenderer is awarded (Anderson and Norrman, 2002).

The tender evaluation process intends to identify the weakness and strengths of the tenders made according to criteria specified in invitation documents. The Public Procurement Law 4734 provides a generic framework to conduct a fair and transparent evaluation for tenders in the public sector. Different models and labels are used in the construction industry to conceptualize the subprocesses of tender evaluation process. Tender evaluation process involves a number of subprocess such as preliminary stage, and detailed evaluation stage from where the general criteria as technical quality, price, qualifications of suppliers, relevant experience and support service/warranty are used against the tenders. In essence, the tender evaluation process involves five main generic subprocesses: (1) submission, (2) opening, (3) examination, (4) evaluation and (5) reporting.

In accordance with the Public Procurement Law 4734 which defines the principles and procedures to be applied in any procurement held by public authorities and institutions governed by public law or under public control or using public funds, the tender evaluation process can be summarized as follows; (1) Receiving of tenders, (2) Opening and evaluation of tenders, (3) Conclusion of tenders, (4) Approval of the tender proceedings, (5) Notification of finalized tender decisions, (6) Invitation to contract signing.

Figure 2.3 shows the mentioned stages of the tender evaluation process in details.

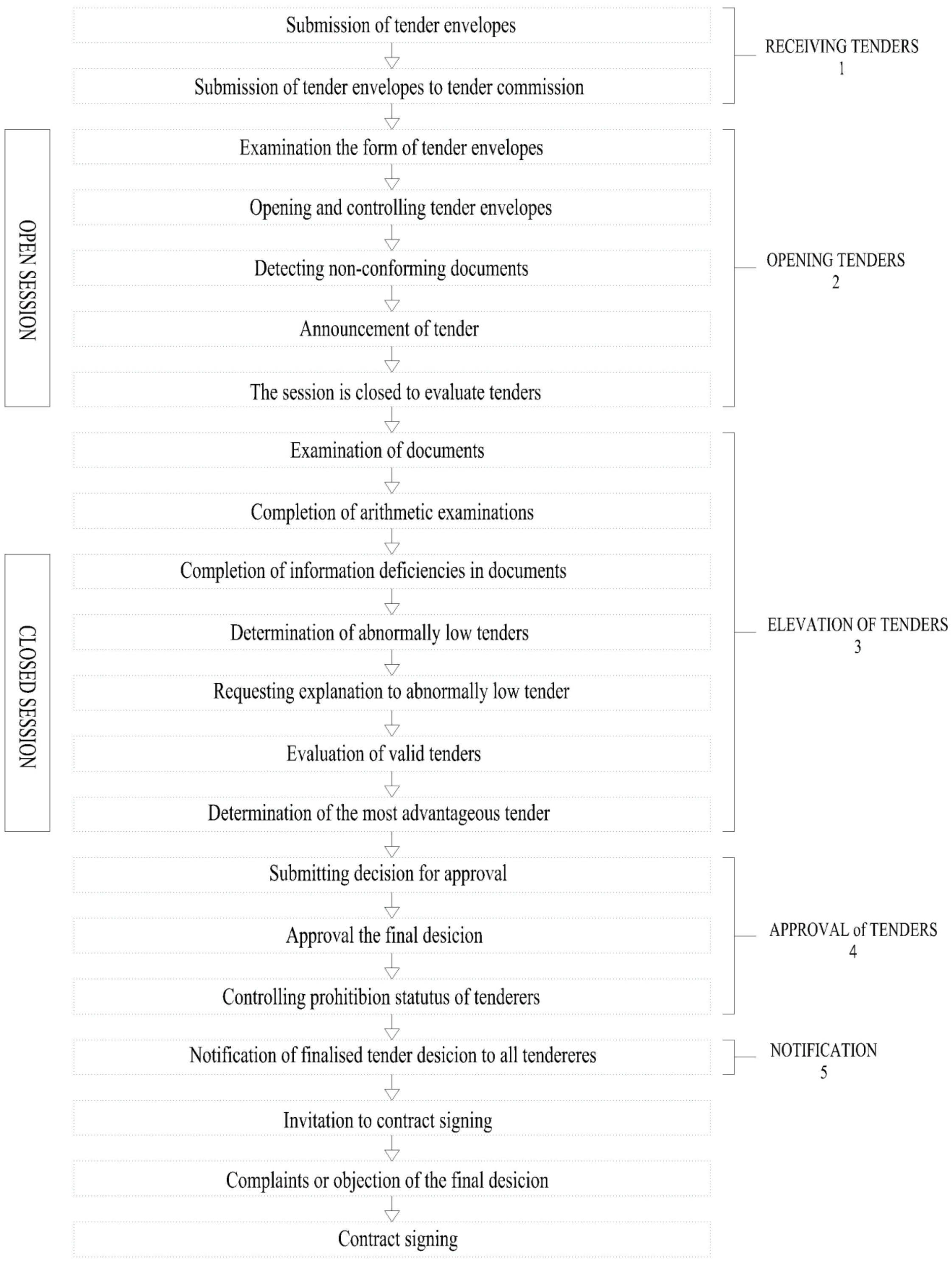


Figure 2.3. Tender Evaluation Process - Flowchart

2.5.3.1 Receiving of Tenders

The tender is submitted to the service officer until the submission time of the tender stated in the tender documents. The number of tenders submitted at the hour of tender submission time is determined and recorded.

2.5.3.2 Opening and Evaluation of Tenders

The tender evaluation process consists of two main sessions: (1) open session and (2) closed session. The first session of the tender evaluation is conducted as an "open session". The opening of tenders begins with the announcement of the total number of tenders by the tender commission in the presence of the tenderers. The tender envelopes are ordered according to submission time. Examinations of the tenders are carried out following this order. Envelopes are examined in term of form, and the inappropriate ones are eliminated. Then the tender envelopes are opened in the order of submission time. Tender opening aims to verify publicly the completeness of bids in order to eliminate those that are not complete.

Documents of tenderers, tender letter, and preliminary guarantee are checked against the possibility of being any incompleteness and unconformity. Tenderers who have missing tender documents and non-conformities are excluded from the evaluation. However, if there is a lack of information in the documents in such way that it does not cause a change in the basis of the tender, the tenderers are allowed to complete missing information within the time specified by the administration. If the incomplete information is not completed within the time, it is not be evaluated in the tender.

The name and address of each contractor whose tender is opened, and the tender price shall be announced to the present and the absent tenderers. The tender price is recorded immediately in the record of tendering proceedings.

The first session is completed after announced tender prices and the amount of estimated cost. There is no such thing as acceptance or rejection of the tender in this stage. At this stage, any correction or completion shall not be made. Minutes of the meeting must be signed by the attendance and the full list is attached.

The second session of the tender is conducted as a "closed session". The tender commission assesses the tenders of tenderers in terms of professional and technical aspects in this session. In the second session, tenders and documents submitted by the tenderers are evaluated by an expert in detail considering the administrative and technical specifications. The main issues examined at this stage are; conformity with the qualification criteria determining the capacity of the tenderers to perform the contract, conditions set forth in the tender documents, arithmetical error exists in unit price charts. Tenders that will be eligible or not to evaluated are determined by looking at these criteria.

The tender commission evaluates the tenders and then calculated the limit value according to the method determined by the institution. The tender commission determines tenders below the limit value as 'abnormally low tender'. Tenderers whose tender is below the limit value are required to disclose tender in detail according to criteria determined by the institution. This explanation must be relevant to components identified as being important to the tender. This explanation documents shall be submitted in writing within at least 3 working days.

The tender commission shall evaluate the abnormally low tenders consider the written explanations. The important points in the written explanation are:

- Economic nature of the manufacturing process, the services provided and the method of works,
- Selected technical solutions and advantageous conditions to be utilized by the tenderer in the supply of the goods and services or fulfillment of the works,
- The originality of the goods, services or works proposed

As a result of this evaluation, the tenders of the tenderers whose explanations are considered insufficient or who fail to make a written explanation are rejected. Tenders that are not rejected by the tender commission are determined a valid tender. With the decision of the tender commission, the institution can cancel the tender by rejecting all tenders.

2.5.3.3 Conclusion of Tenders

The tender shall be concluded in accordance with the conditions previously mentioned in the tender documents. If it is stated in the tender announcement and documents that the tenders which are under the limit value to be rejected, the tenders of the tenderers determined to be below the limit value shall be rejected without any explanations. The tender shall be awarded to the tenderers who submitted the economically most advantageous tender.

There are two kinds of selection of the most advantageous offer in the tenders. First, the most advantageous offer is the lowest tender in terms of price. The second way to choose the best offer is to evaluate the other factors, which are stated in tender documents except for the price. The tender is concluded with the determination of the most advantageous tender in overall.

2.5.3.4 Approval of the Tender Proceedings

Following the completion, the tender decision document, the tender commission shall submit the decision to the contracting officer for approval. Within a maximum five days following the date of the decision, the contracting officer shall approve or cancel the tender decision, clarifying causes of the cancellation. If the decision of the tender decision approved, tender is valid; if the decision canceled, tender is deemed null and void. After the approving the tender decision, contracting authority must check from Electronic Public Procurement Platform (EPPP *namely EKAP in Turkish*) whether the successful tenderer and the owner of the second most economically advantageous tenderer are prohibited from participation in tenders. If the tenderer is prohibited, it is eliminated and prohibited again.

2.5.3.5 Notification of Finalized Tender Decisions

Finalized tender decision and reasons of this decision shall be notified to all tenderers who have submitted an offer, within the three days following the day of approval by contracting officer. The contract cannot be signed until 10 days after the finalized tender decision is announced to all participants. For foreign tenderers, this period is added for another 12 days. During this period, challenge the decision.

2.5.3.6 Invitation to Contract Signing

Within three days following the end of complaint period, and in cases requiring the pre-fiscal control, following the completion date of this control, the successful tenderer shall be notified to sign the contract by issuing a performance bond within ten days following the date of notification.

2.5.4 Tender Evaluation Process

Tender evaluation process is a difficult and critical task. This challenging task requires reviewing and checking compliance of several factors which can have important influence on the efficient and effective use of public resources. Previous research studies in construction management literature mainly focus on developing criteria and/or methods/models to select and in turn award construction project to a “responsible tenderer”.

It is widely acknowledged that two common tender evaluation methods are generally used in the construction industry. The first one is based on the “lowest price”. In the second one is based on the multi-criteria evaluation method, in addition to tender price, other factors (e.g., previous experiences, technical and financial capabilities, current workload) are considered. Meng and Sun present a comparison of these methods in application of a case study and illustrate the advantages and disadvantages of each method. They point out there are still a need for improvements on both methods such as monitoring contractors’ performance and evaluation of promises in the tenders (Meng and Sun, 2015).

Bergman and Lundberg study the tender evaluation and supplier selection methods in public procurement. They conclude that the most commonly used tender evaluation methods are based (1) highest quality, (2) lowest price, and (3) both price-and-quality. Bergman and Lundberg present the advantages and disadvantages of three tender evaluation methods (Bergman and Lundberg, 2013).

Sciancalepore et. al explore the tender evaluation and selection process based on the requirements and expectations of public agencies and/or construction firms. They propose a model, named Most Economically Advantageous Tender (MEAT) scheme for the use of tender evaluation committees in public agencies (Vernay et al., 2011).

Merna and Smith conclude that different methods of prequalification, various types of contract document and bid evaluation procedures are used in awarding contracts for the public sector in United Kingdom. They point out the presence of specific problems of “low tender” in the construction industry (Merna and Smith, 1990).

Alsugair argues that bid evaluation is a difficult process - selecting the best contractor for awarding the construction project not only in private but also public sector. He presents a bid evaluation framework for assessing bids of construction contractors into the systematic procedure. The proposed framework makes the use of bid evaluation factors, the impact, and weights of these factors with its score. Alsugair suggests that the proposed framework can be used for bid evaluation especially in public projects (Alsugair, 1999).

Diabagate proposes a model for analyzing and evaluating the tenders and in turn selecting the best tender. The proposed model is an IT solution which integrates artificial intelligence (AI) and decision support model, e-government approach, to solve tender evaluation problems fully or partially in the public agencies (Diabagate, 2014).

Hatush and Skitmore explore the information gathering, assessment and evaluation procedures used by experienced clients in prequalification and tender evaluation process. They identify a set of evaluation criteria that fulfill the requirements of clients and projects. Hatush and Skitmore conclude that technical and management capabilities, financial competences as well as health and safety performance of contractors are the most important factors during prequalification and bid evaluation process considered by the tenderers (Hatush and Skitmore, 1997).

Watt develops a set of criteria which can be used in the contractor selection process. The relative importance of each criterion is measure by using experimental approach. Based on the results, past performance, technical expertise, and cost are the most important criteria for the actual selection of contractor whereas organizational experience and reputation of the company seemed to be relatively less important (Watt, Kayis, and Willey, 2010).

Mateus et. al argue that tender evaluation criteria and their relative importance should be clearly defined in the European Union public procurement rules and the scoring rules of evaluation criteria should be determined in advance to present more appropriate and comprehensible information for tenderers. Mateus et.al urge the authorities and practitioners for the necessity of developing and implementing a more transparent tender evaluation models (Mateus, Ferreira, and Carreira, 2010).

2.5.4.1 Factors Affecting the Tender Evaluation Process

It is widely acknowledged that the tender evaluation process takes longer time than expected. There may be uncertainties or specified reasons leading to increase in tender evaluation time. The first step to identify these reasons/uncertainties and resolve the problems is define/review tender evaluation process.

Taking into consideration of Public Procurement Law 4734, the time between tender announcement and tender date as well as invitation to contract and contract date are specified according to threshold values. It can be stated that the duration between stages of tender evaluation is changing considering threshold values. While the required time for tender date from tender announcement date varies with threshold values, the allowable time for the contract date from invitation date to contract is constant as 10 days. However, the time in between tender date and invitation date to contract, which is namely tender evaluation time is not specified. Thus, the completion time of tender may change according to the tender evaluation time.

The tender evaluation process may take longer time than the expected duration. There may be many reasons for the elongation of time in the tender evaluation process. Researchers have not studied the actual reasons and effects of delays experienced in the tender evaluation process as well as the completion time of tenders. Instead, the tender evaluation process has been mainly explored in terms of "tender evaluation methods/models" and "contractor selection criteria".

A review of the Public Procurement Law reveals that there are many factors which may have an influence on time required to complete tender evaluation process. The primary factors which may be have influence on time required to complete tender evaluation process include:

- Tendering procedures, clarity of evaluation procedures and requirements,
- Deficiencies in documents and information submitted in tender envelopes by the tenderer,
- Numbers of participants in a tender,
- Existing of abnormally low tenders,
- Qualification of tender in terms of nature, complexity, size, type and other project characteristics etc.,
- Experience and motivation of tender committee members and tenderers,

- Workload of the tender committee.

The above listed factors can delay the completion of the tender evaluation process. Time required to complete tender evaluation process tender evaluation process can be shortened and the variance in the time required to complete tender evaluation process can be reduced by studying the above-mentioned factors. Expediting the tender evaluation process and reducing variability in the tender evaluation process can be achieved by using "process improvement methods"

In the following sections, process improvement methods will be explained.

CHAPTER 3

PROCESS IMPROVEMENT

3.1 Introduction

Nowadays, in order to achieve success and permanence in the globalized business world, it is necessary for public (e.g., governments) and private agents (e.g., firms) to keep their competitiveness and to meet the increasing and changing stakeholder/shareholder expectations. Public and private agents can achieve their own differing objectives if and only if they can ensure the efficient and effective use of available resources in their services, operations and activities. Process improvement methods present a “promising generic framework” for ensuring the efficient and effective use of available resources.

This chapter introduces the process improvement methodologies associated with this thesis. It explains the process improvement and continuous improvement concepts and then provides an overview of the process improvement methodologies. The applications of process improvement methodologies in the service industry will be examined. The chapter concludes by presenting a review literature of process improvement methodologies applied to the construction industry.

3.2 Process Improvement

Process is a “sequence of pre-defined activities executed to achieve a pre-specified type or range of outcomes” (Talwar, 1993). Another definition of process is “a collection of activities that come together in a predetermined sequence that transform inputs to outputs, utilizing resources to effect transformation.” (Shankar, 2009). Harrington says, “There is no product or service without a process, there is no process without a product or service” (Harrington, 1991).

Process is a series of measurable, identifiable, repeatable, controllable, recyclable activities generating value for the customers in which outputs are created. In processes, inputs are generally material, human, equipment, method, and environment. In a process, it is very important to use the inputs in the right place to identify the activities that do not create added value and to remove them from the system. Therefore, organizations need to monitor and control their processes continuously. Only in this way, they will be able to identify errors and take precaution through improvement work.

The planning and implementation of the improvement and development activities for the processes are crucial for updating the processes and meeting the customer needs and expectations.

In order to improve a process, first, it is necessary to recognize the process. Improvement may be possible after good recognition of the processes. Therefore, process analysis is firstly performed in a successful process improvement application. Process analysis is carried out to ensure that a process creates beneficial outputs and to determine ineffective and unnecessary activities in the process. With the contribution of process analysis, the operation of a process can be examined and the root causes of the problems in the process can be determined. In the process analysis, it is determined whether the activities in the process contribute to the output values, and then the critical work steps are determined. In a process, these activities can be classified into two types: value-added activities and non-value-added activities. Value-added activities are activities where resources are used and as a result, acquisitions are obtained when providing a product or service. Non-value-added activities are work steps that do not provide any acquisitions in the process. By reviewing the activities, the process that needs to be improved is determined and improvement teams are created. The origins of the problems in the processes are detected and the appropriate improvement methods are determined, then the most appropriate methods are selected to minimize problems.

Improvement works are a subject that is on the agenda of the organization. The main point underlying the process improvement initiatives is an organization's effort to ensure customer satisfaction in the most effective way. Improvements are made by organizations so as to reduce errors and cycle times, improve motivation and cooperation as well as management practices, increase customer satisfaction, achieve higher performance, reduce idle time and unnecessary procedures and movements, and increase effectiveness. According to Harrington, the focuses of process improvement are reducing the cycle times, decreasing the costs, increasing the quality and job performances, and meeting the customer expectations at the highest level with the specific methods (Harrington, 1991).

Process improvement methods that are preferred in order to realize process improvement are also very important. In order to achieve the desired efficiency, it is recommended that each organization should use the improvement methodology appropriate to their own processes considering that the business processes are different from each other. However, the expected efficiency level can be reached by applying right improvement methodology.

In order to complete the process improvement works, it is not enough to implement only the changes. Conditions change over time; with changing conditions, processes also change. Therefore, making progress by changing in a process should be a continuous activity.

The source of the concept of continuous improvement is the "Kaizen" philosophy. Kaizen, a Japanese word means continual, incremental improvement. It is a term formed by the combination of words *Kai* and *Zen*. In Japanese, Kai means "change" and Zen means "good or for the better" (Palmer, 2001). According to Kaizen philosophy, everything can be improved. The main objective of this approach is to achieve perfection.

Kaizen philosophy emerged in the 1950s. In these years, there was an idea the products produced in Japan were poor quality. Due to this idea, organizations have tried to apply various improvement methods to achieve sustainability and better output. Studies were carried out on producing products with zero defects, intervening problems and solving the problems easily. The main benefits of improvement work can be summarized as follows: increased product and service quality, increased customer satisfaction, increased productivity, increased profit and employee motivation, reduced delivery time and reduced wastes (Fryer, Antony, and Douglas, 2007).

3.3 Statistical and Non-Statistical Process Improvement Methodologies

Various methods have been developed to make process improvement studies systematic. The main process improvement methods are Plan-Do-Check-Act (PDCA), Lean, Six Sigma, DMAIC, Lean-Six-Sigma, Process Capability Analysis (PCA). In order to achieve the desired efficiency, considering the fact that the business processes are different from each other, every organization should analyze its own process and use the improvement method that is most suitable for these processes. Merely, with the usage of the most suitable improvement method, the expected efficiency can be achieved. Therefore, the preferred improvement method is very important for a process.

3.3.1 Plan-Do-Check-Act (PDCA)

The basis of continuous improvement approaches is the PDCA (Plan-Do-Check-Control) cycle. Continuous improvement has repeatable and continuous nature. PDCA is a method that can help to stabilize the process and to make the idea that process improvement works will never be the last.

The PDCA cycle, also known as the Shewart or Deming cycle, is applicable to all stages and situations. Deming's cycle is consisting of a logical sequence of four repetitive steps for continuous improvement(Singh and Singh, 2009). Deming's PDCA cycle can be illustrated as follows:

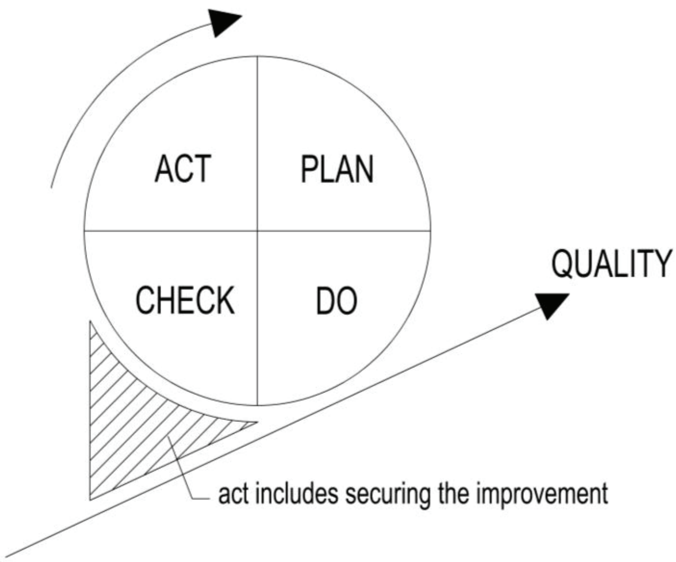


Figure 3.1. Deming's PDCA cycle

The steps in PDCA are summarized as follow:

- "*Plan*", identify and analyze the plan.
- "*Do*", develop solutions and implement solutions.
- "Check", evaluate the results and ask was the desired goal achieved?
- "Act", Standardized the solution (Johnson, 2002).

3.3.2 Process Capability Analysis (PCA)

In the highly competitive world, organizations must constantly improve themselves, their product or service in order to continue their existence. Therefore, quality improvement efforts have an important place in the modern industrial process. In order for organizations to achieve the desired level of quality, the product or service must be presented within the framework of the specifications expressing consumer expectations. Statistical techniques are used to determine and improve the quality levels of products or services. Statistical methods are important tools for improvement methods. By means of statistical tools, improvement methods analyze all aspects of the processes and take decisions in accordance with the findings. Statistical techniques demonstrate graphical and numerical findings to measure process variability, eliminate or reduce variability, and improve the process. Process capability analysis evaluates the variability of the process by considering specification limits. It establishes the basis of quality improvement and development works by revealing the relationship between the process performance and specifications. Two important elements for process capability analysis are process stability and process capability.

Process capability analysis as a tool of statistical process control (SPC) is an important tool in the application of continuous improvement of quality and productivity(Wu, Pearn, and Kotz, 2009). With process capability analysis, process variability can be measured, monitored and reduced (Arcidiacono and Nuzzi, 2017). Process capability analysis was performed to find out actual state of the process. Process capability studies help to verify whether the processes adopted by the manufacturer or the service provider are capable of meeting the customer specifications. In order to measure process capability, performance and specifications limits numerically, process capability indices (PCIs) was defined. Process capability indices are identified as "statistical indicators of the process capability" (Senvar and Toz, 2010). Capability indices were designed to quantify the relation between the actual performance of the process and its specified requirements. They help to determine whether a manufacturing or service process is capable to produce units with dimensions within a specified tolerance range or close to a specified target value.

It is highly necessary to identify the following terms to understand process capability indices. Quality characteristics are evaluated taking into consideration the specifications. Specifications in the manufacturing industry are desired values for the final product. Specifications in the service industry are the amount of the time to process to provide a service. The desired value for that quality characteristic is called the nominal or target value for that characteristic (Montgomery, 2009). Specification limits can be the Upper Specification Limit (USL), the Lower Specification Limit (LSL) and eventually a target value. The lower specification limit (LSL) and the upper specification limit (USL) are the minimum and maximum allowed value for the product or service. Specifications can either be two-dimensionally (when both of USL and LSL are specified) or one-dimensional (either USL or LSL is specified). The distance between the upper specification limit and the lower specification limit (USL – LSL) is defined as the specification spread. The center between the LSL and USL is known as the mean or target value. Measuring the process capability involves the knowledge of mean and standard deviation, μ and σ. These values estimated from data collected from the process.

Various capability indices namely C_P, C_{PU}, C_{PL} C_{PK} have been developed in the offer a standard quantitative measurement on process potential and performance (Gangeshwer, Verma, and Pandey, 2017).

Two most widely used capability indices are C_P and C_{PK}, which have been defined as the following:

$$C_p = \frac{USL - LSL}{6\sigma} \tag{3.1}$$

$$C_{PK} = \left\{\frac{USL-\mu}{3\sigma}, \frac{\mu-LSL}{3\sigma}\right\} \text{ or } C_{PK} = C_P(1 - \text{k}) \tag{3.2}$$

where USL and LSL are the upper and the lower specification limits, respectively, μ is the process mean, σ is the process standard deviation and k is process shift.

C_{PK} values relate to sigma quality levels. A higher C_{PK} value means a better process. The relation between the capability index value and process state is summarized in Table 3.1.

Table 3.1. Relation between capability index values and process performance (Source: Rajvanshi, 2001)

Capability index	**Estimation of the process**
$C_{PK} = C_P$	Process is placed exactly at the center of the specification limits.
$C_P < 1$	Process is not adequate.
$1 \leq C_{PK} < 1.33$	Process is adequate.
$C_P \geq 1.33$	Process is satisfactory enough.
$C_P \geq 1.66$	Process is very satisfactory.
$C_{PK} \neq C_{PK}$	Process is inadequate, new process parameters must be chosen.

The following Figure 3.2. and Figure 3.3. show the graphical comparison of process capabilities.

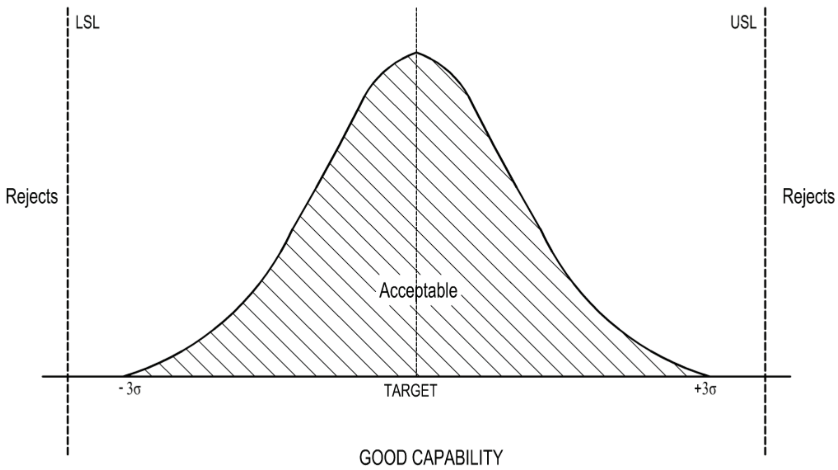


Figure 3.2. Good process capability

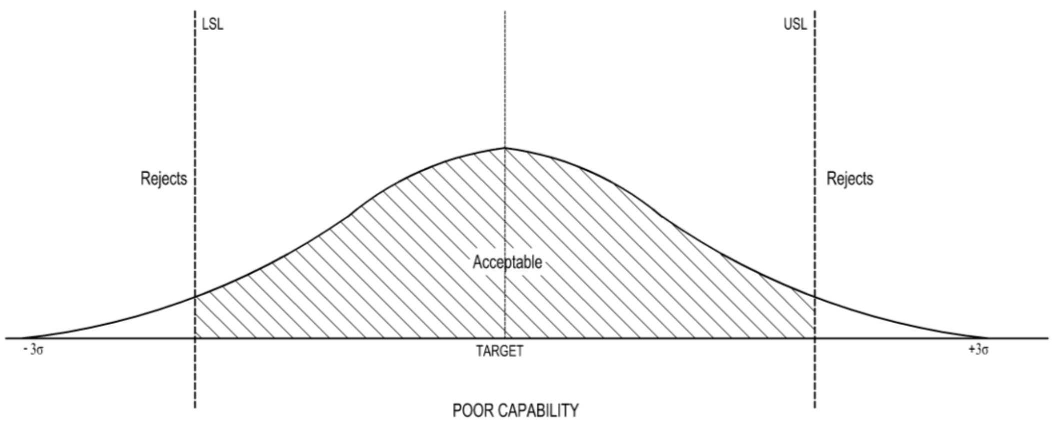


Figure 3.3. Poor process capability

If there is both an upper and a lower specification limit, the process is defined as two-sided and the process spread is 6 standard deviations. If there is only upper limit or lower limit (one-sided), then it will only be concerned with the side of the distribution closest to the specification limit and the process spread is 3 standard deviations. In order to measure the capability of a process in the unilateral tolerance situation C_{PU} and C_{PL} was defined. C_{PU} and C_{PL} have been designed particularly for processes with one-sided specifications which require only the upper or lower specification limit. The two well - known processes capability indices C_{PL} and C_{PU}, which measure larger-the-better (C_{PL}) and smaller-the-better (C_{PU}) process capabilities are given by the following formula:

$$C_{PL} = \frac{\mu - LSL}{3\sigma} \qquad C_{PU} = \frac{USL - \mu}{3\sigma} \tag{3.3}$$

For specification having only a minimum and no maximum, use C_{PL}. If there is only a maximum specification, use C_{PU}. C_P index calculates the tolerance with respect to two-sided specifications. C_{PL}, C_{PU} and C_{PK} indices estimate the tolerance of one-sided specifications.

3.3.3 Six Sigma

Six Sigma, which was first implemented by Motorola, attracted the attention of other companies after the successful results and spread throughout the world over time. While the first applications were in the manufacturing sector, it is possible to see various Six Sigma applications in almost all sectors today.

Six Sigma is a systematic way to improve process by reducing defects and variances based on statistical and scientific methods. Pheng and Hui define the six sigma from two different aspects; 1- "Six Sigma is a statistical measure used to measure the performance of processes or products against customer requirements. This is known as the *''technical''* definition of Six Sigma"; and 2- "Six Sigma is a *''cultural and belief''* system and a *''management philosophy''* that guide the organization in repositioning itself towards world-class business performance by considerably increasing customer satisfaction and enhancing bottom lines based on factual decision making." (Pheng and Hui, 2004). It can be defined as the following: Six sigma is a multidisciplinary, data-driven methodology used to eliminate defects within six sigma levels (lower and upper specification) of any process (Pande et al., 2000).

The variations in the processes prevent product or service provider from reaching the higher quality. W. Edward Deming proved this fact. After the Second World War, the approach that led to the development in the Japanese industry was the idea of "minimizing the variations by analyzing variances in production process" proposed by Deming.

The purposes of the six sigma are; creating lower standard deviations by reducing variation, ultimately ensuring that the offered services or products meet customer expectations, reducing cycle times and defects as much possible as.

Motorola president Robert W. Galvin emphasizes the importance of variability when describing Six Sigma: "If you can control variability, you can reach Six Sigma levels (zero defects) in all your parts and processes. Motorola employees have adopted this terminology. If you can control your variables, you can achieve stunning business results."

The methodology of Six Sigma involves understanding the role of statistical variation. The Sigma (σ) sign is a Greek letter used to indicate the standard deviation in statistics. Standard deviation, which is the measure of variation and distribution in statistic, is used to represent variability in processes. If the variances between values in certain conditions decrease, the standard deviation decreases as well. If the variance increases, the standard deviation increases. In other words, a high level of sigma means that there are fewer defects in a production or service process. There is an inverse proportion between the Sigma level and the defect numbers. Low level of sigma means variability or defects in a process more; high level of sigma indicates that there are fewer errors.

According to statistic aspect, "Six Sigma is the process that has six standard deviations between the target and upper specification or lower specification limit" (Chen et al., 2009). According to six sigma approach, if the number of defects can be measured in a process, the necessary solutions can be found to achieve zero error as soon as possible. The statistical representation of the six sigma provides a numerical indication of process performances. There should not be more than 3.4 errors per million in a process for six sigma approach. The principles behind six sigma are based on the concept of 'bell curve' which was developed by German Mathematician Gauss, called the bell curve, represents variations in a controlled process. In this normal distribution, the largest concentration of values is around the mean (average) and tails off symmetrically. The distance between the centerline and the inflection point (where the curve starts to flatten out) is known as sigma (σ), the standard deviation (George, 2003). The technical detailing of Six Sigma can be achieved by using normal distribution and process capability indexes. Six Sigma methodology is a philosophy that predicts the control of variables and is used as a quality management tool that targets zero error. It focuses on variables in processes while targeting it. Determining when, where, how often errors occur has basic knowledge of six sigma. In order to cope with the uncertainty caused by the variability, it is necessary to know what kind of frequency is seen and how it is distributed between the smallest and the largest of all values within the system/environment or situation. In this context, the most common concept of frequency distribution is normal distribution. If the distributions produced by the processes are seriously moving away from the normal distribution characteristics, it can be considered that a disturbing factor plays a role.

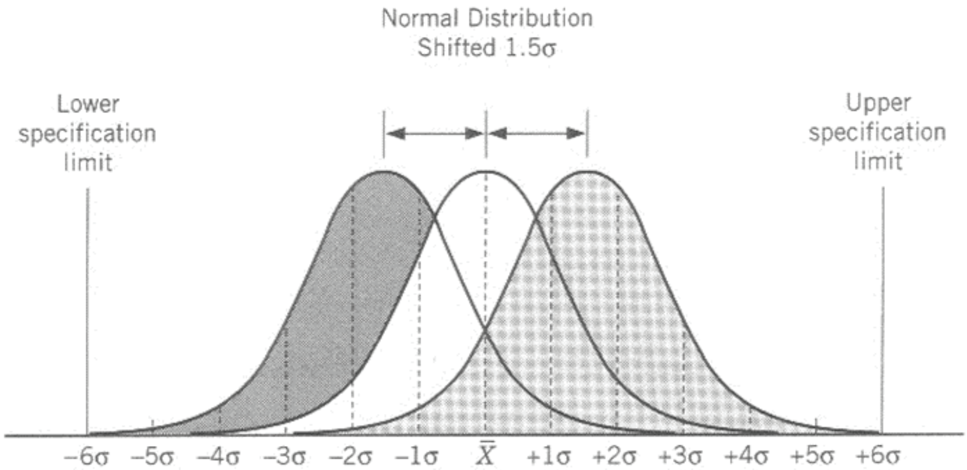


Figure 3.4. Normal Distribution Curve with 1.5 sigma shift
(Source: Yi-Lei Wu, 1999)

In the normal distribution curve graph, the area under the distribution curve is very small and narrow. For this reason, the graph is enlarged to 1.5 sigma on both sides. The purpose of the expansion is to make the results more realistic. A six sigma process has at least six standard deviation between the mean and specification limits. Because of some unavoidable causes, processes need to be shifted 1.5 standard deviations from process mean toward either specification limit that would provide the maximum of 3.4 defects per million. In normal distribution, six sigma levels correspond to 2 faults in a billion. After scrolling in the graph, six sigma corresponds to 3.4 errors per million. In this way, the targets become more realistic and achievable. Figure 3.4 illustrates the graphical details of six sigma capability with 1.5 sigma shift.

The institutions implementing the six sigma methods examine the process efficiency through sigma levels. Sigma levels have been associated with attributes such as error, poor quality, cycle time, efficiency. The sigma level value gives the number of errors made in the process. The larger the sigma level value in a process, the less error is made in that process. The relationship between the level of the sigma and the error rate is given in Table 3.2 below.

Table 3.2. Six Sigma levels and DPMO
(Source: George, 2003)

Sigma Level	**Defects per Million Opportunities (DPMO)**	**Yield**
6	3.4	99.9997%
5	233	99.977%
4	6,210	99.379%
3	66,807	93.32%
2	308,537	69.2%
1	690,000	31%

Statistical methods are important tools for six sigma method. Thanks to the statistical tools, six sigma analyzes all aspects of the processes and takes decisions in accordance with the findings. Six sigma processes and process capability indices are directly related to each other. C_{PK} values are related to sigma quality values. "Higher value of C_{PK} indicates a better process. For instance; a process capability, that is, C_{PK} of 1.00 is roughly equivalent to three sigma capability. That is, the mean plus and the mean minus three standard deviations should be the points at which the nearest specification limits lie. With three sigma capability or $C_{PK} = 1.00$, a process will produce approximately 99.73% good product or 0.27% bad product. This represents an unacceptably high level of poor products (Senvar and Toz, 2010).

3.3.4 Define-Measure-Analyze-Improve- Control (DMAIC)

DMAIC is a data-driven improvement cycle used for improving, enhancing and stabilizing business processes. The DMAIC cycle is the central tool used to drive Six Sigma projects. The main objectives of the Six Sigma methodology are the development of processes and reducing standard deviations. This objective is achieved by the implementation of DMAIC (Define-Measure-Analyze-Improve-Control). DMAIC methodology provides to reach six sigma performance level by solving specific problems in a process (Gardner, 2000). The origin of DMAIC is based on PDCA Cycle as well as other improvement methods. The below Figure 3.5 illustrates the phases of the DMAIC process improvement life cycle.

Figure 3.5. DMAIC cycle

While defining, measuring and analyzing are the processes categorizations steps, process optimization steps are the improve and control steps. Michael George described these steps in detail as follows.

Define: The first step, identification step, is to define the problem and determine the effect of this problem on customer satisfaction, stakeholders, employees, and profitability. To identify the problem, it is necessary to understand the processes and identify customer inputs.

The detailed description of the planned improvement, the limits of the project, the list of factors that are important for the customer, the flow diagram of the process is carried out at this stage. Determining the project boundaries and knowing which indicators to use to assess success are particularly important in service environments. Because, when the processes are mapped and studied on, they are effective to determine the starting and ending points of the process. Usually for service processes before improvement mapping is not done. However, determining the scope of the project is very important for the success of the project. Some metrics of success are customer satisfaction, lead/speed time, sigma level improvement and financial outcomes.

Measure: At this stage, priorities are set and all necessary data are collected to achieve these goals. Data are very important for understanding and accurate analysis of the process. Defects and deficiencies in process performance and the process can only be determined by accurate measurements. For this reason, process capability indices are used for systematic process measurement. However, in services, employee and customer factors in the processes cause variability.

Analyze: The analysis phase includes a detailed examination of all data collected during the measurement phase. The aim of this step is to determine the parameters that cause the variability in the processes. To understand the root causes of defects in processes, to understand the basic causes of variability, to understand the nature and distribution of data, to determine the variables of the basic service processes that cause defects, to evaluate the improvement opportunities financially are the actions to be taken into consideration at this stage. The main purposes; to confirm the origin of delays, low quality, and waste.

Improve: In this step, solutions are created to eliminate problems and these solutions are put into practice. The main objective is to contribute to the process development of innovative solutions based on collected data. At this stage, changes are made by eliminating the defects, wastages, and costs depending on the customer requirement, etc. which are determined at the define stage.

Control: At this stage, the reliability and accuracy of the solutions put forward during the improvement step and the improvement studies are confirmed. It is ensured that process improvement is permanent or not. Feedback is required to understand how well the change works (George, 2003).

3.3.5 Lean

Lean is one of the continuous improvement methodologies. The main idea of lean thinking is to minimize waste while maximizing customer value. Womack and Jones explained the aims of lean thinking, which is satisfying customers by increasing the value of the products or services for them and reducing the lead times. To achieve these goals, he stated that mechanisms such as eliminating waste, reducing process time and simplifying operation should be used (James P. Womack and Jones, 1996).

Toyota engineer Taiichi Ohno explained lean thinking process, as "The only thing we do is look at the timeline, from the time the customer ordered it to the point where we received the cash payment. To shorten this timeline, we eliminate waste that doesn't add value". Lean is not only a production system; it also suggests that it is a business system that covers all aspects of launching a product, including design, supplier management, production, and sales (Graban, 2012).

The origin of the Lean thinking system is based on Toyota's production system. In the 1950s, Toyota engineer Taiichi Ohno made his observations during his visit to the United States to examine Ford and concluded that Ford's mass production system was not suitable for Japan. This decision enabled the development of a new production and management approach, lean production. In the 1940s, Toyota had a system of continuous production in demand. Toyota did not adopt a long production system, and only a small part of the total time and effort for the product value added to the final customer was recognized. However, the western production system was quite different from the system of Toyota. The production system developed by Henry Ford was adopted in the Western production system.

Lean thinking is a system of thought that was put forward by James P. Womack and Daniel Jones in 1996 to guide managers. There are five basic principles of lean thinking to improve the success and effectiveness of an organization or business. According to Womack & Jones, these principles are value specification, value stream mapping, flow optimization, pull production system and perfection or continuous improvement (Rand, Womack, and Jones, 1997). Detailed explanations of these steps are like below.

- Identifying the value: Value is expressed based on how the specific product meets the needs of the customer at a given time, at a specific time, so the value must always be determined by the customer's perspective.
- Mapping the value stream: It is determined simultaneously in the activities contributing to the value by determining the value. The value stream is a series of activities from the point of origin of the product or service to the cost. Wastes can only be destroyed by analyzing the actual value flow of

the process. Activities are carried out on whether the activities that do not add value to the product or service are required and activities that do not create value are removed from the process.

- Creating the flow: It is very important for the removal of waste. If the flow does not continue, waste is generated. Therefore, the continuous flow should be created in the processes. After the removal of waste from the value stream, it should be ensured that there are no problems such as bottleneck, travel, interruption in flow.
- Establishing the pull: Companies should ensure that the product or service is not exactly before or after the customer need, exactly when the customer needs it. With the improved flow, time to market or customer can be significantly improved. This means full-time production or delivery. Thus, the customer may withdraw the product or service as required. Customer demand should be expected since the formation of products or services without customer demand will cause waste.
- Seeking the perfection: This effort is the repeated and constant attempt to remove nonvalue activity, improve flow and satisfy customer delivery needs. Lean focuses on removing waste and improving flow. In addition, quality is improved with lean thinking, less time is needed for product operations. the possibility of damage and damage is reduced. Simplification of processes with simple thinking contributes to the reduction of variation, significant improvements in process performance are achieved (Nave, 2002).

Lean thinking is based on continuous quality improvement philosophy. Continuous review of the steps is necessary to follow the process's perfection. Figure 3.6 displays lean thinking working system based on PDCA cycle. The first four steps of these five principles are aimed at establishing a lean system, and in step 5, it is aimed at cultural change with the excellence approach.

Figure 3.6. Lean Thinking sequential steps

Lean process improvements identify inefficiencies, reduce process steps, reduce process time, and reduce errors in work. The lean methodology is to eliminate waste or non-value adding activities such as waiting and reworks. It also aims to increase the speed of operations and simplify process flow (Man, Zain, and Nawawi, 2015). In addition to reducing waste and improving a specific process, lean is also to build a culture that is respectful to all employees and can develop opportunities to improve their work and share ideas for continuous improvement.

One of the most effective methods to improve business processes is lean thinking. The effects of lean thinking on business processes are as follows: Improves the quality of business processes, minimizes errors and defects in business processes, reduces costs, improves flow of process, simplifies complex processes, shortens lead-time, and increases employee motivation. Liker states lean thinking as best quality, lowest cost, shortest lead-time, best security, high morale (Liker, 2004).

3.3.6 Lean-Six Sigma

Six sigma and lean are now two of the most important improvement approaches in service and production. Under favor of their success, lean manufacturing and six sigma principles and their tools are used not only in production but also in many areas such as education, construction and health. Lean Six Sigma (LSS) combine the features of Lean and Six Sigma in business performance enhancement (Corbett, 2011).

The lean six sigma that combines the lean and the six-sigma approach under one roof brings together the strengths of these two methods in a balanced manner. The focus of the six sigma method is to improve the quality by reducing errors and variability as much as possible, while the focus of lean is the elimination of waste and the removal of activities that do not create added value from the production process. It must be the least of the variability with the losses in the processes. In this context, lean and six sigma will be more meaningful and efficient when used together. More decisive processes are achieved by reducing the change and eliminating the losses. By means of the synergy created using these two techniques together and in a way to support each other, slow work processes change, interruptions in the workflow are eliminated, the variability decreases and the process speed increases directly.

While both Lean and Six Sigma have been used for many years, they were not integrated until the late 1990s and early 2000s, Nowadays, production, marketing, sales, service, service design can be applied easily in many business areas and it provides very important returns. The main advantages of this are: to reduce costs, shorten delivery time, reduce stock levels, increase customer satisfaction, reduce product cost (10-25%), more powerful and robust (Atmaca et al., 2009).

Lean six sigma is a business development approach. In the service industry, lean six sigma increases the value of shareholders by providing rapid improvements in customer satisfaction, cost, quality process speed, and investment capital. Lean six sigma is a method that enhances the speed and results of improvement projects by combining the speed principles of lean and the immediate response of the six sigma to the improvement process. In another point of view, Lean six sigma includes the six sigma aspect of the evils of variation and decreases its effect on waiting time.

The benefits of Lean Six Sigma in both manufacturing and services industry can be summarized the following:

1. Ensuring services or products conform to what the customer needs
2. Removing non-value adding activities called as waste in critical business processes.
3. Reducing the cost of poor quality.
4. Reducing the incidence of defective products or transactions.
5. Reducing the cycle time.
6. Delivering the correct product or service at the right time in the right place.

3.4 Process Improvement Methodologies in the Service Industry

Most work on quality management and improvement philosophies are designed to improve product quality in the manufacturing industry. But it works just as effectively in service industries too. There are some reasons to need application six sigma in the service industry. These reasons can be explained as follows. Six sigma methodologies offer significant opportunities for reducing costs and increasing process efficiency in service processes. Service processes generally perform less than 3.5 sigma quality. Improving the quality of Sigma contributes to the reduction of the defect rate and improvement of the process performance. It also improves the financial return in service processes. Another reason for the implementation of six sigma in the service sector is that the customer can recognize process variability (Antony et al., 2007). With the six sigma applications in service processes, it is aimed to determine the causes of defects in the process and to improve the processes by eliminating the causes of defects. Reducing the defects in the process will improve the quality of the processes and increase customer satisfaction.

Service industry has different characteristics than manufacturing. “A service cannot be stored on a shelf, touched, tasted or tried on for size.” (Chakrabarty and Tan, 2006). In order to implement six sigma in the service sector, it is important to understand the special characteristics of service industry. Laureani studies these characteristics into four main topics: intangibility, perishability, inseparability, variability. Measuring and objectifying services are difficult. Services are not taken inventory. concurrent realization of delivery and consumption of the services causes complexity in the process. A service cannot be duplicated easily like products. Each process is unique. This leads to increased variability in processes and different customer experiences (Laureani, 2012).

Due to the mentioned features of service processes, some difficulties can be experienced in six sigma applications. By the reason of intangible criterions, gathering, and measurement of data in service processes, is more difficult than production process. Measuring customer satisfaction is also difficult. In addition, it is hard to distinguish main processes and sub-processes in service processes. This makes it difficult to control the measurement and analysis stages of the six sigma. Unlike production processes, data cannot be collected automatically and regularly in service processes. It is usually done manually by face-to-face interaction (Benedetto, 2003).

The benefits of six sigma for service industry can be summarized as follows: it develops cross-functional team-work in the organization. It provides changes to prevent damages in organizational culture. With systematic elimination in critical business processes, it decreases the value-added process steps, lead times and provides faster service delivery. Lower quality indicators such as late delivery, customer complaints, misdirection are reduced. Problem-solving and awareness-raising activities throughout the organization provide job satisfaction in employees. It develops management skills based on data and facts, understanding customer needs and expectations. Six sigma has a great impact on customer satisfaction and loyalty. It contributes to an increase in market share (Antony et al., 2007). Briefly, the proven benefits of six sigma in many different areas can be summarized as a reduction in costs, increase in productivity, increase in market share, increase in customer satisfaction, decrease in cycle time, decrease in error rate, positive cultural change, product/service development.

From the emergence of lean thinking to the present day, the popularity of lean thinking has spread widely. Previous practices have focused on manufacturing companies. In the manufacturing sector, lean thinking has a good place for itself. Therefore, concepts such as lean production were introduced. However, the philosophy of lean thinking is spreading in many areas such as service, trade, and public sector (James P. Womack and Jones, 2005). Service industry benefits from lean to the increase organizational competitiveness and customer satisfaction, and the reduce process variability and wastes (López, Requena, and Lobera, 2015). Lean is a method of determining where the value is in a process, destroying the waste in the process and creating value for the customer. Therefore, it can be applied to all kinds of organizations.

Unlike the manufacturing industry, the customer is involved in the service industry. Quality for the service industry is customer experience. Service quality is also determined by taking into account the degree of compliance between the customer's expectations and service perception. Customer is the descriptor of value in the service industry (López, Requena, and Lobera, 2015).

There is no standard in services when and where to use lean tools. However, it is a fact that the applications used in production produce positive effects both economically and financially when applied to services. Lean creates process speed by reducing cycle time and efficiency in any process (George, 2003). It is a fact that service processes and production processes are different from each other. The human factor is quite important for in the service sector. Abid argues that the human factor is a significant variable in the service sector (Abdi, Shavarini, and Hoseini, 2006). Because, human is directly responsible for the submission, implementation, delivery of services. Services face slow processes and high costs due to non-value-added activities leading to low quality and low customer satisfaction. The high costs caused by the services and the competitive environment cause more customer losses than manufacturing. For this reason, many organizations aim to satisfy the customers, reduce costs and increase profitability by integrating the lean principle.

In the service sector, lean is an effective way to offer higher quality services, add value to customers and accelerate the process with less but accurate resources. In order to reduce the cost and complexity, it is necessary to analyze and reduce the value-added activities. Employees should identify waste and hidden costs in the process. This may require companies to be reorganized to perform less capacity, materials and work more efficiently. Additionally, organizations should focus on value-added activities from a customer perspective. Due to this way, they will better understand how much they want to pay to improve their customers' needs and service quality (George, 2003).

Lean thinking is a system of thought that focuses on processes that add value to the customer and aims at eliminating and reducing waste. According to lean thinking, waste is any activity that does not directly or indirectly add value to the customer's product or service. In some processes, there are wastes that cannot be eliminated, which have been an important part of the process. Otherwise, all ‘Muda’, as the Japanese call waste, should be eliminated (Melton, 2005). There are seven forms of waste: over-production, waiting, defects, excessive transportation, unnecessary motion and inventory, inappropriate processing (Pepper and Spedding, 2010). According to Rother and Shook, the factors that cause waste in processes are inadequate working methods, long preparation times, insufficient processes, lack of training, insufficient maintenance, long distances and lack of leaders (Rother and Shook, 1999).

George (2003) explains the 7 forms of waste in lean discipline from a service perspective.

Over-processing: Over processing is trying to add more value to a product or service and to do more work than is necessary to satisfy customers. There are two main elements of over-processing: adding more ‘value’ than needed and adding non-value work into a process.

Transportation: It is defined as an unnecessary movement of materials, products or information which should be reduced for activities that do not add value or cause to the occurrence of waiting time and queues. In the processes, transitions between activities take time and the waiting causes to occurring queues. For this reason, lean thinkers aim to minimize excessive transport.

Motion: Transportation is used to define the movement of the works, motions used to define the movement of workers. Needless movement of workers does not add value to services, it takes only additional time and cost. Because of this, the needless movement of people is seen as waste. Measuring the motion in the service sector is harder than manufacturing.

Inventory: This waste, which usually occurs as a result of overproduction, is the process that exceeds what is necessary to serve customers. It does not meet customer expectations and leads to long lead times and waiting times.

Waiting time: The delay in activity also causes a delay in the next step. Waiting time can be analyzed by looking at each activity in the process to identify delays. Process mapping technique is essential to identify the process delay.

Defect: It is defined as any aspects of service that cause the customer to be unhappy with the results. Examples such as missing or incorrect information and documents, applications, missed delivery times can be shown as examples of defect. Services should not only consider error costs but also customers.

Overproduction: The waste is generated by organizations producing more service data or products than customers want (George, 2003).

Lastly, in recent time, one more waste is defined by Womack and Jones which is known as ‘the misuse of intellectual capital waste’. It is explained as not using the complete employee capacity in improvement processes (Womack and Jones, 1997).

Lean six sigma is a business development approach. In the service industry, lean six sigma increases the value of shareholders by providing rapid improvements in customer satisfaction, cost, quality process speed, and investment capital. Lean six sigma is a method that enhances the speed and results of improvement projects by combining the speed principles of lean and the immediate response of the six sigma to the improvement process. In another point of view, Lean six sigma includes the six sigma aspect of the evils of variation and decreases its effect on waiting time. Additionally, Lean Six Sigma attacks against the hidden costs of the complexity of offering.

George illustrated the three main reasons why service process needs to apply Lean Six Sigma:

- Service processes are expensive and slow processes. Slow processes are often low quality and costly. This reduces customer satisfaction and incomes directly. As a result; the majority of service applications are actually non-added value wastes.
- There is a lot of “work-in process” in service process so, processes are very complex and slow. Too much “work in process” causes losses in work time. The loss of time makes it difficult to help customers and creates substantial waste in the process.
- Some of the activities in slow processes cause delays. Work steps leading to delays should be identified and developed to reduce cycle times and ensure more on-time delivery (George, 2003).

3.5 Process Improvement Methodologies in Construction

The construction sector contributes greatly to the economy of the countries. It has been viewed as “special form of industry” – a hybrid between product and service industry. With its impact on other sectors, construction sector, it has a great role in the development of the country and providing employment to individuals. In addition, the construction sector plays an important role in trade in the country in terms of both expenditures and revenues. Construction sector consumes many resources and produces wastes. Large amount of waste and delays may greatly affect the productivity and efficiency of the construction projects.

Continuous improvement is a crucial factor for the success of each organization or company. Continuous improvement was initially used only by firm operating in the production industries, but it spread to firms operating in the service industries over time. Today’s competitive market has created the need for continuous improvement in the construction industry. The customer needs in terms of time and cost efficiency and competition between the companies in the construction industry has increased day by day. Today’s conditions and competition make it necessary to provide more than the customer’s needs as well as to meet the basic needs of the customer.

The continuous improvement methodologies such as lean, six sigma and lean Six Sigma etc. can be applied in the construction process to reduce the wastes and variability, while increasing the process performance, quality, and customer satisfaction. Although continuous improvement methods have been used frequently in other areas and they give successful results, their use in construction areas is limited. There is a limited source of research on continuous improvement in the construction industry compared to production industry. This section represents the review of literature collected from various journals and articles that are most relevant to continuous improvement methodologies used in the construction sector.

Pheng and Hui explore the investigate benefits of applying the concept of six sigma in construction organizations. They present the implementation process of six sigma program and responsibilities of team members. Pheng and Hui report that the implementation of six sigma method in the construction organization resulted a noticeable improvement – reduce the variability in the processes. They conclude that management initiative and support, relevant training program, appropriate selection of pilot projects, and commitment by team members are considerable importance for successful implementation of six sigma in the organizations (Pheng and Hui, 2004).

Stewart and Spencer suggest that a few construction companies have been using applied six sigma method. They present the outcomes of sig-sigma method and its benefits on the construction industry for both researchers and practitioners. The case study in their research is the results of six sigma process improvement project accomplished for the construction of concrete longitudinal beams in the St Pancras raised railway station in London. The outcomes are listed as the productivity increase of beam construction, improved interaction between project teams and decreased project delays (Stewart and Spencer, 2006).

Sukumar and Radhika investigate lean six sigma as a process improvement method on construction processes by evaluating the factors affecting construction wastes. They use Six Sigma DMAIC method to improve construction process. Sukumar and Radhika conclude that reducing waste and increasing efficiency can be obtained at the same time using lean six sigma DMAIC methodology (Sukumar and Radhika, 2017).

Amitha and Shanmugapriya focus on the occurrences of wastes in the construction site. They identify an existing problem in the construction industry by using lean methods. Non-value adding activities in the construction industry induce the loss of quality. Amitha and Shanmugapriya report the application of lean six sigma methodology to eliminate wastes and improve the process. In their study, six sigma concept is regarded as a continuous improvement method to reduce variation and prevent the occurrence of defected product and services in the process. Lean six sigma is applied under the guidance of DMAIC and DMADV to improve performance, enhance the effective leadership, reduce waste and variation and satisfy the customer. The combination of lean and six sigma concepts is logical for continuous improvement methods for the construction sector. The final results of their study show that the implementation of lean six sigma concept in construction help to reduce the defects and increase the value. They argue that integration of lean and six sigma concepts create a more powerful tool to improve the construction process (Amitha and Shanmugapriya, 2016).

Oguz, explains how lean and six sigma methods widely used in production are applied on construction projects and how they measure the process capability index (cp) through a case study. They argue that lean six sigma methods can also be used in the construction sector. The case study tries to prove that the combination of six sigma and lean concept eliminates variations in the process and can be used in process improvement by creating a workflow. In the case study, lean six sigma methods are applied on a reinforced concrete production system in a multi-story complex project. As a result of the study, it reported that that lean six sigma improved the production rate of concrete panels. Six Sigma lean methods are integrated with each other and they are defined as a powerful production management tool. The lean method eliminates any activity that does not add value and provide a secure workflow; six sigma control and reduces the variables. Lean six sigma encourages continuous improvement of processes by analyzing both the root cause of variation and eliminating waste. Therefore, it proposed that construction companies use both lean and six sigma tools to solve business problems. The calculated Cp (process capability index) value was denoted as 0.9 which was lower than the recommended level for new production in the manufacturing sector (Oguz, 2012).

Banawi believes that the construction sector is a sector that consumes a lot of resources and creates waste when it is managed poorly and inefficiently. In order to improve the performance of the construction process and to improve the efficiency of the processes and to improve their environmental impact, a framework has been developed which combines three different approaches: lean, six sigma and green. This framework aims to improve process performance and to reduce wastes during construction phases of projects. A case study of the installation of the pile caps process is implemented to exemplify and validate the framework. In the study, it suggested that determined that delays and faults in material estimation and order caused waste generation in the process. Environmental effects of wastes are investigated. Additionally, the sources of waste generation are analyzed in detail. According to the survey conducted by construction professionals, a great majority of construction wastes are caused by design changes during construction (Banawi and Bilec, 2014).

Han et. al investigate the key factors affecting construction performance enhancement by using Six-Sigma. The suggested method is designed to obtain reliable workflows by decreasing process variables such in the desired range. Two case studies which are Iron-Reinforced Bar Assembling and Deck Plate Installation Process are selected for the verification of the proposed methodology. Han et. al suggest that Six Sigma methods can be used in construction projects to reduce workflow variability and provide more concrete measures of project performance. They conclude that six-sigma offered more advantages by optimizing solution sets from performance indices, specifically for the cases which are complex and lengthy. Six-sigma technique is reported to be a managerial instrument for productivity and quality enhancement as well as a systemized tool for quality and process control. Han et. al point out that the quality inconsistencies and faults in the construction process may be controlled in more practical ways by using six sigma principles (Han et al., 2008).

Desale and Deodhar state that six-sigma is a widely accepted philosophy in manufacturing and production industries, and it can be used in construction within a few modifications. This study contains a literature review and discussing process improvement methods in the construction industry and analysis of features and principles of six sigma. According to Desale and Deodhar, six sigma can provide improved quality concept, detailed performance measurement and coordination and performance improvement in an iterative process, However, they also argue that there is still a gap in the literature for the implementation of six-sigma in the construction industry. They propose that there are technological, financial, external and internal barriers to implement lean. Also, it is stated that the main problem faced by organizations is the application of theoretical knowledge of Six Sigma into a practical manner (Desale and Deodhar, 2013).

Tcihidi, He and Li argue that using six-sigma principles may increase the cost but on the other hand six sigma management increases quality management in the long term.

Also, they suggest that six-sigma approach can be used in the construction quality management for their construction applications. They state that six sigma provides to decrease energy consumption, pollution noise pollution and waste during the construction. Additionally, it helps to create new ideas and strategies to complete life cycle of a building (Tchidi, He, and Li, 2012).

It is argued that applying lean six-sigma in construction increases quality while it reduces cost. Abdelwanis and Feitouri apply the concept of "lean six-sigma" in Libyan construction projects. They investigate the main reasons behind the waste in a part of water distribution system and applied lean six sigma to find major causes and eliminate the waste (Abdelwanis, Faisal, and Feitouri, 2018).

Dave and Appleby state that construction organizations need to use continuous improvement in order to survive in a competitive environment. Dave and Appleby focus on how construction organizations can improve their efficiency by using improvement methods such as simple construction with information and communication systems. The work presented his study describes process improvement project in a large-size construction organization. Dave and Appleby recommend that business processes and information technologies should be considered together in order to achieve better results (Dave and Appleby, 2015).

Samman and Graham investigate the benefits of Six Sigma in the construction industry. They propose a road map for the implementation of Six Sigma in the construction industry. The case study investigates reducing personal lost days owing to injuries and to improve safety and health program by implementing use of Six Sigma methodologies in a construction company (Samman and Graham, 2007).

Anderson and Kovach report that the implementation of Lean Six Sigma methodology result in decrease in welding defects and schedule delays in a turnaround project of a construction organization. They suggest that using Lean Six Sigma methodology may reduce the possibility of defects, delays and financial losses (Anderson and Kovach, 2014).

Ullah et. al argue that one of the important aspects of Six Sigma is that the use of Six Sigma in the construction industry is still so rare. Ullah et report that half of the construction professionals in Pakistan have no knowledge about the Six Sigma implementation. They also report that the application of Six Sigma result in increase in project performance by 50%. Yet improvement project performance comes with increasing complexity of projects (Ullah et al., 2017).

Smita Pataskar explain the basic theory of Six Sigma, principles, methodology and various tools. In their paper, DMAIC methodology of Six Sigma is used to increase the quality of internal finishing work for residential building. Sigma levels are calculated to identify and improve the construction process. They conclude that Six Sigma is a scale to measure quality and it provides a systematic approach to identify and improve the construction process (Sawant and Pataskar, 2014).

Sahimol Eldhose examine the defects in high-rise building causing low-quality standards. They use a survey-based approach incorporating including DMAIC method of Six Sigma. The building quality level is evaluated by using Six Sigma method. Their study presents factors (e.g., lack of knowledge, low-quality materials and tools low-quality tools, unsafety measures at sites and delays in schedule) that affect the quality level of buildings (Michael and Eldhose, 2014).

Muharrem reports that Six Sigma can be useful in enhancing quality in an efficient way in the construction industry as well as it may increase motivation, knowledge, and skills of workers. In his paper, the characteristics of six sigma in construction context are discussed, and metric and belt system are also explained. The results reported in this paper are based on a literature review and a series of interviews conducted construction organizations adopted and implemented DMAIC and DFSS methodologies of Six Sigma (Muharrem, 2012).

Table 3.3. Literature Review

Author	Year	Methodology	Application Area	Stage in Project Life Cycle	Continuous Improvement Methodology
Pheng, L. S., and Hui, M. S.	2004	Case study Interview Documentation	An organization in the building industry : the Housing and Development Board (HDB) in Singapore	Construction	Six Sigma DMAIC

(cont. on next page)

Table 3.3. (cont.)

Stewart, R. A., and Spencer, C. A.	2006	Case study Interview	Construction of concrete longitudinal beams on the St Pancras raised railway station in London, UK.	Construction	Six Sigma DMAIC
Sukumar, S., and Radhika, R.	2017	Problem Identification Questionnaire Data collection Analysis	Questionnaire about the factors affecting implementation of lean six sigma	Construction	Six Sigma DMAIC
Amitha P, and Shanmugapriya, T.	2016	Literature review Data Analysis	The Indian Construction industry	Construction	Lean Six Sigma
Oguz, C., Kim, Y. W., Hutchison, J., and Han, S	2012	Case study Interview	Concrete Panel Production for villas in Jubail Industrial City in Saudi Arabia	Construction	Lean Six Sigma
Banawi, A., and Bilec, M. M	2014	Case study and Questionnaire	Installation of pile caps for the Mascaro Center for Sustainable Innovations (MCSI) building	Construction	Lean, Six Sigma and Green
Han, S. H., Chae, M. J., Im, K. S., and Ryu, H. D.	2008	Case Study Data analysis	Iron bar assembling process and deck plate installation process in building construction	Construction	Six Sigma DMAIC
Desale, S. V, and Deodhar, S. V.	2013	Literature Review		Construction	Six Sigma DMAIC

(cont. on next page)

Table 3.3. (cont.)

Tchidi, M. F., He, Z., & Li, Y. B.	2012	Data collection and analysis Case study	Composite structure prefabrication construction process	Construction	Six Sigma DMAIC
Abdelwanis, N., Faisal, M., and Feitouri	2018	Observation Data collection and analysis	Infrastructure construction project at Al-Abyar City	Construction	Lean Six Sigma
Dave, B., and Appleby, C.	2015	Case study	Construction and property company	Construction	Lean
Rafat A Samman and Ian Graham	2007	Case study Data collection (interview, documentation)	Construction company to reduce personal lost days	Construction	Six Sigma DMAIC
Nicole C. Anderson & Jamison V. Kovach	2014	Case Study	Construction company		Lean Six Sigma
Fahim Ullah Muhammad Jamaluddin Thaheem Siddra Qayyum Siddiqui Muhammad Bilal Khurshid	2017	Semi-structured interviews And questionnaire survey	Pakistani construction sector		Six Sigma DMAIC
Sneha P. Sawant1 and Smita V. Pataskar	2014	Case study	internal finishing works of Residential building	Construction	Six Sigma DMAIC
Susmy Michael1 , Sahimol Eldhose	2014		Construction works of multi-storeyed buildings	Construction	Six Sigma DMAIC
Yilmaz Muharrem Firat	2012	Literature Review and interviews			Six Sigma DMAIC

The preceding sections (Summarized in Table 3.3) point out the process improvement methods have been mainly used to improve construction operations and activities. The main driving force behind the research studies presented in Table 3.3 to reduce wastes, minimize variability, increase process performance, improve service quality and, meet customer expectations. It is also clear from Table 3.3 that process improvement methods in the construction management literature mainly focus on construction phase of the projects (i.e., construction operations and activities). Yet the process improvement methods offer significant potential benefits for the other stages and sub-stages of construction projects. A promising application area of process improvement methods is the "tender evaluation process". The application of process improvement methods to this neglected but important sub-stage of construction project, tender evaluation process, has the potential to fill an important gap in the literature.

CHAPTER 4

RESEARCH METHOD

4.1 Introduction

The research method used in this thesis developed by following general guidelines used in previous process improvement studies.

4.2 Sampling

In this thesis, the tender database of Public Procurement Authority (PPA) was used to collect data. The screenshot of this database is shown in Figure 4.1. Data collection process was performed by using a number of search criteria. Eight search criteria are used to construct the research sample. The criteria used to construct the research sample are as follows:

- Top administration
- The name of the public agency
- Department of public agency
- Tender information
- Tender procedure
- Tender type
- The year of registration
- Sorting

In the selection process of tenders, all filters were used except tender information filter. The main criteria are (1) top administration, (2) tender procedure, and tender type. The top administration was chosen as Council of Higher Education (CoHE-namely YÖK in Turkish). This administration is responsible for planning, coordination, and governance of higher education system in Turkey. Tender procedure and type were determined as open procedure and construction works, respectively. Considering these filters, all tenders for construction works that were published by public universities attached to CoHE between 2005-2010 were investigated.

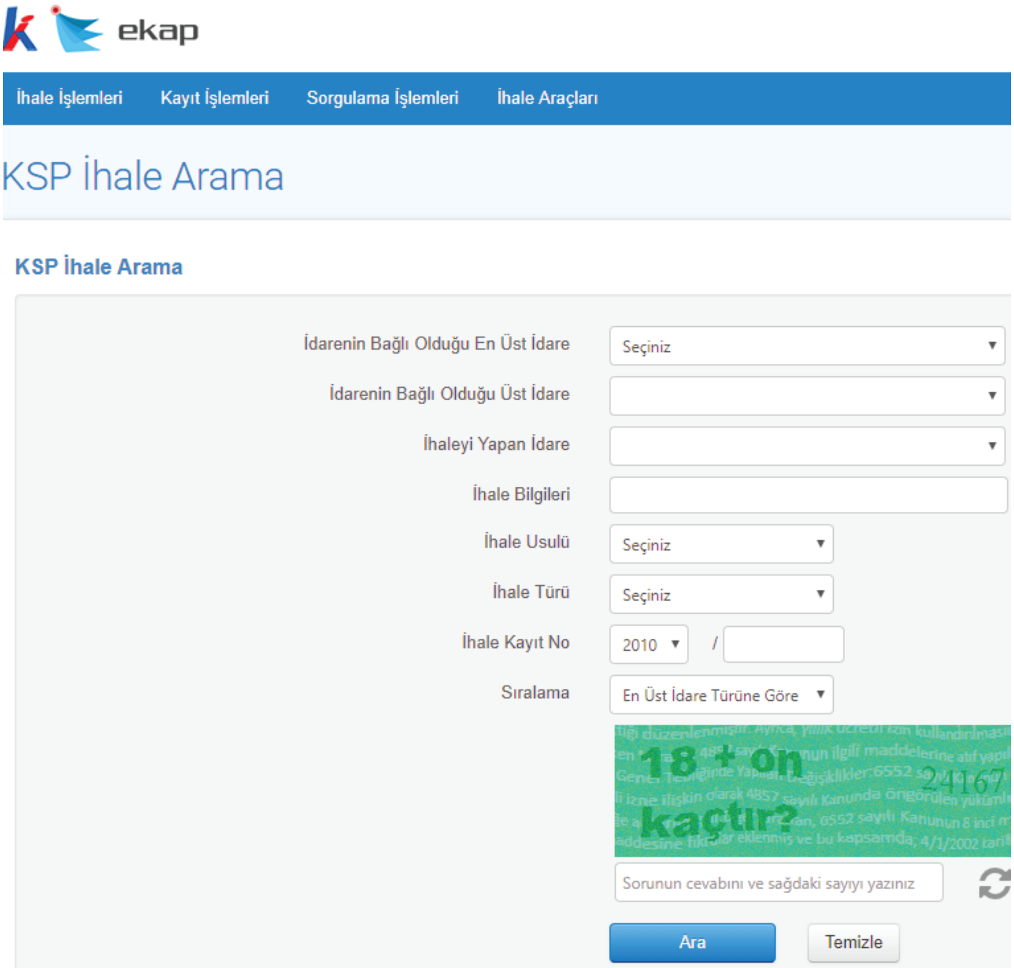


Figure 4.1. Public procurement database interface

The results according to the selection criteria were listed in the tender search webpage and then, the details and information of these listed tenders were documented. (As shown in Figure 4.2) The data from gathered from the mentioned database were formed in MS Excel file as a table. In this table, the headings are as below: *tender registration number, tender date, the name of public agency, department of public agency, tender name, tender type and procedure, approval date, announcement date, name of the firm, estimated cost, contract information, highest and lowest bid, contract date, number of valid bids, total number of bids, the name of complainant firm, date of complain, document number, results of complaints*. Additionally, tender duration, preparation time, complaint status and the logarithm of tender duration were added to the table according to the given information. A total number of 650 tenders were found according to a specified date, tender type, and procedure.

	A	B	C	D
1	Tender Registration Number	Tender Date	The Name of Public Agency	Department of Public Agency
2	2010/5437	22.2.2010	AKSARAY ÜNİVERSİTESİ	YAPI İŞLERİ VE TEKNİK DAİRE BAŞKANLIĞI
3	2010/32913	22.4.2010	AKSARAY ÜNİVERSİTESİ	YAPI İŞLERİ VE TEKNİK DAİRE BAŞKANLIĞI
4	2010/27826	1.4.2010	AKSARAY ÜNİVERSİTESİ	YAPI İŞLERİ VE TEKNİK DAİRE BAŞKANLIĞI
5	2010/115435	14.9.2010	AKSARAY ÜNİVERSİTESİ	YAPI İŞLERİ VE TEKNİK DAİRE BAŞKANLIĞI
6	2010/100869	3.8.2010	AKSARAY ÜNİVERSİTESİ	YAPI İŞLERİ VE TEKNİK DAİRE BAŞKANLIĞI
7	2010/73966	12.7.2010	AKSARAY ÜNİVERSİTESİ	YAPI İŞLERİ VE TEKNİK DAİRE BAŞKANLIĞI

	E	F	G	H
1	Tender Name	Tender Type-Procedure	Tender Approval Date	Tender Notice Date
2	BEDEN EĞİTİMİ SPOR YÜKSEKOKULU YAPIM İŞİ	CONSTRUCTION WORK-OPEN	14.1.2010	28.1.2010
3	MERKEZİ DERSLİK VE AMFİ BİNASI YAPIM İŞİ	CONSTRUCTION WORK-OPEN	18.3.2010	29.3.2010
4	ANAOKULU BİNASI YAPIM İŞİ	CONSTRUCTION WORK-OPEN	5.3.2010	17.3.2010
5	KAPALI YÜZME HAVUZU YAPIM İŞİ	CONSTRUCTION WORK-OPEN	6.8.2010	17.8.2010
6	MEVCUT ATLETİZM PİSTİNE EK ISINMA PİSTİ VE EK	CONSTRUCTION WORK-OPEN	16.7.2010	22.7.2010
7	ÇARŞI BİNASI YAPIM İŞİ	CONSTRUCTION WORK-OPEN	14.6.2010	21.6.2010

	I	J	K	L	M
1	Contractor Firm	Cost Estimation	Contract Information	The Highest Bid	The Lowest Bid
2	KARTAL İNŞ. SAN. TİC. VE NAK. LTD. ŞTİ.	9.136.478,00	6.968.968,00	8.864.000,00	6.968.968,00
3	RUTO TAAHHÜT VE İNŞ.LTD.ŞTİ.	12.405.242,00	8.541.377,00	10.233.000,00	8.541.377,00
4	MARTAŞ ULUSLARARASITAŞIMACILIK İNŞ.	1.162.856,00	749.000,00	1.193.000,00	699.800,00
5	TEZGEL İNŞ TURZ.SAN TİC LTD ŞTİ	3.570.977,00	1.982.000,00	2.917.000,00	1.982.000,00
6	İSMET BÜLENT KÖPRÜLÜ	136.864,00	129.500,00	129.500,00	129.500,00
7	SÜER OKMAN	3.124.658,00	2.393.000,00	2.990.000,00	1.983.000,00

	N	O	P	Q	R
1	Contracting Date	The Number of Valid Bid	Total Number of Tenderer	Complainant	Complaint Date
2	22.6.2010	13	16	KARTAL İNŞAAT SA	1.4.2010
3	2.9.2010	5	13	VİT - VAROL İNŞAAT	21.6.2010
4	3.6.2010	9	10		
5	27.10.2010	16	18		
6	16.8.2010	1	1		
7	9.12.2010	8	12	SÜER OKMAN	20.8.2010

	S	T	U	V	W	X
1	Document Number	Results of Complaint	Tender Duration	Complaint Status	Preparation Time	Logarithm of Tender
2	2010/7578	Düzeltici işlem belirlenmesine	145	1	25	4,976733742
3	2010/14492	Düzeltici işlem belirlenmesine	157	1	24	5,056245805
4			78	0	15	4,356708827
5			71	0	28	4,262679877
6			25	0	12	3,218875825
7	2010/21149	Düzeltici işlem belirlenmesine	171	1	21	5,141663557

Figure 4.2. Excel table of tender data

Tender duration was calculated by finding the number of days in between tender notice and signing of the contract. The time between the tender date and the tender notice was called preparation time for the tender and the time between these two dates was calculated and added to the excel table.

4.3 Data Preparation and Analysis

Lean have the ability to identify wastes in a process. Unlike the Six Sigma method, it does not present any method to reduce waste in the process and it does not have statistical characteristics. For this reason, six sigma DMAIC method is preferred in this thesis. The details of the DMAIC methodology and the studies about the application of the DMAIC are presented in Chapter 3. The research presented here in partially builds on DMAIC – only first three steps of this methodology (Define-Measure-Analyze) were applied to the tender evaluation process The following Figure 4.3 shows the flow diagram of methodology.

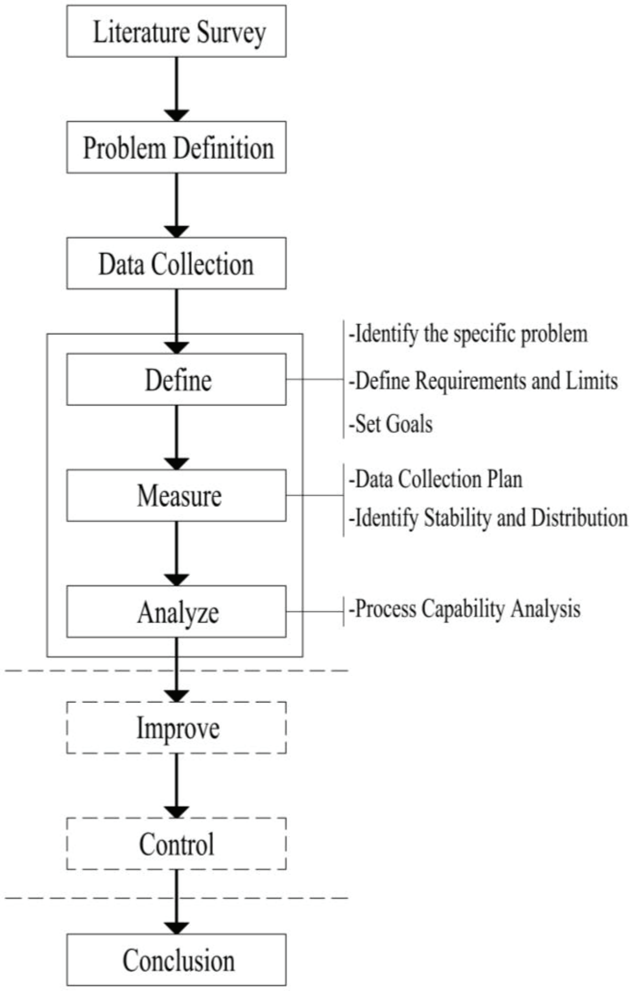


Figure 4.3. Scope of the methodology

In the study, the five simple steps were followed to achieve the existing process capability levels of public agencies. Figure 4.4 is prepared to show the process flow of these steps.

Firstly, to define the existing state of collected data (i.e., tender evaluation process durations) a summary report including a histogram, boxplots, descriptive statistics, and normality tests were created in Minitab. Summary reports were prepared for all groups to explain the frequency distribution and statistical values of the groups, respectively. The following inferences can be made using these summary reports; i) identifying and evaluating the performance of the process with accurate reliable measurements, ii) determining the effects of the improvements made and iii) making comparisons. These inferences present comprehensive information about the data including statistics as the mean, median, mode, minimum, maximum, standard deviation, range, etc.

Data screening process was performed at two stages: (1) conducting normality tests and (2) constructing control charts. Shapiro Wilk and Kolmogorov Smirnov normality tests were performed for each group. The decision criteria used in the tests are based on a 95% confidence interval at $p < 0.05$. The skewness value describes the symmetry of the distribution and the kurtosis value describes the peak of the distribution. Considering the kurtosis, skewness and sigma values in the test results and the normality of groups were analyzed. In addition, the normal distribution graph of each group was obtained by means of 'Normality test' which is a measuring tool of Minitab software and probability plot was analyzed. Normal Q-Q Plot of each variable illustrates that the cases fall more or less in a straight line. It shows whether the observed value matches the expected value. If the data is distributed normally, there appears an up and down movement around a straight line. In normality test results, it was accepted that the data whose probability value (p-value) is higher than 0.05 shows normal distribution and the data whose probability value (p-value) is less than 0.05 does not show normal distribution characteristics.

Following the completion of normality tests, I-MR control charts, were created to determine where the problems were in the process and to examine the process stability. I-MR control schemes have identified non-controlled data that adversely affect the distribution and the results of abnormal variation were investigated. Then, non-control variables were excluded from the calculations.

It is essential to define the correct distribution when conducting a capability analysis. Individual distribution identification tool in Minitab was used to select the distribution that best fits data prior to conducting a capability analysis. After determining the distribution obtained the highest p-value for each group by help of individual distribution identification tool, process capabilities were analyzed using box-cox transformation. It is decided whether the processes are adequate according to the specified specification limits. In the decision-making phase, performance index, sigma levels, capability index values were considered.

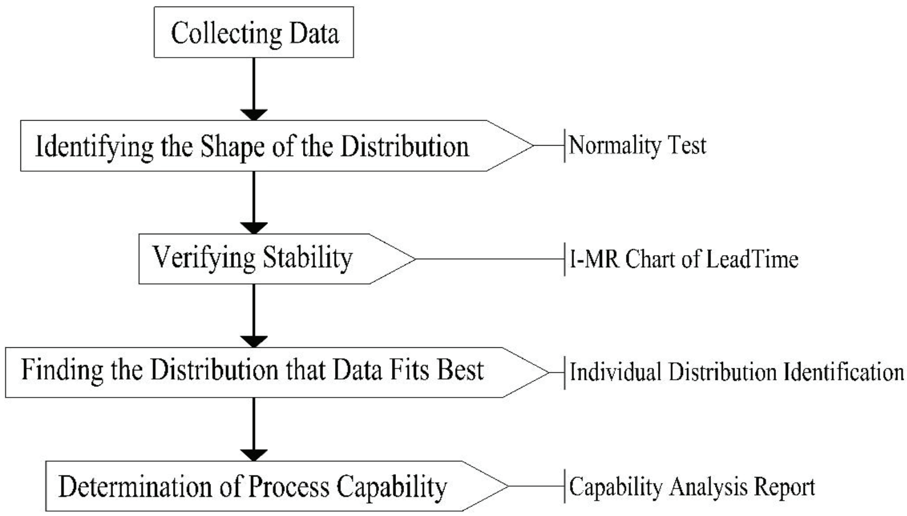


Figure 4.4. Flow diagram to conduct process capability analysis

CHAPTER 5

RESEARCH FINDINGS AND DISCUSSIONS

5.1 Introduction

The following chapter presents the statistical analysis of the research data and the interpretation of the research findings. In our research, **DMA**IC phases followed, the measurements were made with the help of MINITAB statistical software program and the process capabilities have been analyzed. In Section 5.2 tender periods were analyzed in considering estimated cost, and in Section 5.3 tender periods were analyzed in view of a total number of tenderers. In the study, frequency distribution, normality tests results, I-MR control chart, distribution fit graphs, distribution parameters, box-cox plot, and process capability report and C_{PU} change charts are given for Group A-B-C and Group 1-2-3 respectively.

5.2 Process Capability Analysis of Tender Evaluation Process Based on Estimated Construction Costs (*PCA-ECC)*

As it is stated in Chapter 2 in details, tender announcement duration is defined according to their estimated costs by considering Public Procurement Law. Four groups of tenders were determined according to their estimated costs of 2010 years as stated in Public Procurement Law 4734. These groups are named as group A, B, C, and D.

- Tenders that would have an estimated cost less than 140.157 TL are allowed to have 7 days of announcement duration. (namely *Group A*)
- Tenders that would have an estimated cost higher than 140.157 TL but less than 1.168.007 TL are allowed to have 14 days of announcement duration. (namely *Group B*)
- Tenders that would have an estimated cost higher than 1.168.007 TL but less than 23.551.044 are allowed to have 21 days of announcement duration. (namely *Group C*)

- Tenders that would have an estimated cost equal or higher than 23.551.044 TL are allowed to have 40 days of announcement duration. (namely *Group D*)

The duration of tenders varies according to the estimated costs. The tenders collected in the Excel file were grouped according to their estimated costs. According to this, a total of 650 tenders, 61 in Group A, 370 in Group B, 215 in Group C, and 1 in Group D, were examined. It was noted that when examining these group of tenders, there is lack of some tender information for three of tenders, so these are excluded from calculation. And, there is not enough observation for Group D. Therefore, no studies were conducted for group D in the followings. Figure 5.1. shows the distribution of number of tenders according to specified groups.

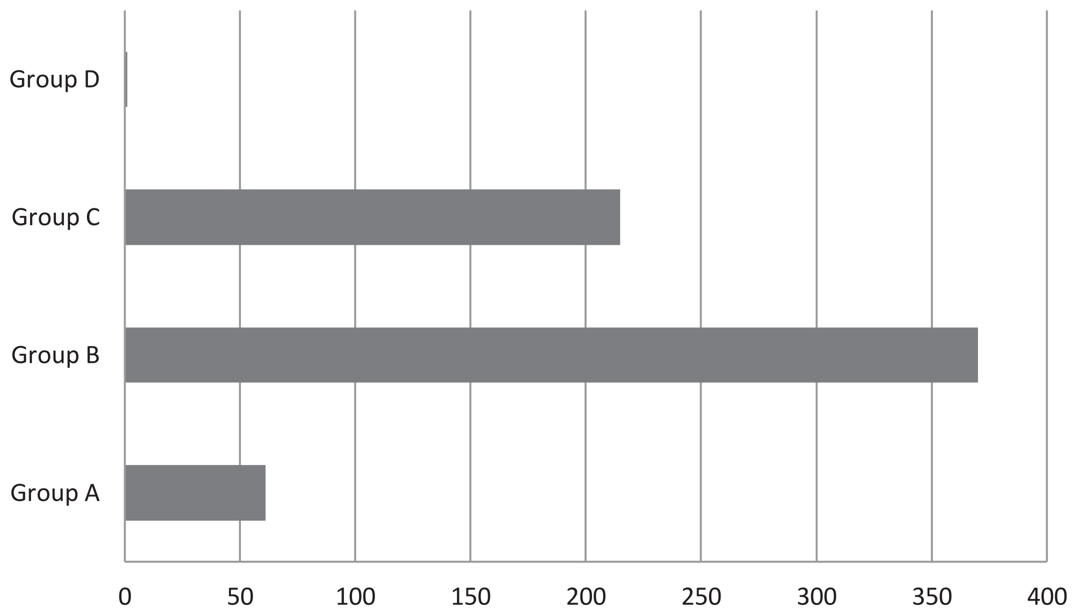


Figure 5.1. Number of tenders

5.2.1 Descriptive Statistics

In Table 5.1 values of tender duration, preparation time, number of tenderers, number of valid bid and complaint status, as well as standard deviations of them, were tabulated for all the data. All tenders were grouped according to their cost estimations of threshold values as stated in public procurement law. Table 5.2, Table 5.3, Table 5.4 and Table 5.5 provide descriptive statistics (minimum, mean, maximum and standard deviation) Group A, B, C, and D, respectively.

Table 5.1. All Tenders (N=647)

	Minimum Value	Mean Value	Maximum Value	Standard Deviation
Tender Duration	18.00	63.01	554.00	36.38
Time to Prepare	7.00	18.48	36.00	4.73
Number of Valid Bid	1.00	6.30	31.00	3.99
Number of Tenderer	1.00	8.73	35.00	5.06
Number of Complaint	0.00	0.10	1.00	0.30

Table 5.2. Group A (N_A=61)

	Minimum Value	Mean Value	Maximum Value	Standard Deviation
Tender Duration	18.00	39.84	80.00	12.36
Time to Prepare	7.00	10.70	19.00	2.67
Number of Valid Bid	1.00	4.20	12.00	2.58
Number of Tenderer	1.00	5.62	16.00	3.38
Number of Complaint	0.00	0.02	1.00	0.12

Table 5.3. Group B (N_B=370)

	Minimum Value	Mean Value	Maximum Value	Standard Deviation
Tender Duration	20.00	52.64	161.00	16.17
Time to Prepare	14.00	16.72	27.00	2.42
Number of Valid Bid	1.00	6.25	22.00	3.63
Number of Tenderer	1.00	8.21	35.00	4.61
Number of Complaint	0.00	0.03	1.00	0.16

Table 5.4. Group C (N_C=215)

	Minimum Value	Mean Value	Maximum Value	Standard Deviation
Tender Duration	36.00	86.89	554.00	50.29
Time to Prepare	21.00	23.62	33.00	2.26
Number of Valid Bid	1.00	6.95	31.00	4.64
Number of Tenderer	2.00	10.48	35.00	5.57
Number of Complaint	0.00	0.25	1.00	0.43

Table 5.5. Group D (N_D=1)

	Minimum Value	Mean Value	Maximum Value	Standard Deviation
Tender Duration	177.00	177.00	177.00	177.00
Time to Prepare	36.00	36.00	36.00	36.00
Number of Valid Bid	13.00	13.00	13.00	13.00
Number of Tenderer	14.00	14.00	14.00	14.00
Number of Complaint	1.00	1.00	1.00	1.00

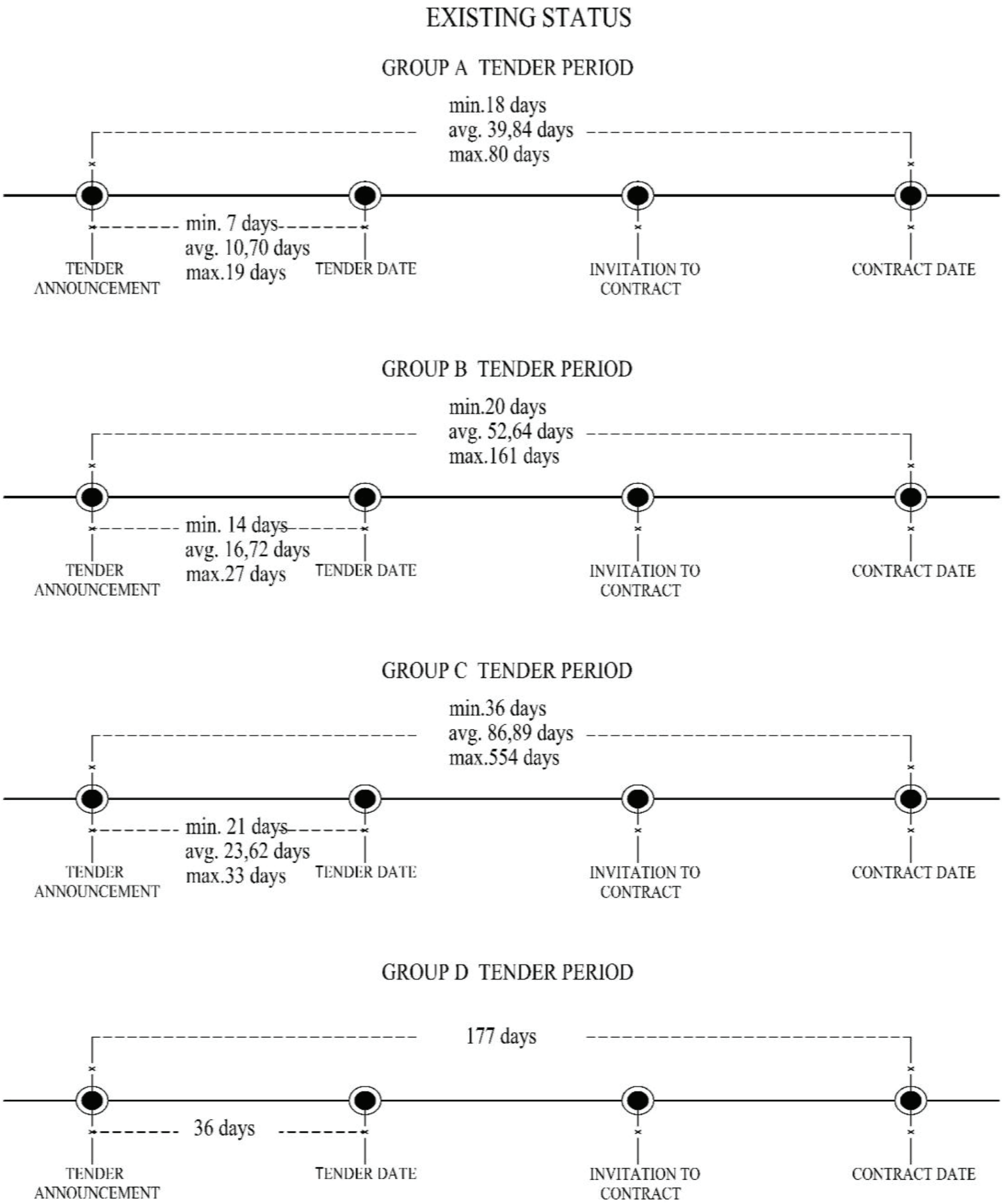


Figure 5.2. Timeline – existing status of tender period for Group A, B, C, D

5.2.2 Group A

Figure 5.3. presents the descriptive statistics and frequency distribution for Group A. It is clear from Figure 5.3 that, Group A does not follow normal distribution. The distribution is skewed to the left.

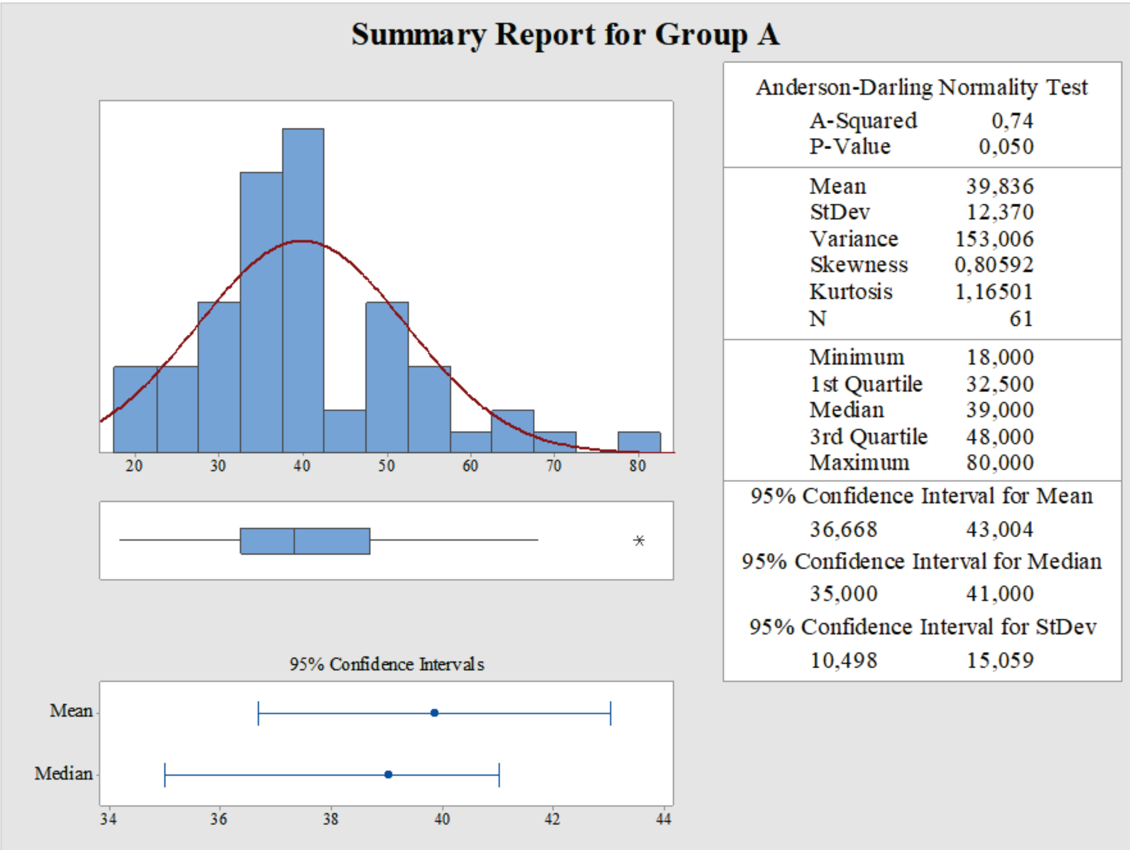


Figure 5.3. Frequency distribution graph and descriptive statistics for Group A

Table 5.6. Shapiro Wilk normality test results for Group A

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Group A	0.135	61	0.007	0.957	61	0.030

Table 5.7. One- sample Kolmogorov-Smirnov test results of Group A

Group A - N	61
Kolmogorov-Smirnov Z	1.058
Asymp. Sig. (2-tailed)	0.213

The mean, standard deviation, variance, minimum, maximum values, skewness and kurtosis were given in the 95% confidence interval. Skewness is an indication of whether the data are distributed symmetrically. The skewness value of the symmetrically distributed data is 0. As stated in Figure 5.3., the skewness value is 0.805 and the kurtosis value is 1.165 for Group A. Since the skewness and kurtosis findings are in the range of $-1.5 < x < +1.5$, it can be said that they are distributed normally. The results of Shapiro Wilk normality test results point out that (See Table 5.6) (KS = 0.135, df 61, $p < 0.05$ and SW = 0.957, df 61, $p < 0.05$), the data do not follow normal distribution. Yet the results of Kolmogorov-Smirnov test (See Table 5.7), (p-value= 0.213>0.05) reveal that the data follow normal distribution. As shown in Figure 5.4., test results for normal probability plot for the data from MINITAB-18 statistical software output shows Mean: 39,84, Standard deviation: 12.37, Anderson Darling test statistic: 0.743 and p- value: 0,050 is significance level (α= 0.05). This shows that the data is marginal. Thus, it has been concluded that data can go either way.

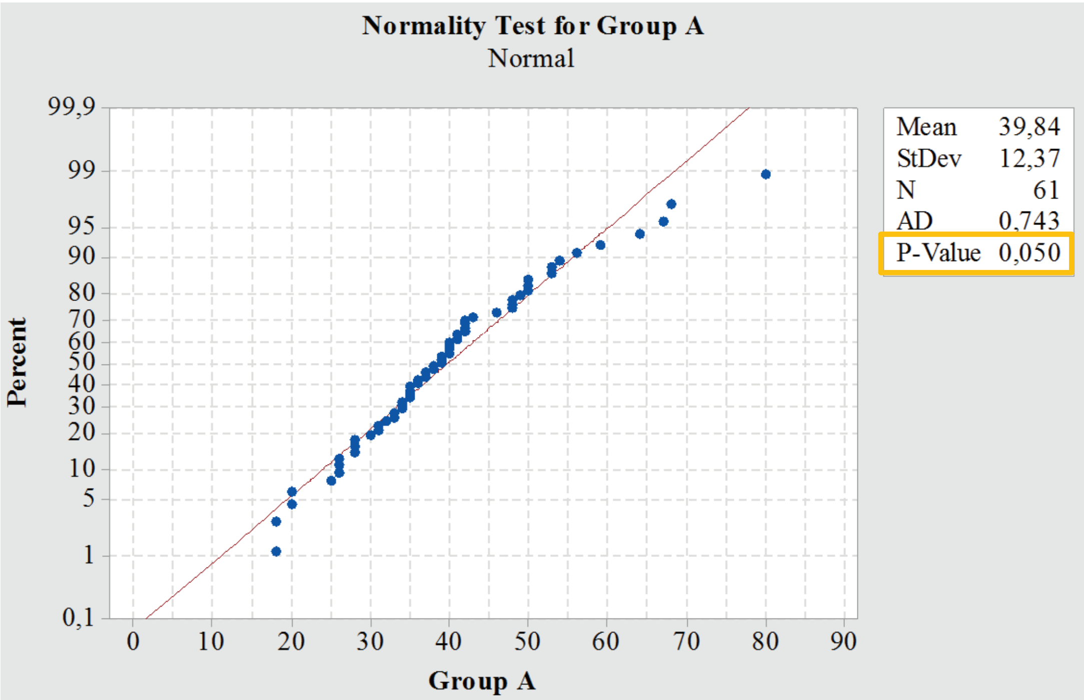


Figure 5.4. Normality Plot of Group A

With I-MR control chart, it is determined whether process mean is in control nor not. Red points in Figure 5.5. imply uncontrolled variation in Group A. Only one uncontrolled variable was detected for this group. This out of control point was omitted from calculations.

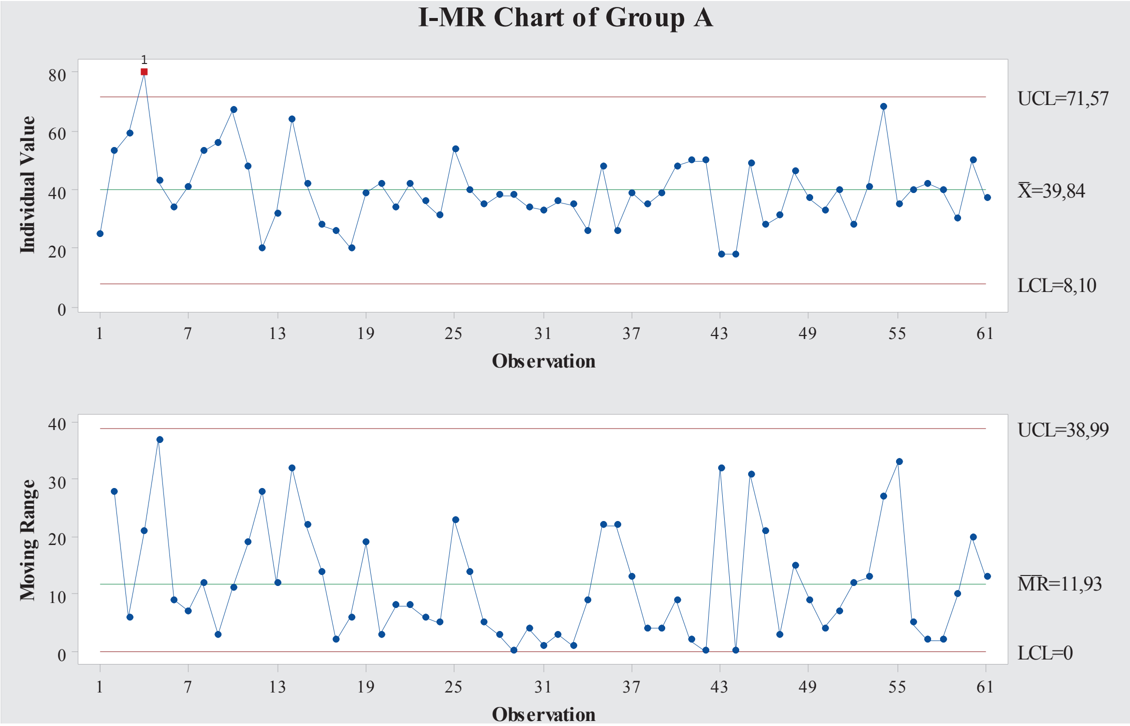


Figure 5.5. I-MR chart of Group A

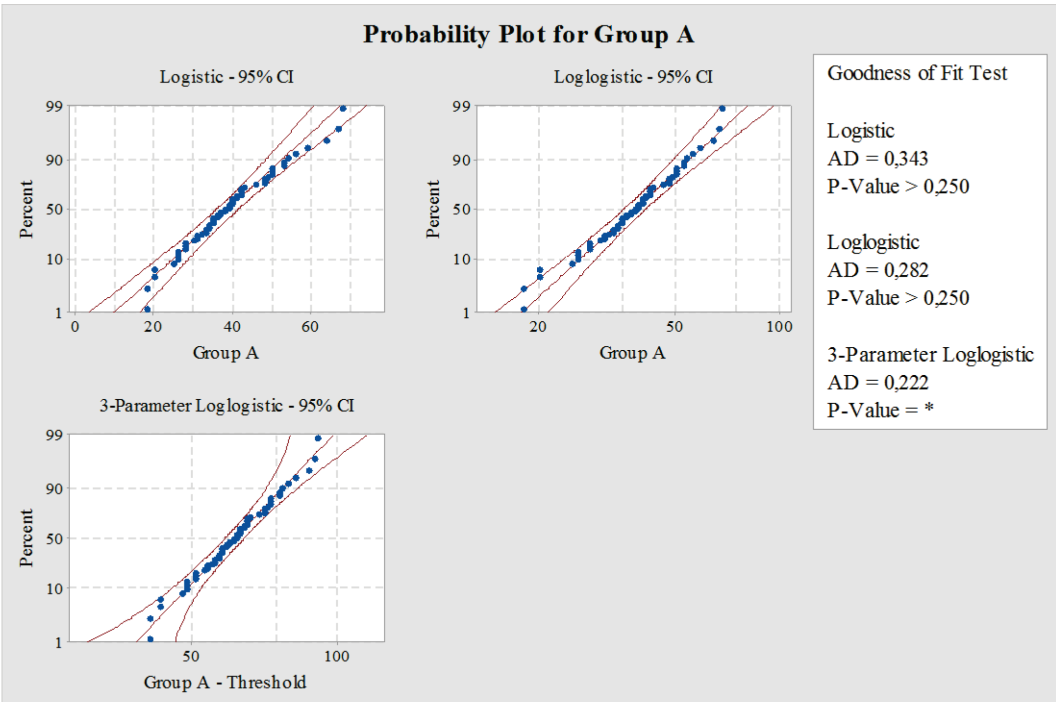


Figure 5.6. Logistic, Loglogistic, 3-Parameter Loglogistic distribution plots for Group A

The results of the individual distribution identification for the Group A are shown in Figure 5.6.-9. The results point out that Box-Cox transformation distribution has the highest p-value (p=0.567). In this case, the probability plot and corresponding p-value suggest that the data are successfully transformed to follow a normal distribution when using the Box-Cox transformation.

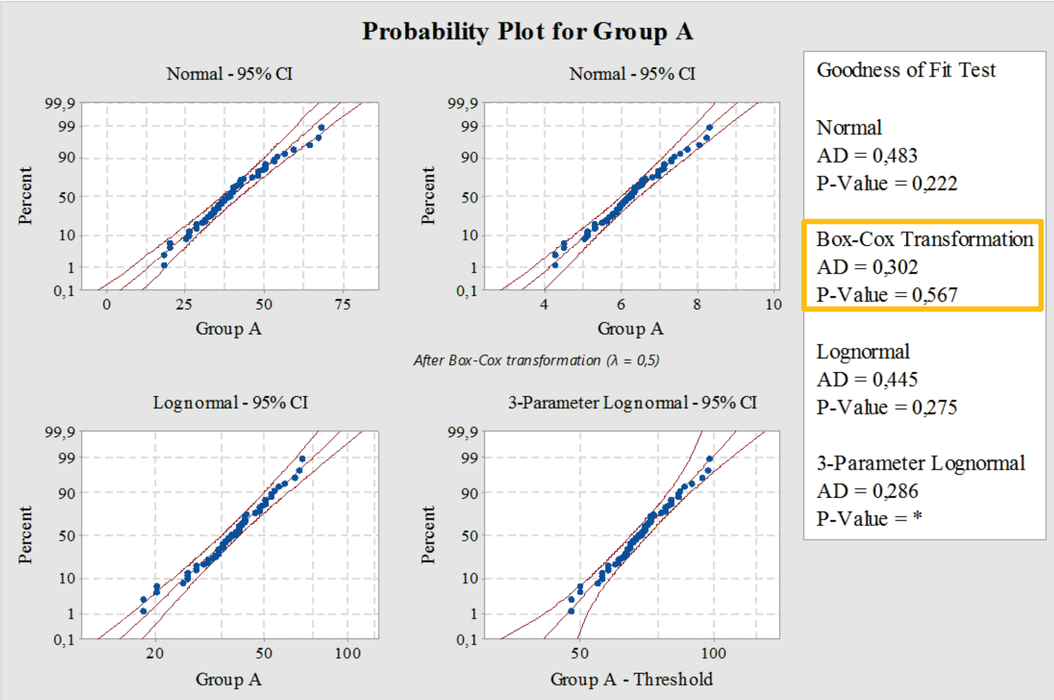


Figure 5.7. Normal, Box-Cox Transformation, Lognormal, 3-Parameter Lognormal distribution plots for Group A

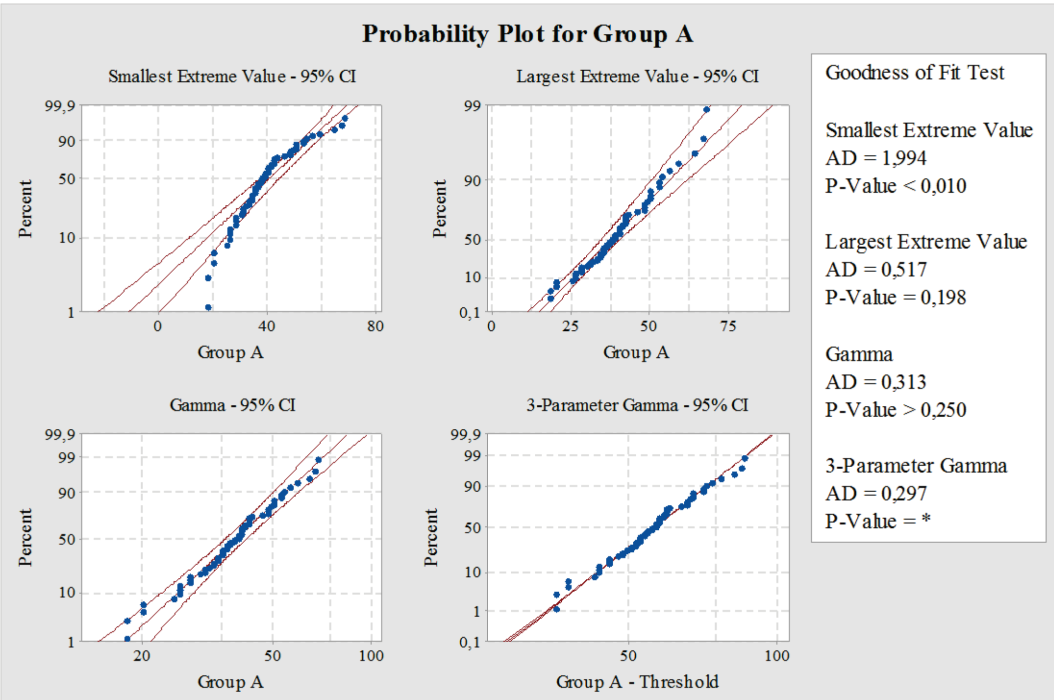


Figure 5.8. Smallest Extreme Value, Largest Extreme Value, Gamma, 3-Parameter Gamma distribution plots of Group A

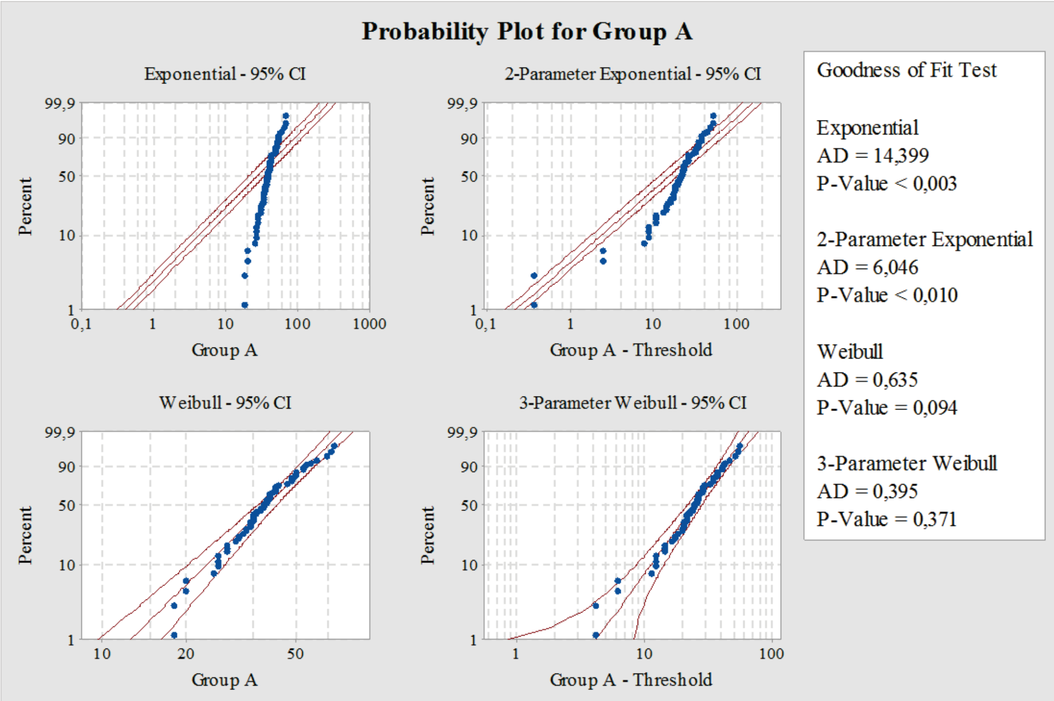


Figure 5.9. Exponential, 2-Parameter Exponential, Weibull, 3-Parameter Weibull distribution plots of Group A

Table 5.8. Goodness of Fit Test Results for Group A

Distribution	**AD**	**P**	**LRT P**
Normal	0.483	0.222	
Box-Cox Transformation	0.302	0.567	
Lognormal	0.445	0.275	
3-Parameter Lognormal	0.286	*	0.213
Exponential	14.399	<0.003	
2-Parameter Exponential	6.046	<0.010	0.000
Weibull	0.635	0.094	
3-Parameter Weibull	0.395	0.371	0.057
Smallest Extreme Value	1.994	<0.010	
Largest Extreme Value	0.517	0.198	
Gamma	0.313	>0.250	
3-Parameter Gamma	0.297	*	0.915
Logistic	0.343	>0.250	
Loglogistic	0.282	>0.250	
3-Parameter Loglogistic	0.222	*	0.413

According to the goodness of fit test results in Table 5.8, several distributions have a p-value greater than 0.05. These distributions are normal, lognormal, Weibull, 3-parameter Weibull, largest extreme value, gamma, logistic, log-logistic distribution. Box-cox transformation distribution (p = 0.567) have the largest p-values and appear to fit the data better than the other distributions.

Table 5.9. ML Estimates of distribution parameters for Group A

Distribution	**Location**	**Shape**	**Scale**	**Threshold**
Normal*	39.16667		11.30497	
Box-Cox Transformation*	6.19360		0.90533	
Lognormal*	3.62542		0.29942	
3-Parameter Lognormal	4.21692		0.16223	-29.55560
Exponential			39.16667	
2-Parameter Exponential			2152532	17.64124
Weibull		3.71540	43.32690	
3-Parameter Weibull		2.37868	28.42432	13.94152
Smallest Extreme Value	45.01047		12.12721	
Largest Extreme Value	33.79259		9.96193	
Gamma		11.95563	3.27600	
3-Parameter Gamma		25.81604	2.19503	-17.51512
Logistic	38.62045		6.28103	
Loglogistic	3.63665		0.16572	
3-Parameter Loglogistic	4.11347		0.10167	-22.94645

** Scale: Adjusted ML estimate*

Figure 5.10 illustrates the Box-cox Plot of Group A. The lower and upper confidence levels (CLs) show that the best results for normality were reached with Lambda values between -0.58 and 1.20. The estimated value for the optimal λ is 0.26. However, the rounded value of 0.50 is within the confidence interval.

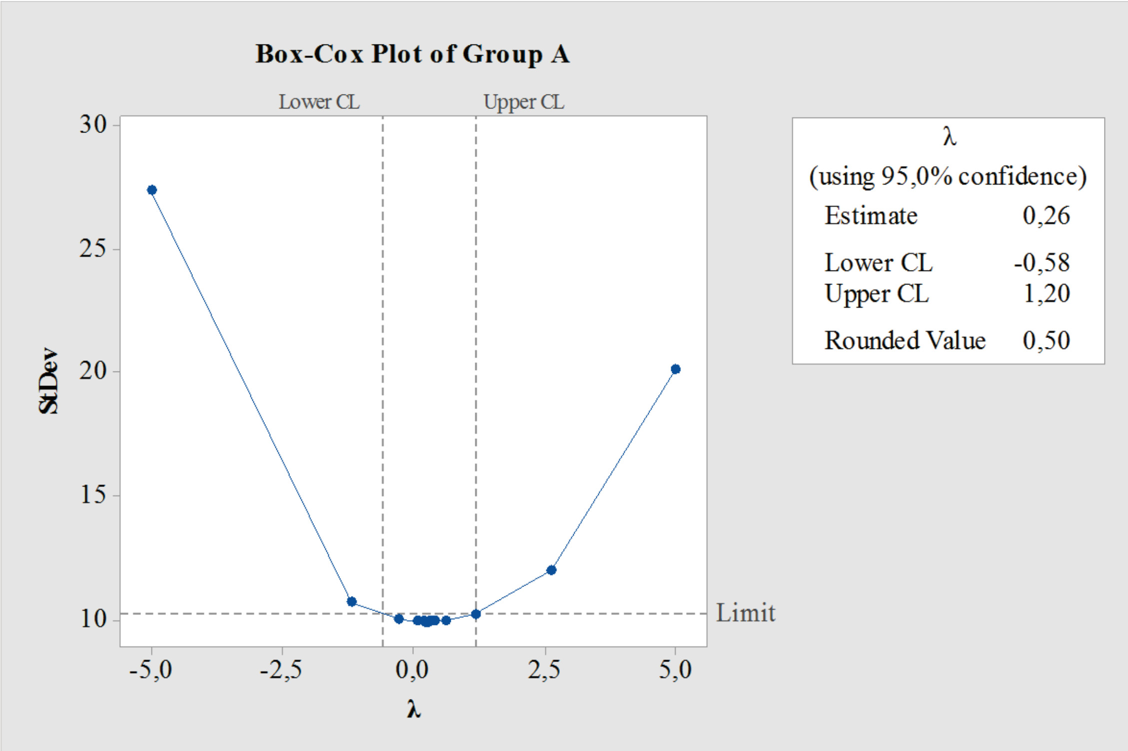


Figure 5.10. Box-Cox plot of Group A

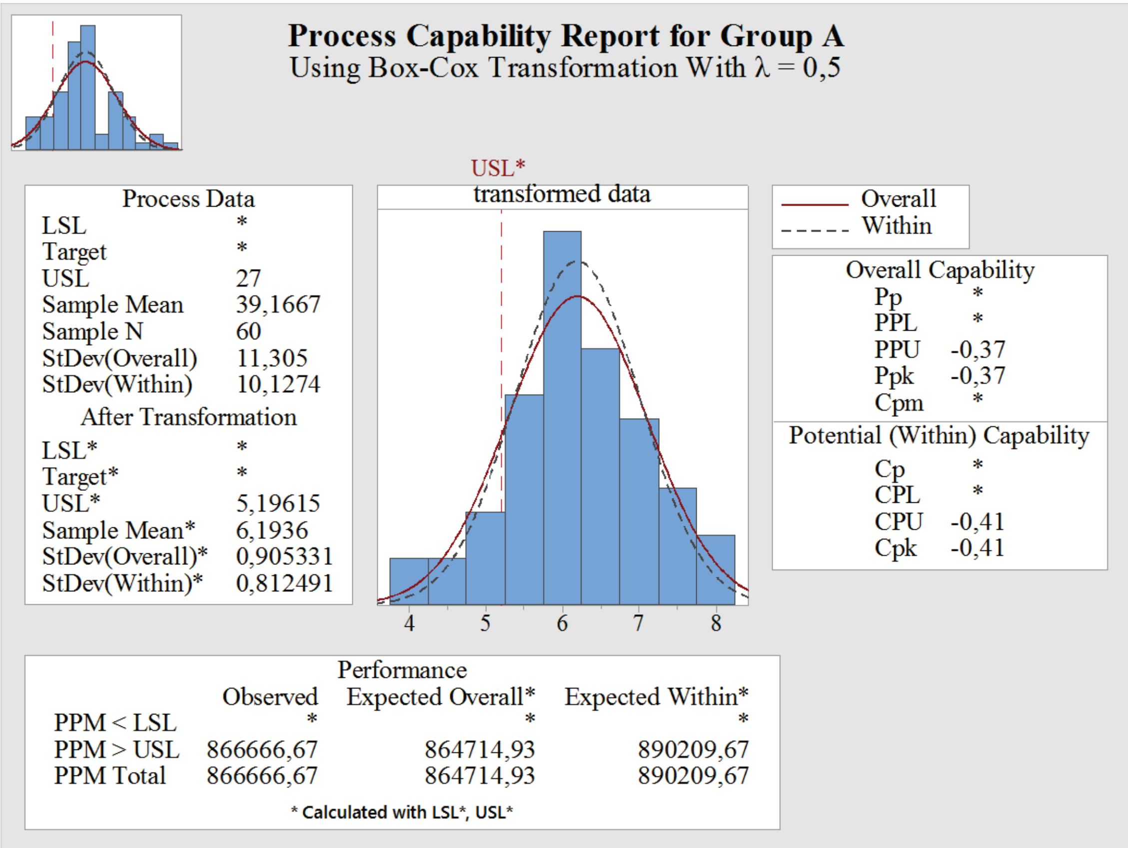


Figure 5.11. Process capability report for Group A

Figure 5.11 shows the process capability analysis of Group A using Box-Cox transformation. The histogram on the center of the report shows the histogram of the transformed data using Lambda=0.50, now more normally distributed. According to the report, after the transformation, the data closely follow a normal distribution. The statistics and capability indexes are calculated and shown in Figure 5.11. The upper left box in Figure 5.11 provides the statistics of the process data before and after the transformation. All results of process capability calculations are lower than 1. So, the process is not adequate. The upper specification limit of 27 days is simultaneously transformed to 5.1961, producing a DPMO of 864714.93. The change in the process capability index according to number of days is shown in Figure 5.12.

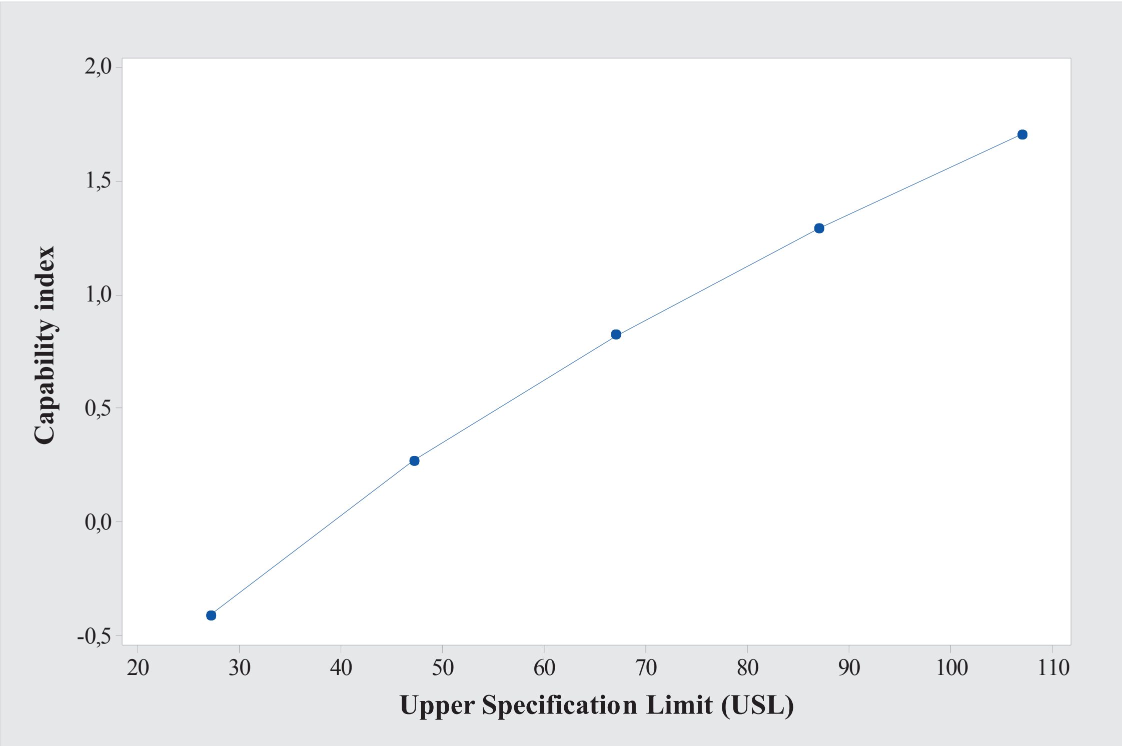


Figure 5.12. C_{PU} change by USL (day) in Group A

5.2.3 Group B

In Figure 5.13, the frequency distribution graph and descriptive statistics for Group B is presented. There is positive skewness in histogram. The distribution skewed to left. Group B does not follow normal distribution. Normality test results for Group B are stated in Table 5.10 and Table 5.11.

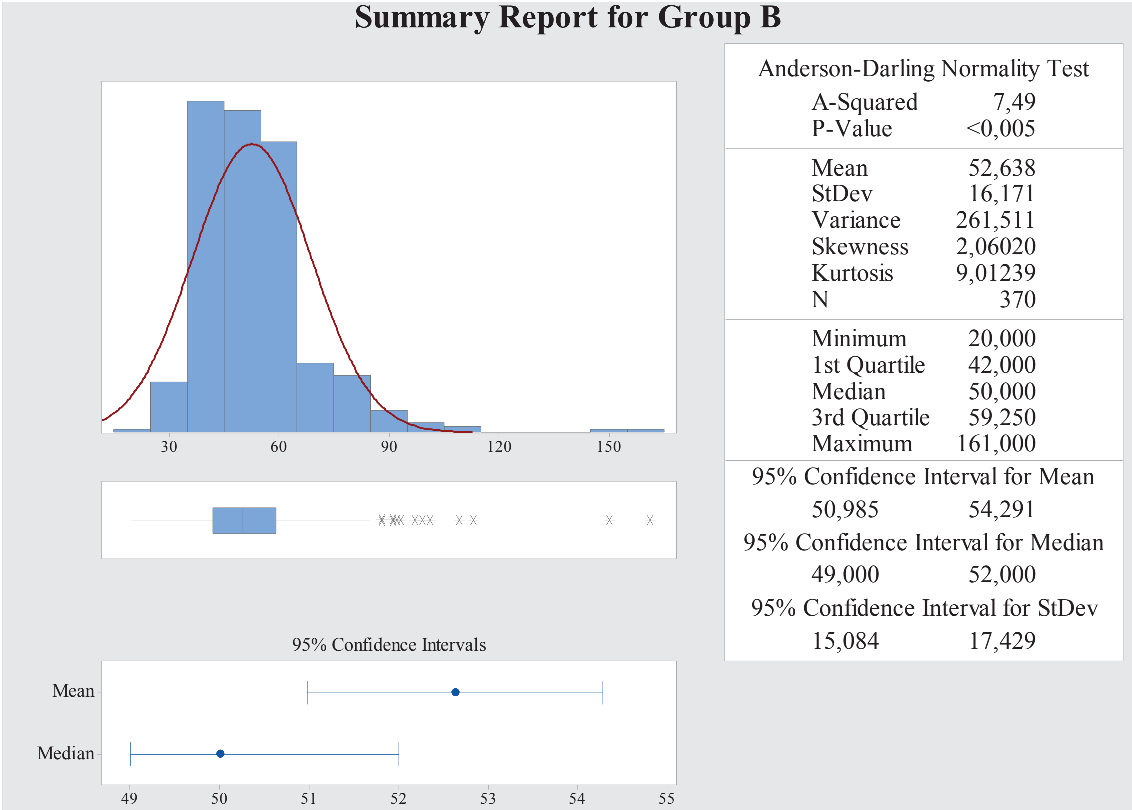


Figure 5.13. Frequency distribution graph and descriptive statistics for Group B

Table 5.10. Shapiro Wilk normality test results for Group B

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Group B	0.110	370	0.000	0.868	370	0.000

Table 5.11. One- sample Kolmogorov-Smirnov test results of Group B

	Group B
N	370
Kolmogorov-Smirnov Z	2.114
Asymp. Sig. (2-tailed)	0.000

The mean, standard deviation, variance, minimum, maximum values, skewness and kurtosis were given in the 95% confidence interval of the mean. As stated in Figure 5.13, the skewness value is 2.060 and the kurtosis value is 9. 012 for Group B. Since the skewness and kurtosis findings are not in the range of $-1.5 < x < +1.5$, it can be said that data of Group B are not distributed normally. When the Table 5.10 was examined (KS=0.110, df 370, $p < 0.05$) and (SW=0.868, df 370, $p < 0.05$), according to the statistical KS and SW tests, the data were not normally distributed. In the normality test, the hypothesis H_0 is rejected because both the value of the test (p-value) is less than 0.05. So, the data is not normally distributed according to the results of Shapiro Wilk normality test. Additionally, Kolmogorov-Smirnov results (see in Table 5.11), p-value =0.00 <0.05. Consequently, it can be said that the data of Group B does not follow normal distribution.

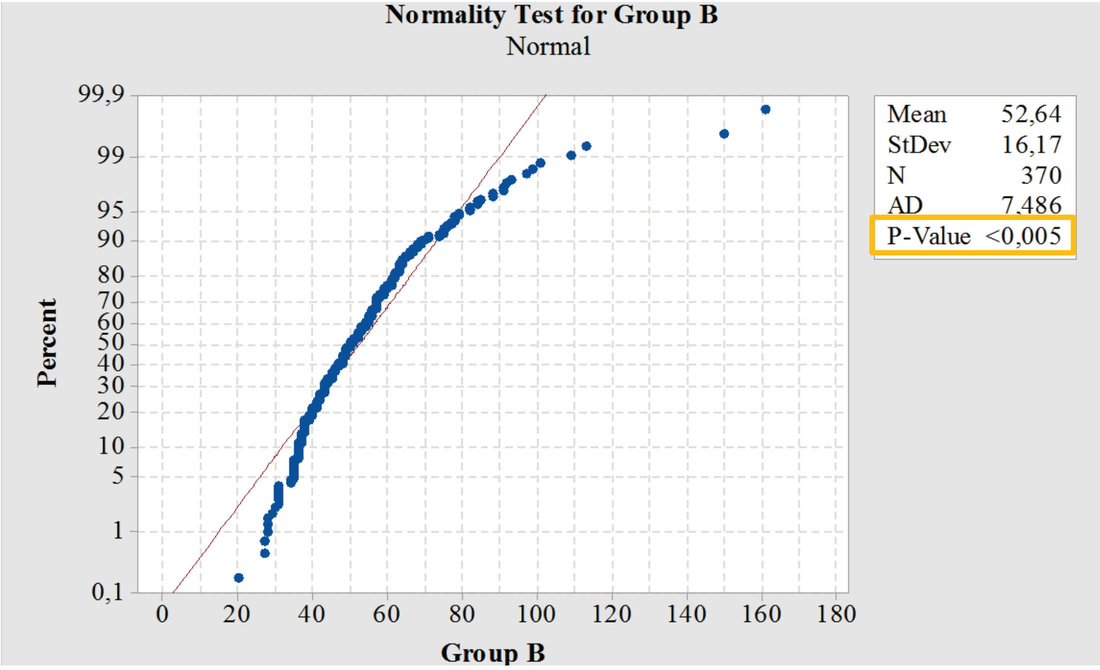


Figure 5.14. Normality plot of Group B

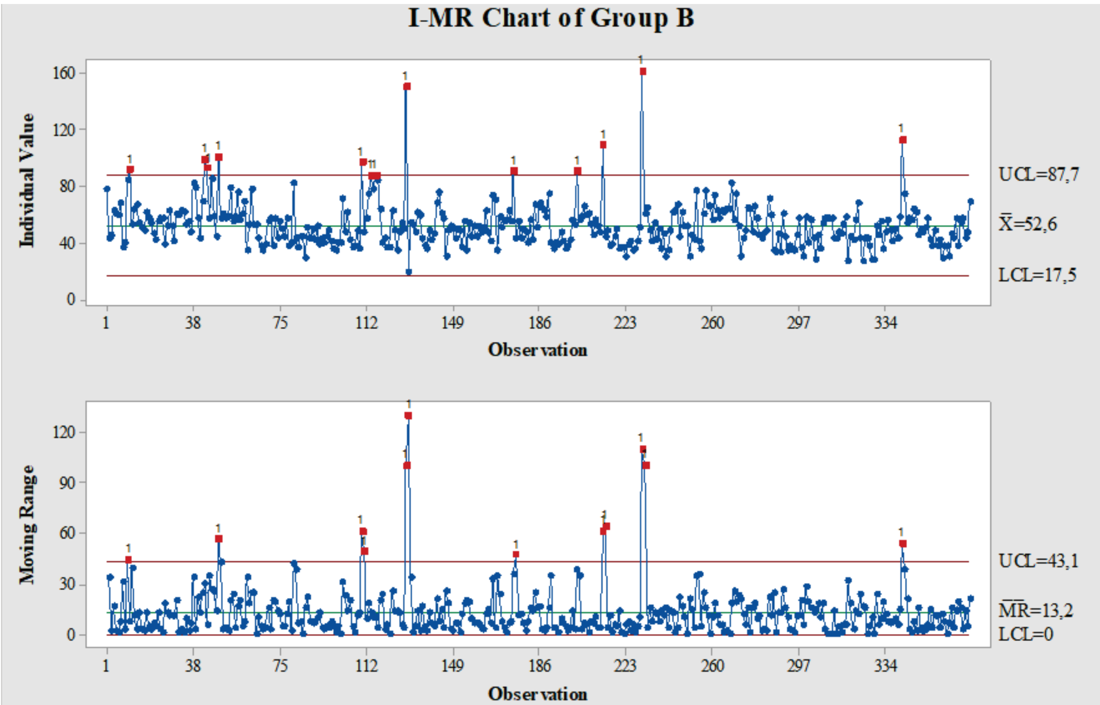


Figure 5.15. I-MR chart of Group B

Figure 5.14 illustrates the normality test results of MİNİTAB-18 statistical software for Group B. In reference to probability plot, mean:52.64, standard deviation:16.17 Anderson Darling test statics: 7.486 and p-value is less than significance value. Therefore, data is not distributed normally.

Uncontrolled variations in Group B are shown in Figure 5.15. According to the I-MR chart, many uncontrolled points were determined for Group B and these points were indicated in red in the graph. The four major variables, which distort the symmetry of the graph, were excluded from the calculations.

Figure 5.16-19 show the results of individual distribution identification for Group B. The highest p-value (p=0.148) was obtained from Box-Cox transformation and Lognormal distribution. Box-Cox transformation and lognormal are effective for Group B in transforming the data to follow a normal distribution. So, it was concluded that Box-Cox transformation creates better capability indices for Group B.

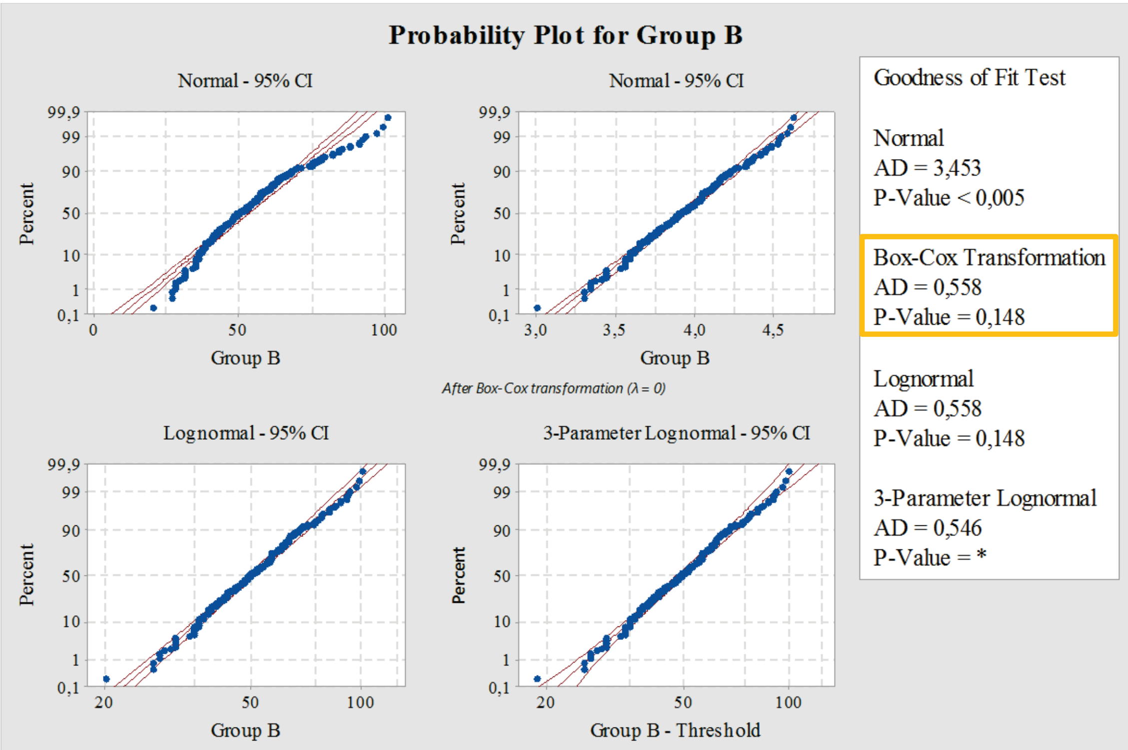


Figure 5.16. Normal, Box-Cox Transformation, Lognormal, 3-Parameter Lognormal distribution plots for Group B

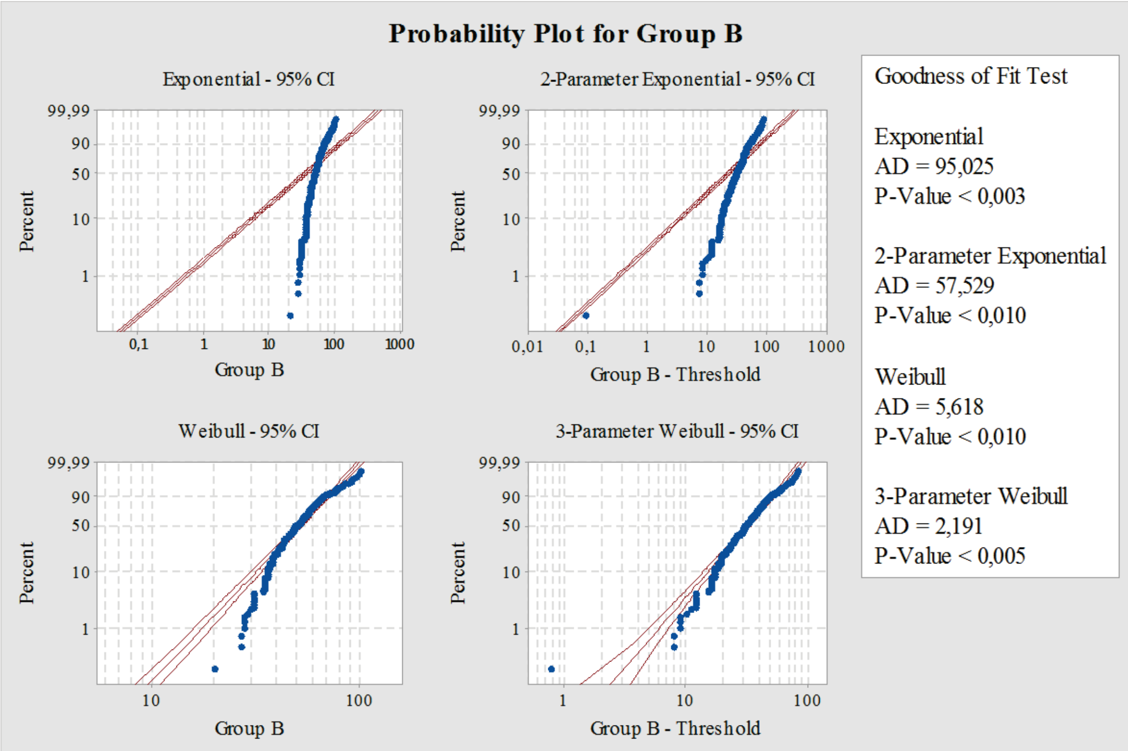


Figure 5.17. Exponential, 2-Parameter Exponential, Weibull, 3-Parameter Weibull distribution plots of Group B

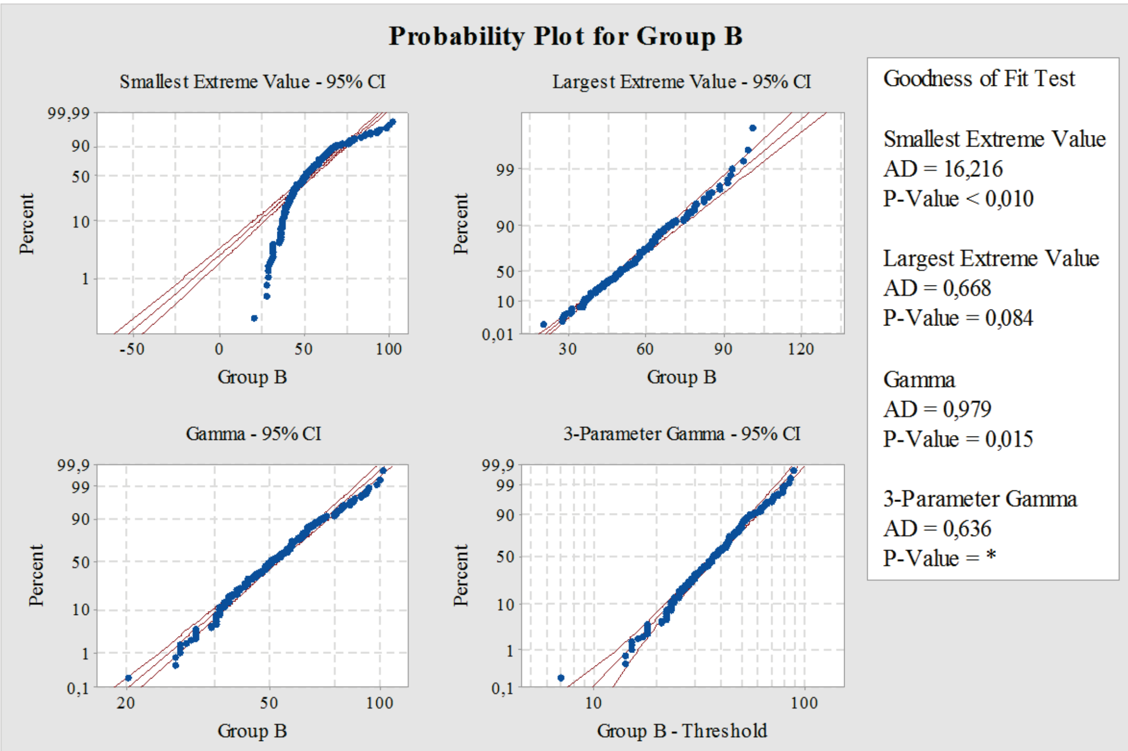


Figure 5.18. Smallest Extreme Value, Largest Extreme Value, Gamma, 3-Parameter Gamma Distribution Plots of Group B

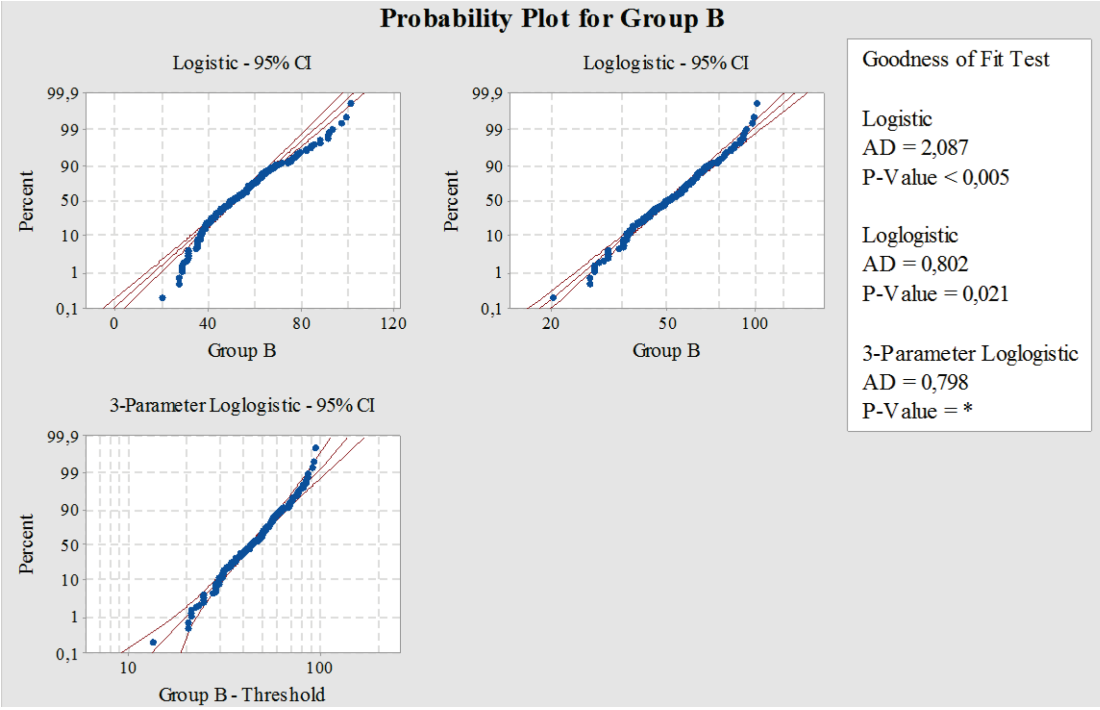


Figure 5.19. Logistic, Loglogistic, 3-Parameter Loglogistic distribution plots for Group B

Table 5.12. Goodness of Fit Test Results for Group B

Distribution	**AD**	**P**	**LRT P**
Normal	3.453	<0.005	
Box-Cox Transformation	0.558	0.148	
Lognormal	0.558	0.148	
3-Parameter Lognormal	0.546	*	0.835
Exponential	95.025	<0.003	
2-Parameter Exponential	57.529	<0.010	0.000
Weibull	5.618	<0.010	
3-Parameter Weibull	2.191	<0.005	0.000
Smallest Extreme Value	16.216	<0.010	
Largest Extreme Value	0.668	0.084	
Gamma	0.979	0.015	
3-Parameter Gamma	0.636	*	0.047
Logistic	2.087	<0.005	
Loglogistic	0.802	0.021	
3-Parameter Loglogistic	0.798	*	0.448

Table 5.12 lists the results of the goodness of fit test for Group B. Box-cox transformation distribution, lognormal distribution, largest extreme value distribution calculated p-value greater than 0.05 for this group. Box-Cox transformation (p = 0.148) have the largest p-values and appear to fit the data better than the other distributions.

Table 5.13. ML estimates of distribution parameters for Group B

Distribution	**Location**	**Shape**	**Scale**	**Threshold**
Normal*	51.75683		13.66641	
Box-Cox Transformation*	3.91323		0.25801	
Lognormal*	3.91323		0.25801	
3-Parameter Lognormal	3.88220		0.26576	1.47781
Exponential			51.75683	
2-Parameter Exponential			31.84383	19.91299
Weibull		3.85935	56.99074	
3-Parameter Weibull		2.50743	36.63264	19.24552
Smallest Extreme Value	59.07288		16.23879	
Largest Extreme Value	45.46056		11.20496	
Gamma		15.16587	3.41272	
3-Parameter Gamma		8.20991	4.70423	13.13555
Logistic	50.76048		7.53894	
Loglogistic	3.91184		0.14694	
3-Parameter Loglogistic	3.76330		0.17080	6,77917

** Scale: Adjusted ML estimate*

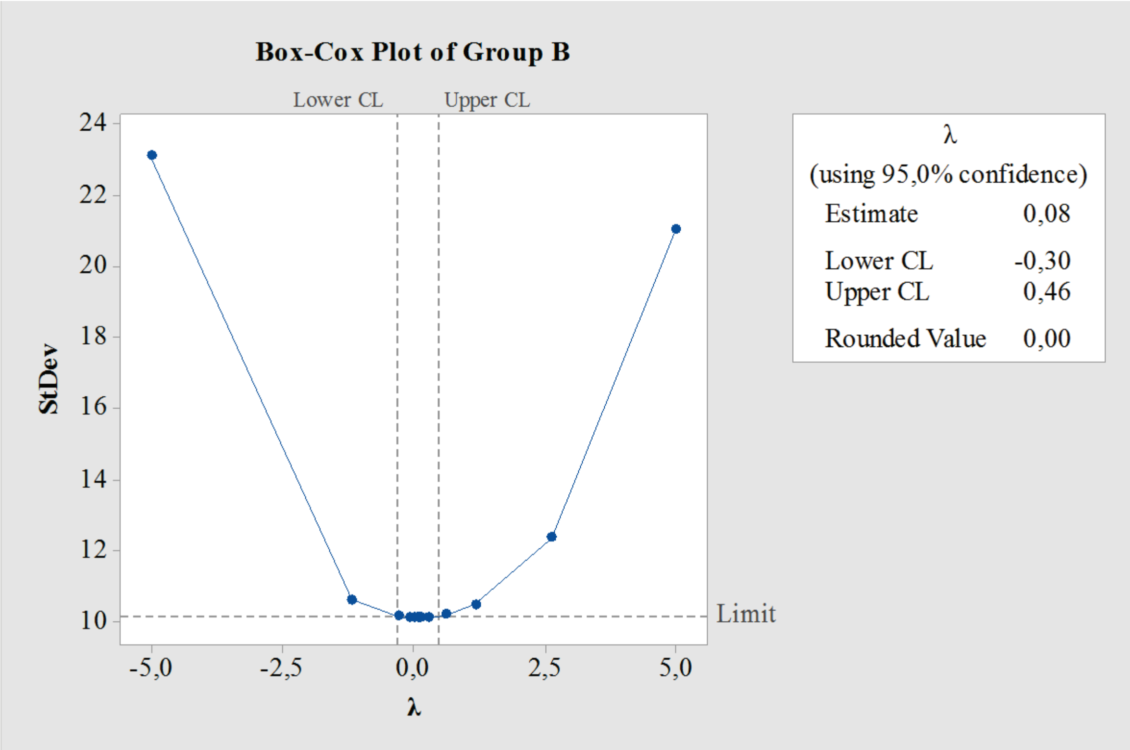


Figure 5.20. Box-Cox plot of Group B

Figure 5.20 displays the Box-Cox Plot of Group B. The lower and upper confidence levels (CLs) show that the best results for normality were reached with Lambda values between -0.30 and 0.46. The estimated value for the optimal λ is 0.08 and, the rounded value for λ is 0.00.

Figure 5.21 presents the process capability report of Group B using Box-Cox transformation. The histogram on the center of the report shows the histogram of the transformed data using Lambda=0. Using the transformation, the data closely follow a normal distribution. The statistics and capability indexes were calculated and indicated in Figure 5.21. The upper left box in Figure 5.21 provides the statistics of the process data before and after the transformation.

According to the results of the capability index, the process is inadequate. The upper specification limit of 34 days is simultaneously transformed to 3.52 producing a DPMO of 933117.32. The change in the process capability index according to the days is shown in the Figure 5.22.

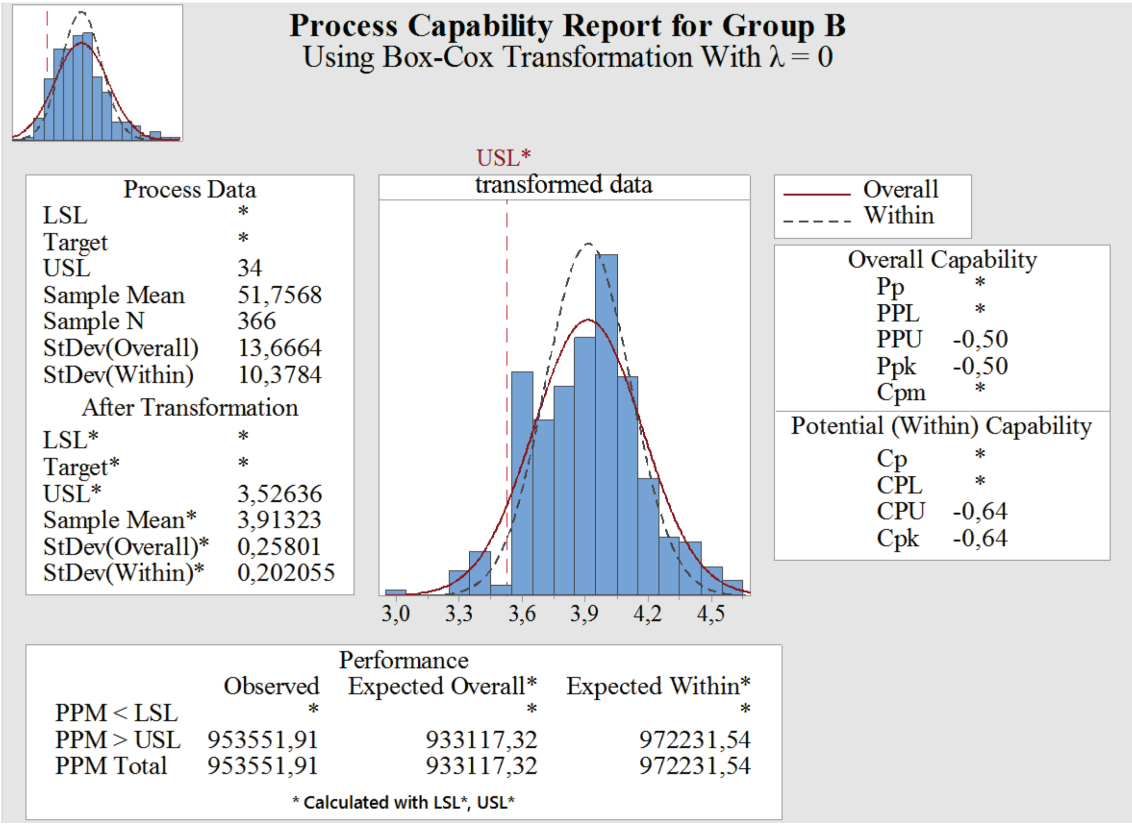


Figure 5.21. Process capability report for Group B

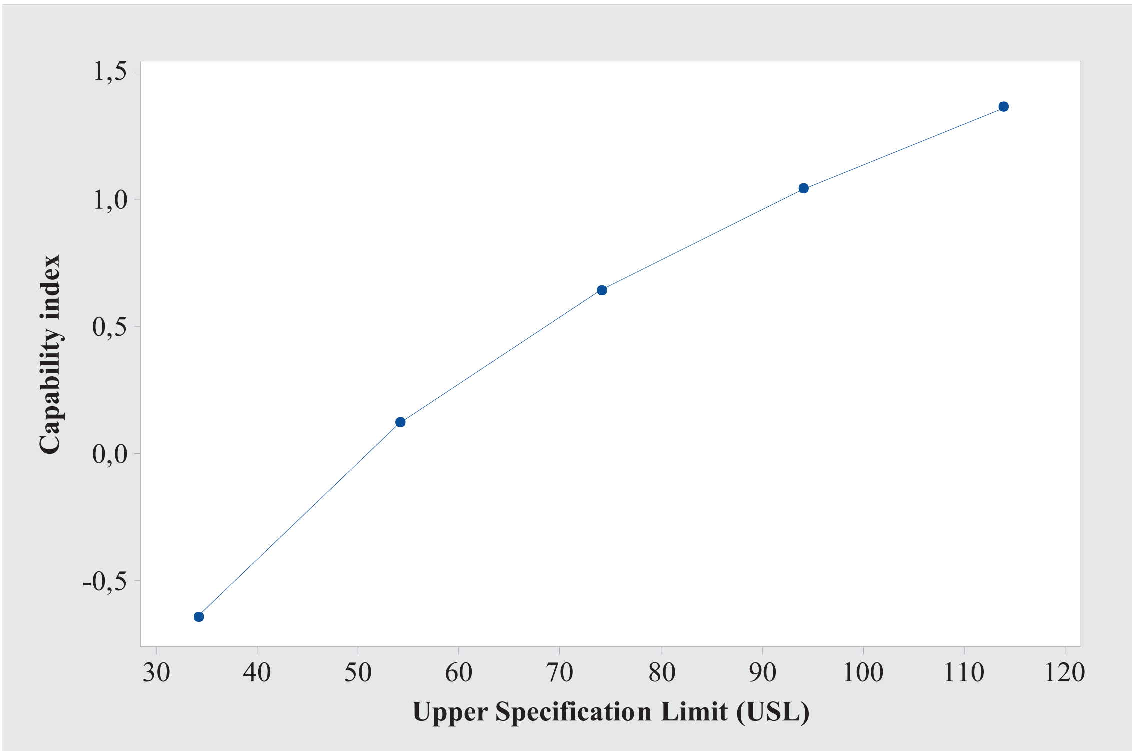


Figure 5.22. C_{PU} change by USL (day) in Group B

5.2.4 Group C

Frequency distribution graph and descriptive statistics for Group C are displayed in Figure 5.23. Group C does not follow normal distribution in reference to the histogram. In the graph, positive skewness is observed. The distribution is skewed to the left. Table 5.14 and Table 5.15 tabulated the normality test results for Group C.

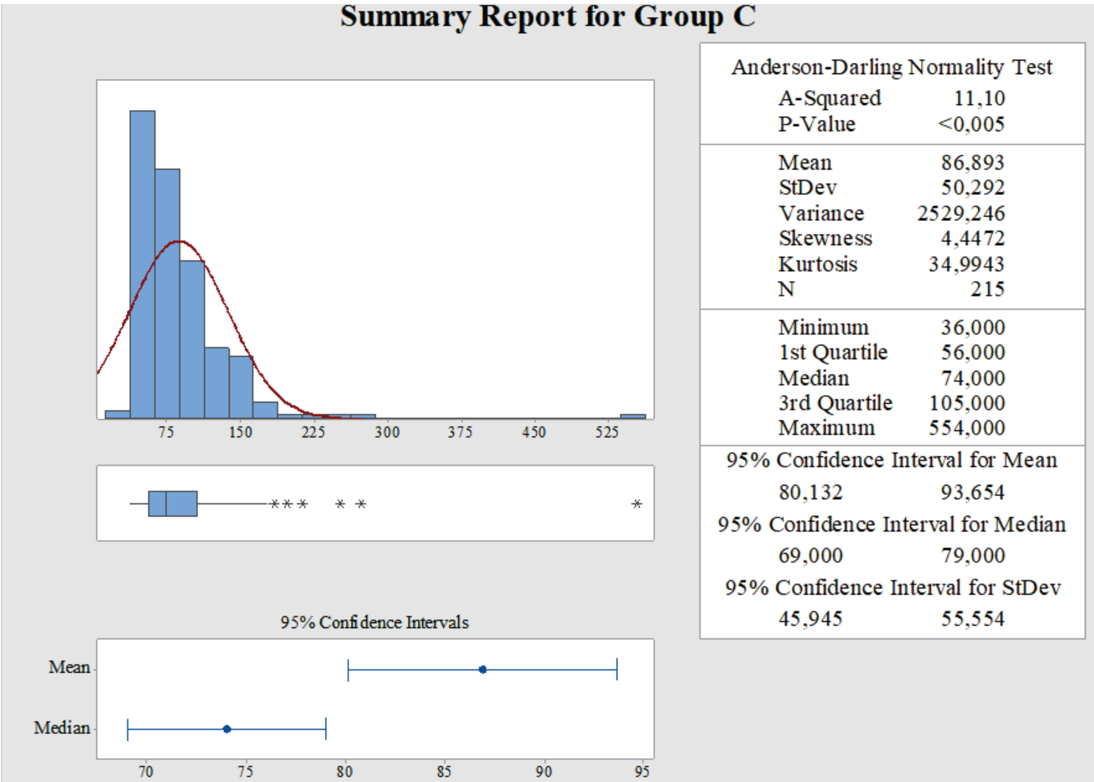


Figure 5.23. Frequency distribution graph and descriptive statistics for Group C

Table 5.14. Shapiro Wilk normality test results for Group C

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Group C	0.157	215	0.000	0.682	215	0.000

Table 5.15. One- sample Kolmogorov-Smirnov test results of Group C

	Group C
N	215
Kolmogorov-Smirnov Z	2.309
Asymp. Sig. (2-tailed)	0.000

The mean, standard deviation, variance, minimum, maximum values, skewness and kurtosis were given in the 95% confidence interval of the mean. Skewness is an indication of whether the data are distributed symmetrically. The skewness value of the symmetrically distributed data is 0. As shown in Figure 5.23, the skewness value is 4.447 and the kurtosis value is 34.994 for Group C. Since the skewness and kurtosis findings are not in the range of -1.5 <x <+1.5, it can be said that they are not distributed normally. According to Shapiro Wilk normality test results for Group C in Table 5.14 (KS = 0.157, df 215, p <0.05) and (SW = 0.682, df 215, p <0.05), the data were not distributed normally. In additionally, according to the Kolmogorov-Smirnov test results (see in Table 5.15) p-value is 0.00. It is smaller than 0.05. It is concluded that the data is not distributed.

The normality test results of MİNİTAB-18 statistical software for Group B is displayed in Figure 5.24. In reference to probability plot, mean:86.89, standard deviation:50.29 Anderson Darling test statics: 11.097 and p-value is less than 0.005. Hereby, it is interpreted that Group C is not distributed normally.

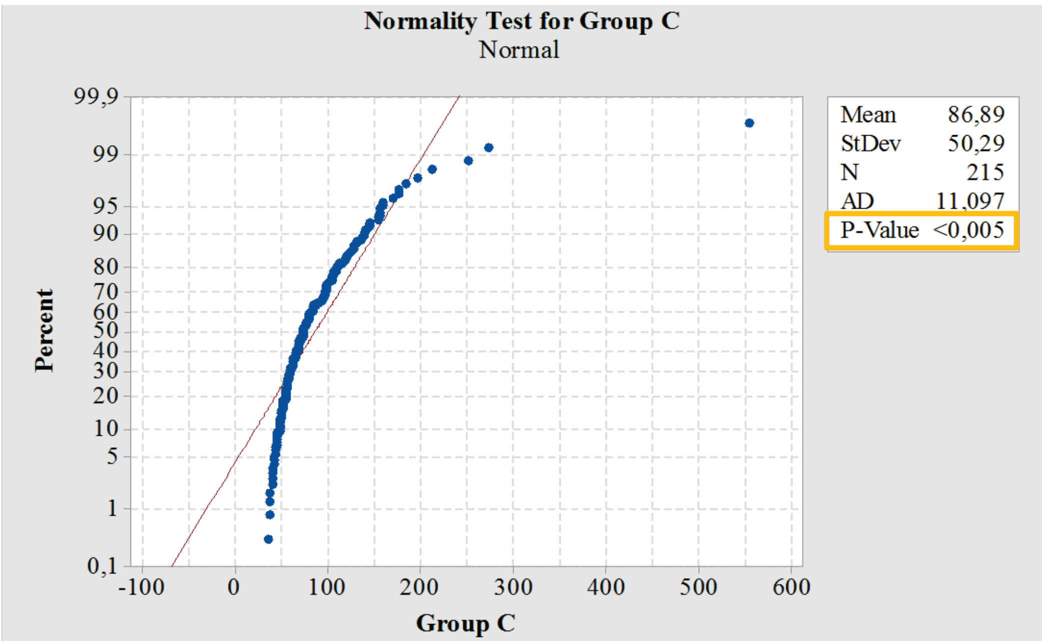


Figure 5.24. Normality plot of Group C

With I-MR chart it was controlled that process mean of Group C is in the control or not. Red points in Figure 5.25 imply uncontrolled variation in Group C. For Group C, Totally, 4 uncontrolled variations were detected. The three of them were excluded from the calculations. The results of the individual distribution identification for Group C are shown in Figure 5.26-29. The results point out that box-cox transformation distribution has the highest p-value (p=0.077) for Group C.

The probability plots and corresponding p-value recommend that the data are successfully transformed to follow a normal distribution when using the box-cox transformation.

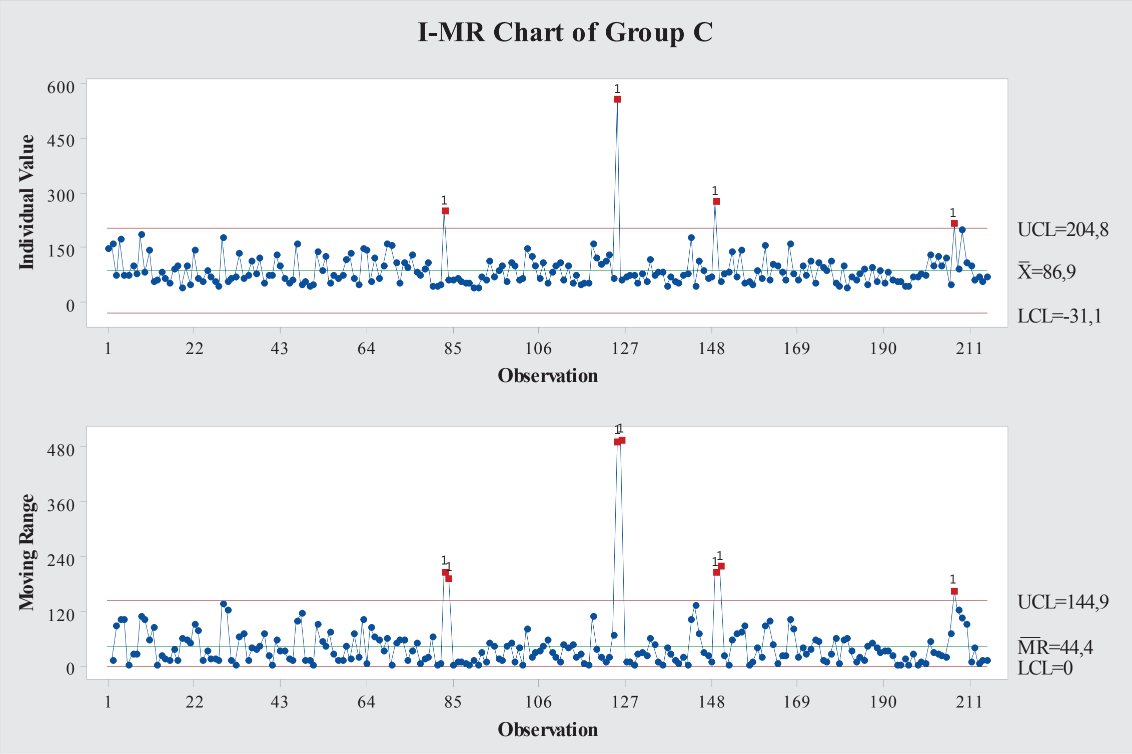


Figure 5.25. I-MR chart of Group C

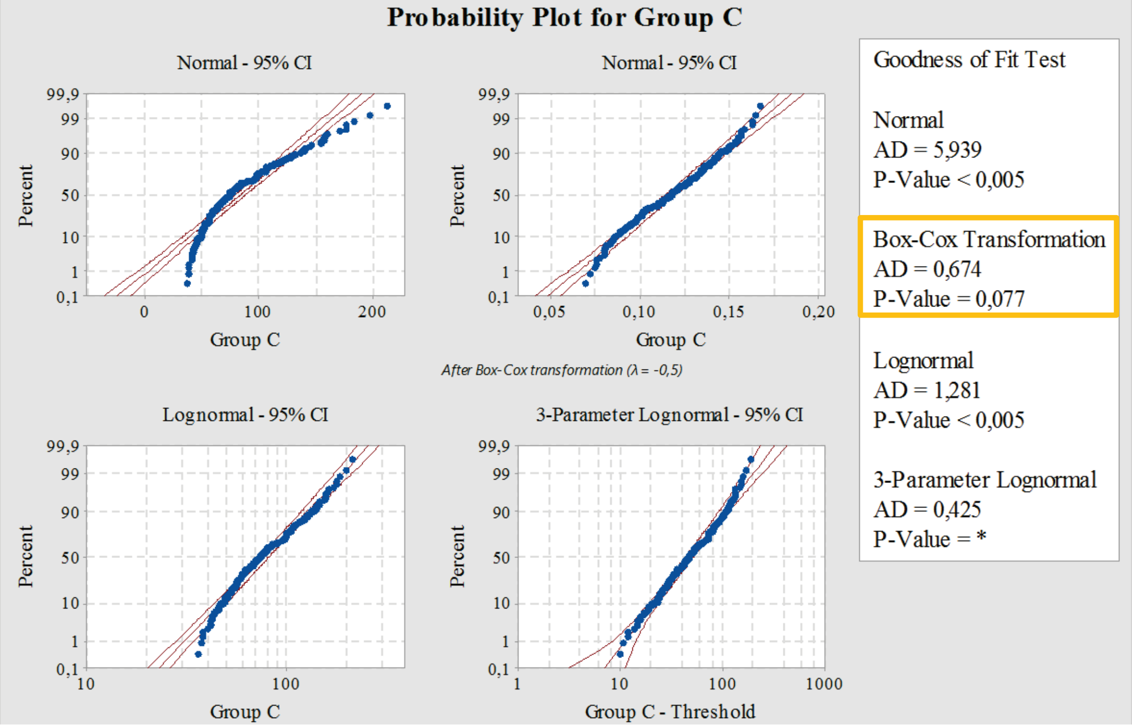


Figure 5.26. Normal, Box-Cox Transformation, Lognormal, 3-Parameter Lognormal distribution plots for Group C

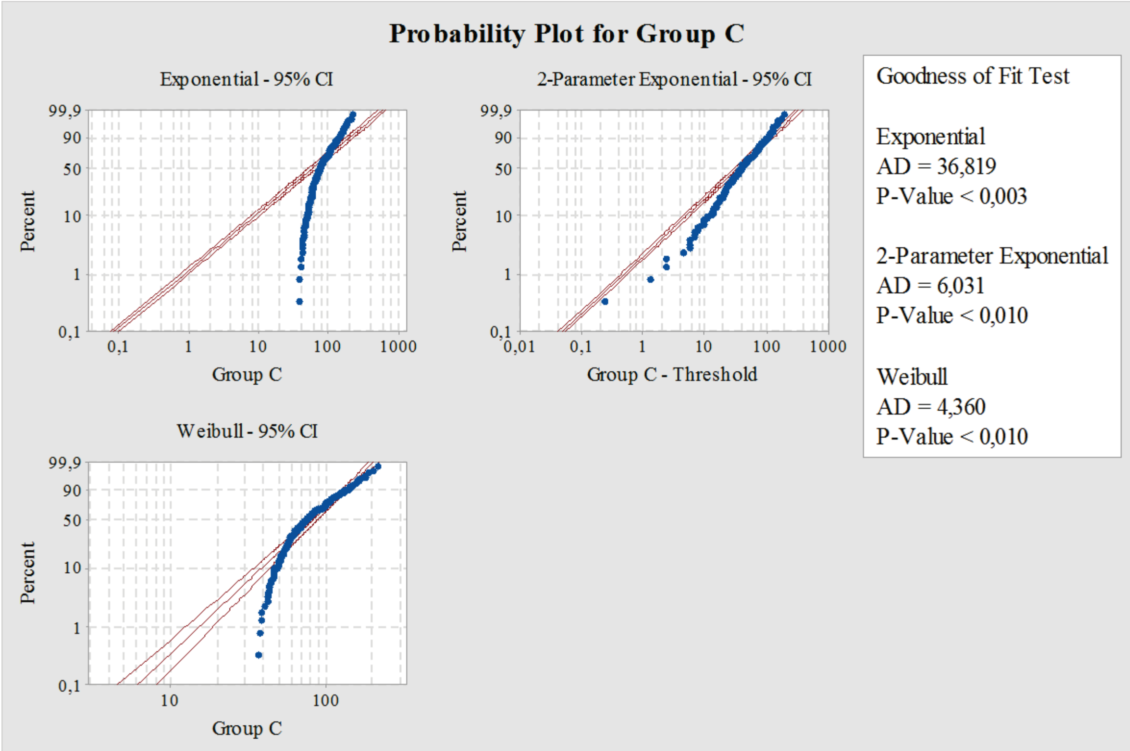


Figure 5.27. Exponential, 2-Parameter Exponential, Weibull distribution plots of Group C

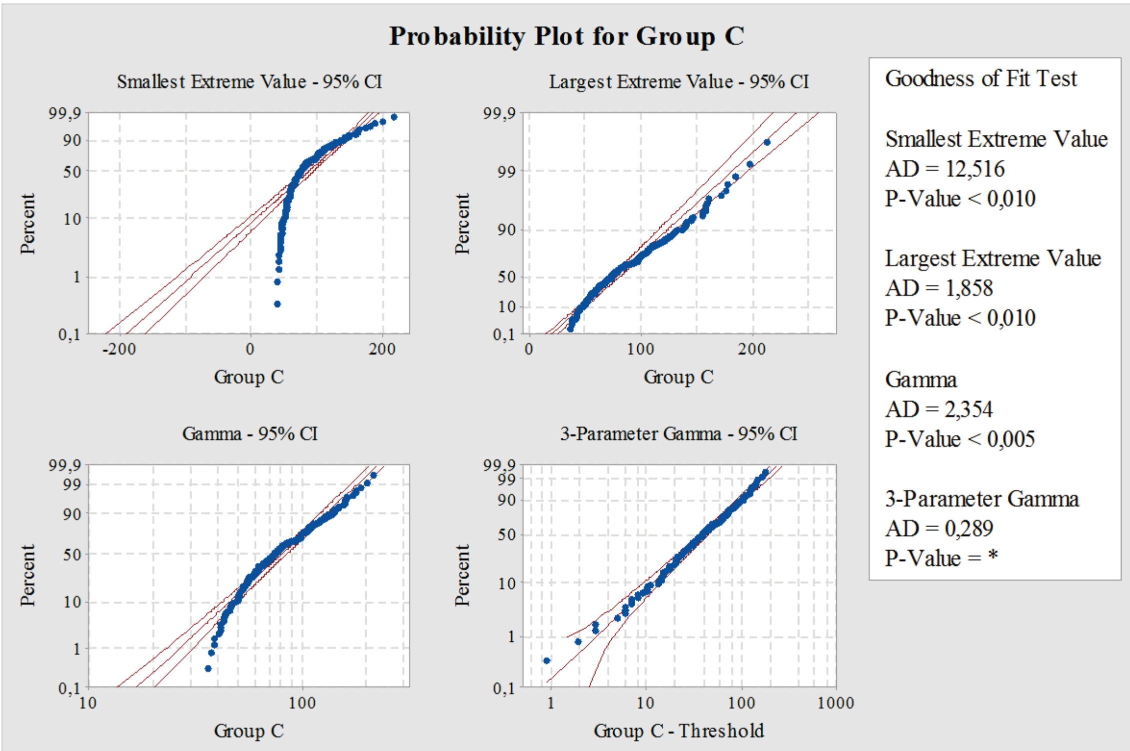


Figure 5.28. Smallest Extreme Value, Largest Extreme Value, Gamma, 3-Parameter Gamma distribution plots of Group C

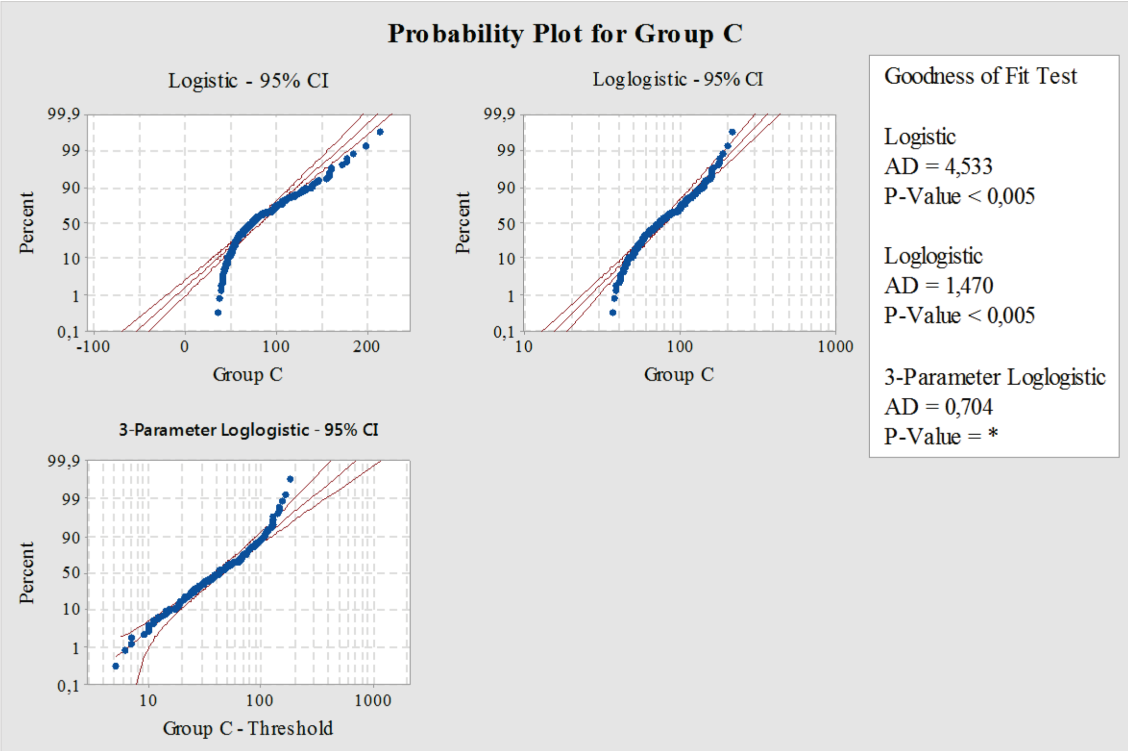


Figure 5.29. Logistic, Loglogistic, 3-Parameter loglogistic distribution plots for Group C

Table 5.16. Goodness of fit test results for Group C

Distribution	**AD**	**P**	**LRT P**
Normal	5.939	<0.005	
Box-Cox Transformation	0.674	0.077	
Lognormal	1.281	<0.005	
3-Parameter Lognormal	0.425	*	0.001
Exponential	36.819	<0.003	
2-Parameter Exponential	6.031	<0.010	0,000
Weibull	4.360	<0.010	
3-Parameter Weibull	0.427	0.336	0,000
Smallest Extreme Value	12.516	<0.010	
Largest Extreme Value	1.858	<0.010	
Gamma	2.354	<0.005	
3-Parameter Gamma	0.289	*	0,000
Logistic	4.533	<0.005	
Loglogistic	1.470	<0.005	
3-Parameter Loglogistic	0.704	*	0.000

Table 5.16 lists the results of Goodness of fit test for Group C. Box-cox transformation distribution, 3-Parameter Weibull distributions calculated p-value greater than 0.05 for Group C. These are fit the data better than the other distributions.

Table 5.17. ML estimates of distribution parameters for Group C

Distribution	**Location**	**Shape**	**Scale**	**Threshold**
Normal*	83.03774		34.99165	
Box-Cox Transformation*	0.11634		0.02213	
Lognormal*	4.33990		0.39262	
3-Parameter Lognormal	3.85109		0.62202	26.39169
Exponential			83.03774	
2-Parameter Exponential			47.26066	35.77707
Weibull		2.51219	93.82076	
3-Parameter Weibull		1.38057	51.83359	35.73496
Smallest Extreme Value	102.10146		42.47639	
Largest Extreme Value	67.63121		24.85808	
Gamma		6.45983	12.85447	
3-Parameter Gamma		1.79712	26.65883	35.12867
Logistic	78.72136		19.21238	
Loglogistic	4.32247		0.23014	
3-Parameter Loglogistic	3.74152		0.41211	30.96690
Johnson Transformation*	0.00437		0.99700	

** Scale: Adjusted ML estimate*

The Box-Cox Plot of Group C is presented in Figure 5.30. The lower and upper confidence levels (CLs) express that the best results for normality are reached with Lambda values between -0.90 and -0.16. The estimated value for the optimal λ is -0.50 and, the rounded value for λ is -0.50.

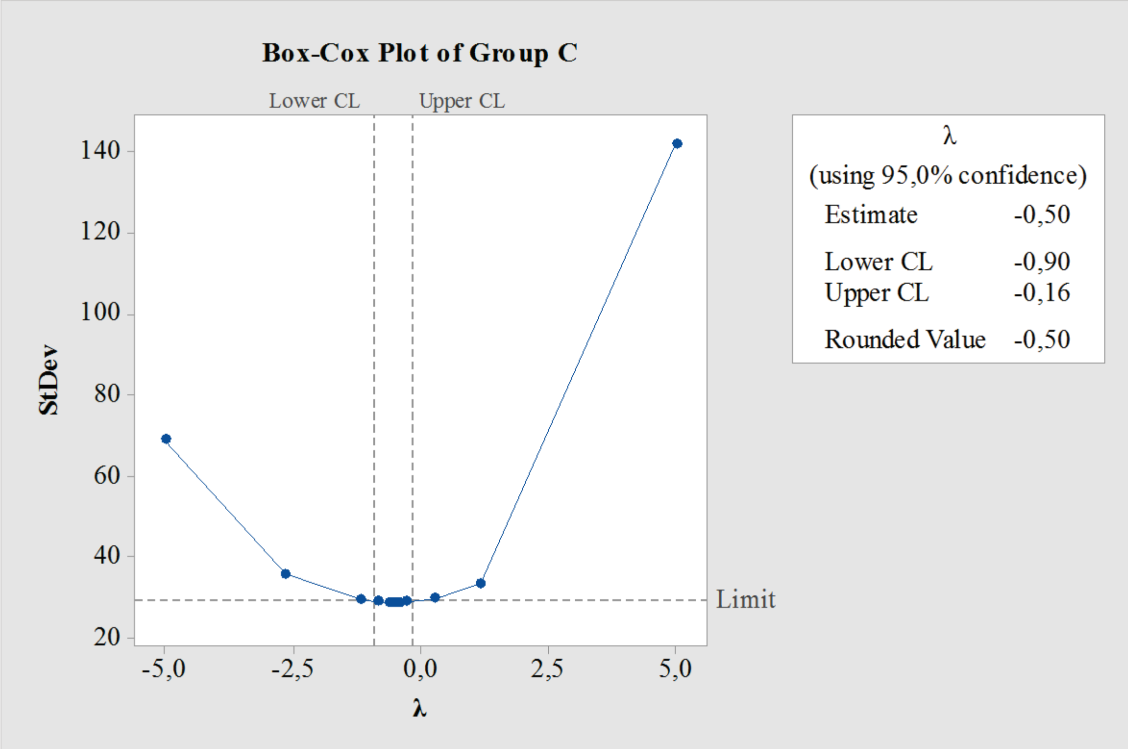
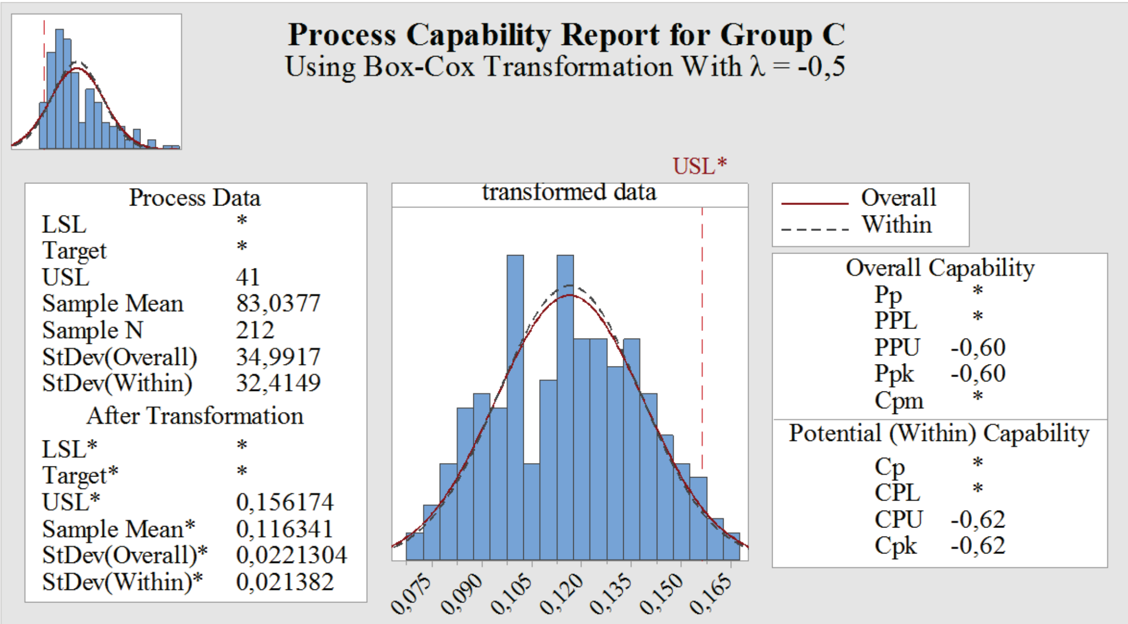


Figure 5.30. Box-Cox plot of Group C



Process Data	
LSL	*
Target	*
USL	41
Sample Mean	83,0377
Sample N	212
StDev(Overall)	34,9917
StDev(Within)	32,4149
After Transformation	
LSL*	*
Target*	*
USL*	0,156174
Sample Mean*	0,116341
StDev(Overall)*	0,0221304
StDev(Within)*	0,021382

Overall Capability	
Pp	*
PPL	*
PPU	-0,60
Ppk	-0,60
Cpm	*
Potential (Within) Capability	
Cp	*
CPL	*
CPU	-0,62
Cpk	-0,62

Performance

	Observed	Expected Overall*	Expected Within*
PPM < LSL	*	*	*
PPM > USL	962264,15	964063,77	968763,55
PPM Total	962264,15	964063,77	968763,55

* Calculated with LSL*, USL*

Figure 5.31. Process capability report for Group C

Figure 5.31 demonstrates the process capability report of Group C using Box-Cox transformation. The histogram on the center of the report displays the histogram of the transformed data using Lambda= -0,5 According to the report, after the transformation, the data is more normally distributed. The statistics and capability indexes are calculated and summarized in Figure 5.31. The upper left box in Figure 5.31 provides the statistics of the process data before and after the transformation. The values of all capability indexes are lower than 1. So, the process is not adequate. The upper specification limit of 41 days is simultaneously transformed to 0.15, producing a DPMO of 964063.773.

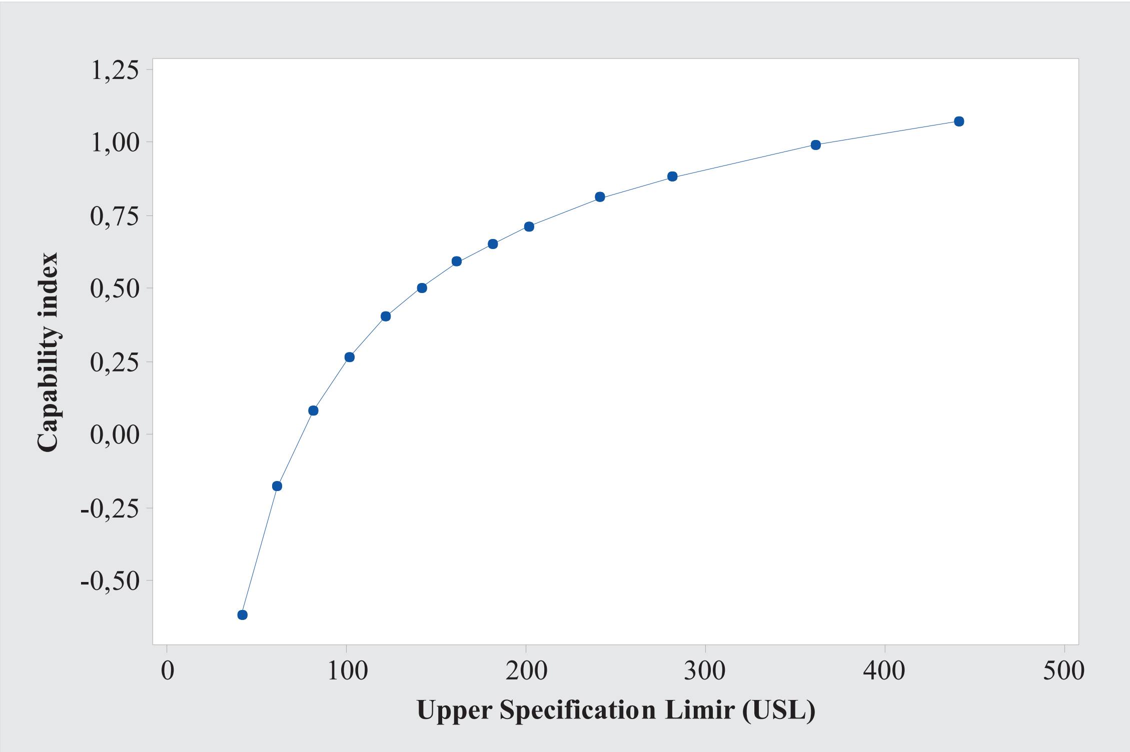


Figure 5.32. C_{PU} change by USL (day) in Group C

5.3 Process Capability Analysis of Tender Evaluation Process Based on Number of Tenderers (*PCA-NT)*

In this thesis, it is examined whether the number of tenderers affects the tender period. The following Figure 5.33 shows the frequency of the number of tenderers in all tenders. In the study which examined 647 tenders, the minimum number of tenderers is 1 and the maximum number of tenderers is 35. The tenders that have less than 10 and 10 participants are Group 1, tenders that have 10 to 20 participants are Group 2, and tenders that have more than 20 participants are specified as Group 3. The number of tenders classified in considering the participants are shown in Figure 5.34. Accordingly, Group 1 has 449 tenders; Group 2 has 180 tenders and Group 3 has 18 tenders.

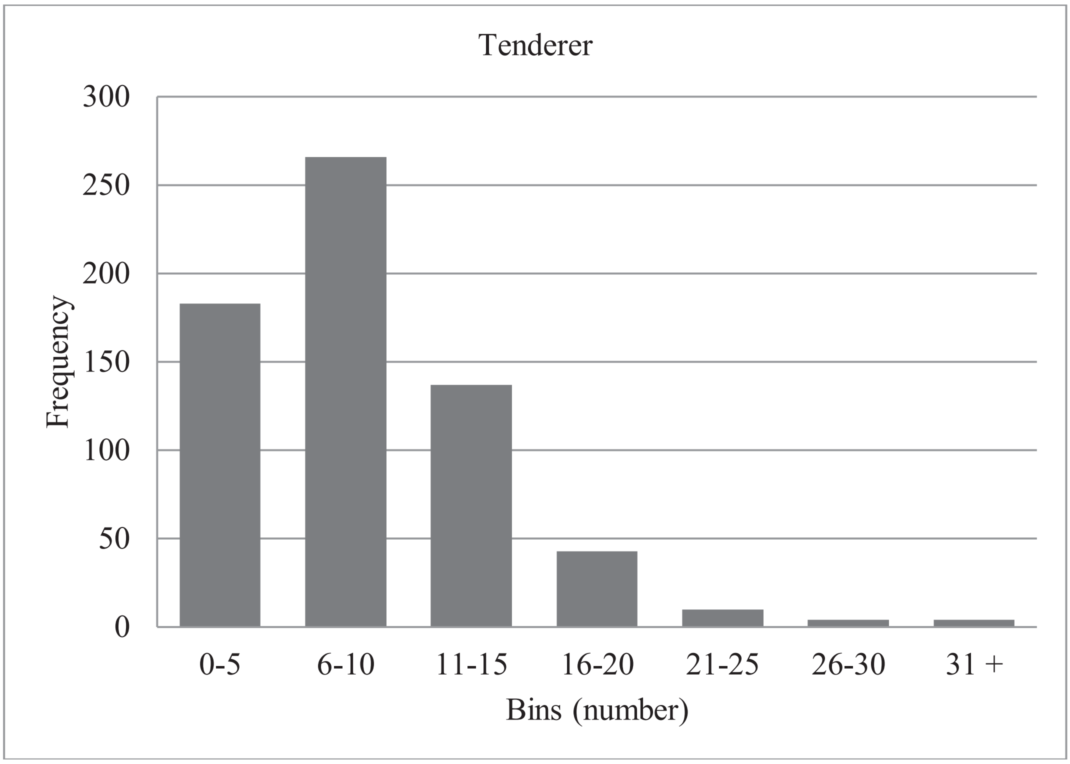


Figure 5.33. Frequency of the number of tenderers in all tenders

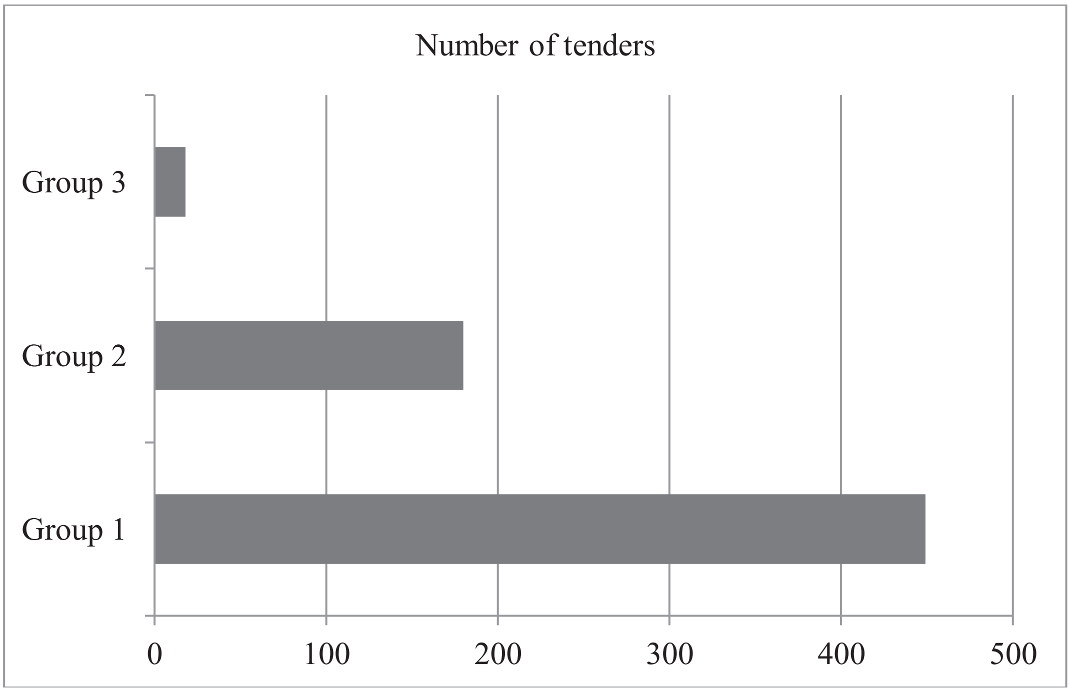


Figure 5.34. Number of tenders

5.3.1 Descriptive Statistics

In this part of the study, values of tender duration, preparation time, number of tenderers, number of the valid bid and complaint status as well as standard deviations of Group 1-2-3 were tabulated. All tenders were grouped considering number of tenderers. Table 5.18-20, respectively provide summary information (the minimum, mean, maximum and standard deviation) for Group 1-2 and 3.

Table 5.18. Group 1 (N_1=449)

	Minimum Value	Mean Value	Maximum Value	Standard Deviation
Tender Duration	18,00	55,71	554,00	33,39
Time to Prepare	7,00	17,73	33,00	4,61
Number of Valid Bid	1,00	4,54	10,00	2,16
Number of Tenderer	1,00	6,08	10,00	2,30
Number of Complaint	0,00	0,07	1,00	0,26

Table 5.19. Group 2 (N_2=180)

	Minimum Value	Mean Value	Maximum Value	Standard Deviation
Tender Duration	31,00	77,59	273,00	37,19
Time to Prepare	10,00	20,08	36,00	4,60
Number of Valid Bid	1,00	9,64	18,00	3,39
Number of Tenderer	11,00	13,63	20,00	2,44
Number of Complaint	0,00	0,17	1,00	0,37

Table 5.20. Group 3 (N_3=18)

	Minimum Value	Mean Value	Maximum Value	Standard Deviation
Tender Duration	53,00	99,22	213,00	36,02
Time to Prepare	15,00	21,00	28,00	4,45
Number of Valid Bid	5,00	16,78	31,00	6,64
Number of Tenderer	21,00	25,72	35,00	5,19
Number of Complaint	0,00	0,17	1,00	0,38

5.3.2 Group 1

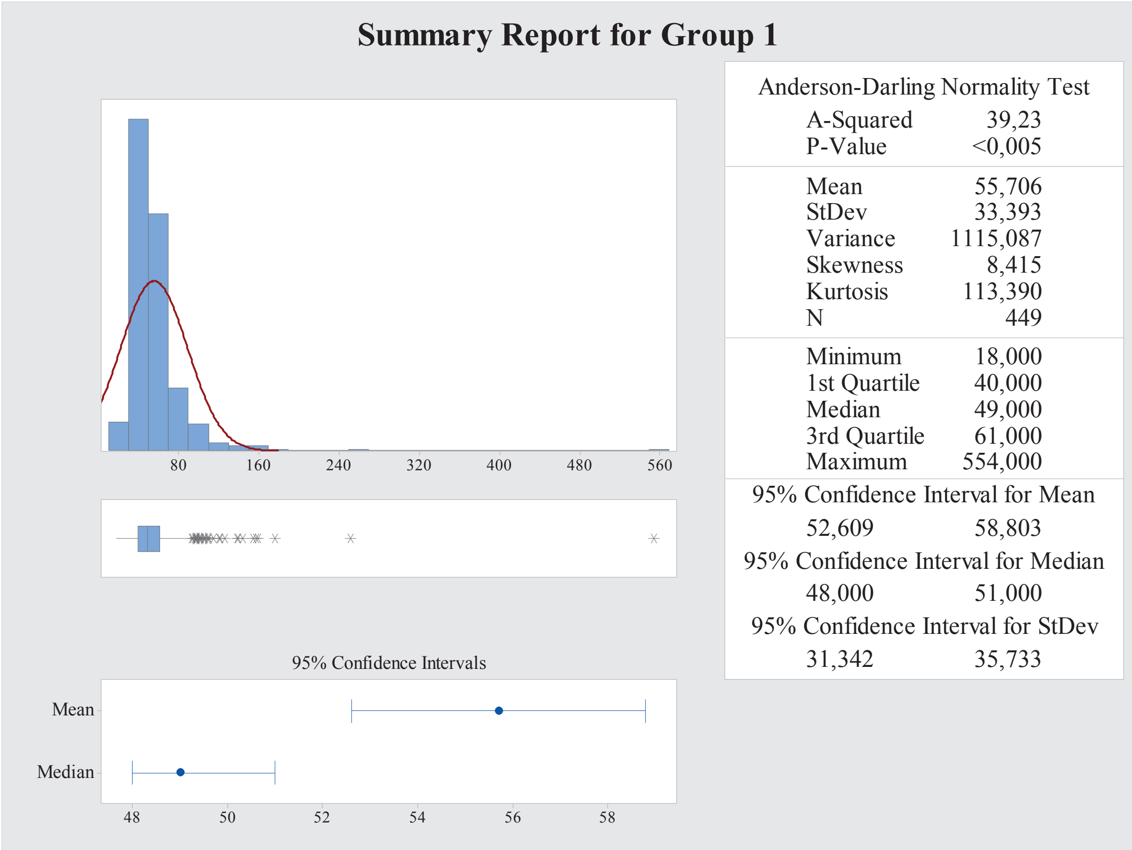


Figure 5.35. Frequency distribution graph and descriptive statistics for Group 1

In Figure 5.35, the frequency distribution graph and descriptive statistics for Group 1 are demonstrated. The histogram in Figure 5.35 shows that Group 1 do not have normal distribution characteristics. In the histogram, positive skewness is observed. The distribution is skewed to the left. Normality test results for Group 1 are presented in Table 5.21 and Table 5.22.

Table 5.21. Shapiro Wilk normality test results for Group 1

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Group 1	0,209	449	0,000	0,516	449	0,000

Table 5.22. One-sample Kolmogorov-Smirnov test results of Group 1

		Group 1
N		449
Normal Parameters[a,b]	Mean	55,71
	Std. Deviation	33,393
Most Extreme Differences	Absolute	0,209
	Positive	0,209
	Negative	-0,189
Kolmogorov-Smirnov Z		4,433
Asymp. Sig. (2-tailed)		0,000

The mean, standard deviation, variance, minimum, maximum values, skewness, and kurtosis were given in the 95% confidence interval of the mean. Skewness is an indication of whether the data are distributed symmetrically. The skewness value of the symmetrically distributed data is 0. As stated in Figure 5.35 and the skewness value is 8.41 and the kurtosis value is 113.39 for Group 1. Since the skewness and kurtosis findings are not in the range of $-1.5 < x < +1.5$, it can be concluded that they are not distributed normally.

According to Shapiro Wilk normality test results for Group 1 in Table 5.21 , (KS = 0.209, df 449, $p < 0.05$) and (SW = 0.516, df 449, $p < 0.05$), the data is not normally distributed. In addition, according to the Kolmogorov-Smirnov test results (see in Table 5.22), the p-value is 0.00. It is lower than the significance level which is 0.05. As a result, it can be said that the data is not distributed normally for Kolmogorov-Smirnov normality test.

Figure 5.36 displays the normality plot of Group 1 obtained from MİNİTAB-18 statistical software. According to the probability plot, mean:55.71, standard deviation:33.39 Anderson Darling test statics: 39.225 and p-value is less than significance value. As a result, data is not distributed normally.

With I-MR chart it was controlled that process mean of Group 1 is in the control or not. Red points in Figure 5.37 indicate the uncontrolled variation in Group 1. For Group 1, total number of uncontrolled variations are 12. The three of them were excluded from the calculations.

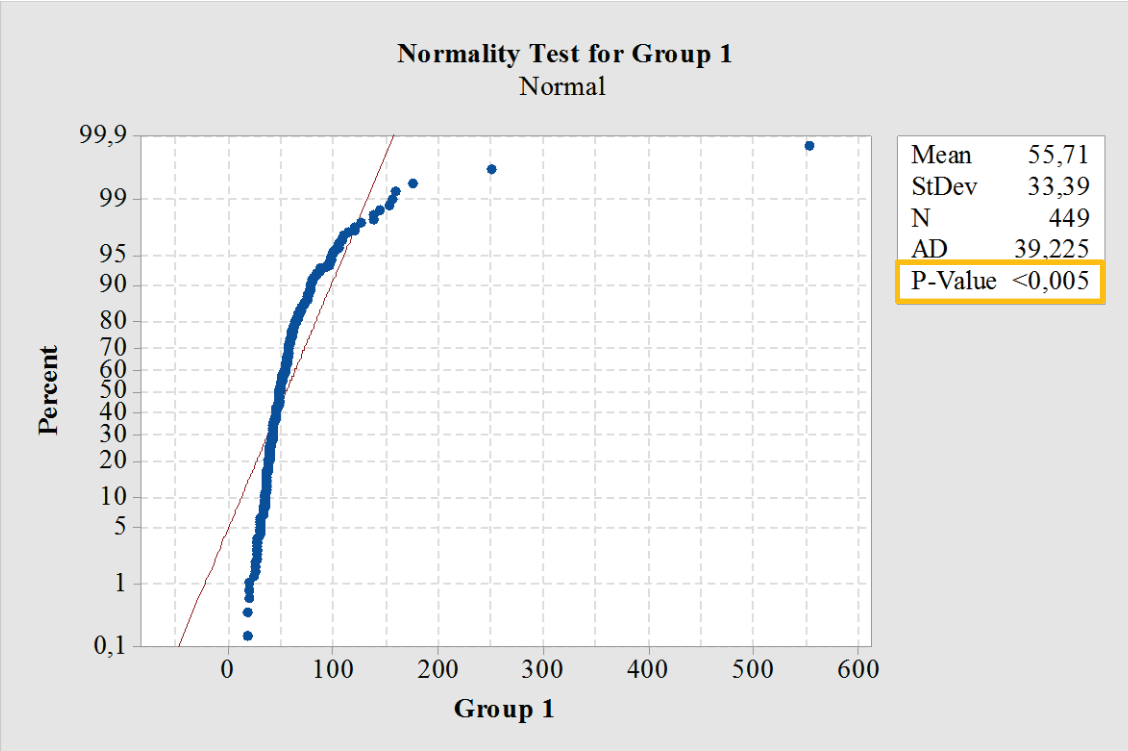


Figure 5.36. Normality plot of Group 1

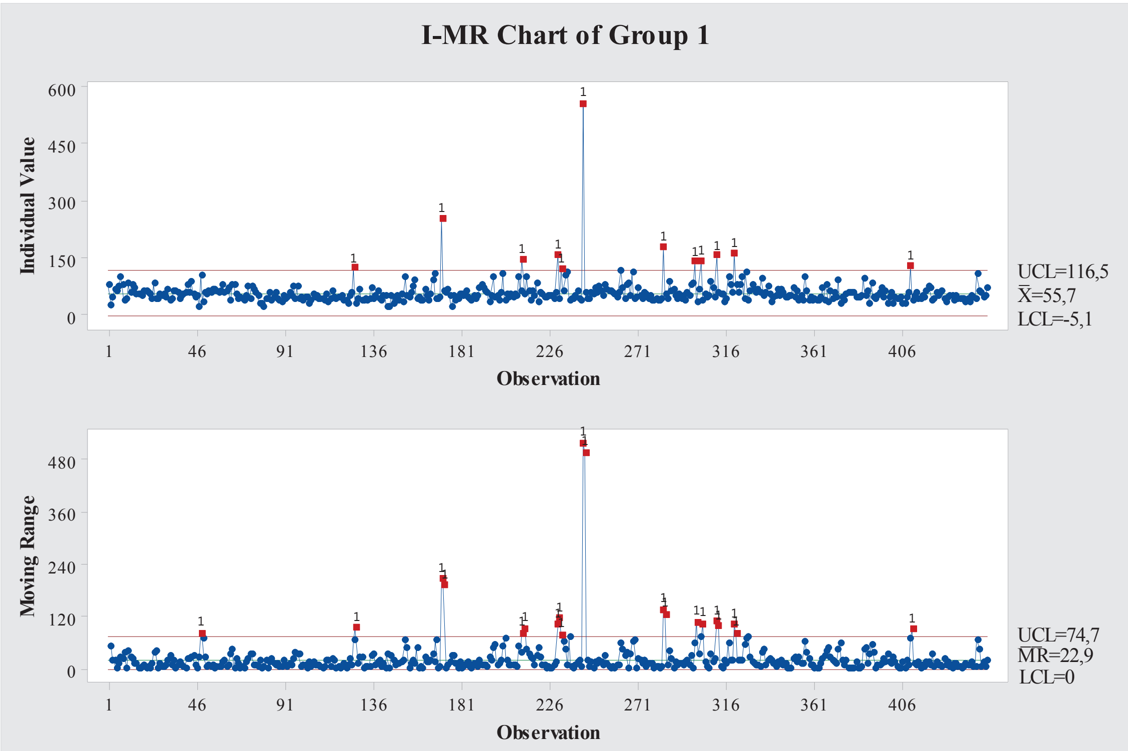


Figure 5.37. I-MR chart of Group 1

Figure 5.38-41 illustrate the results of individual distribution identification for Group 1. For all distribution p-value is too small. None of these distributions is an effective way enough to transform data into normal distribution Group 1.

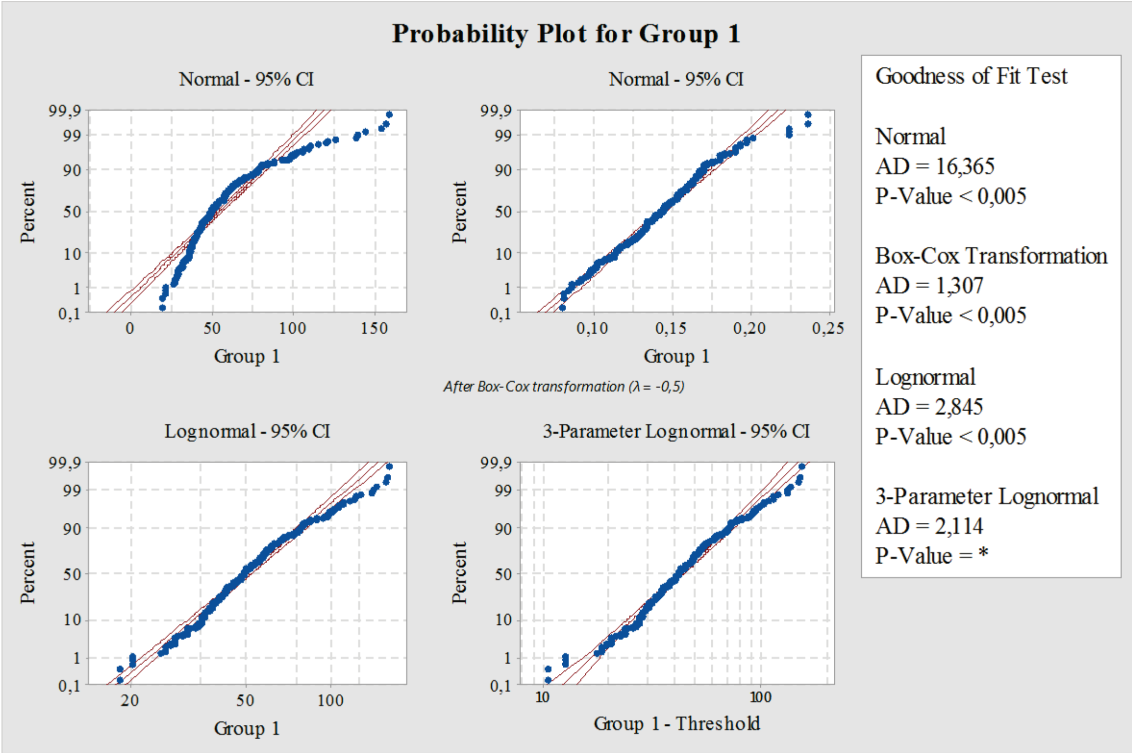


Figure 5.38. Normal, Box-Cox Transformation, Lognormal, 3-Parameter Lognormal distribution plots for Group 1

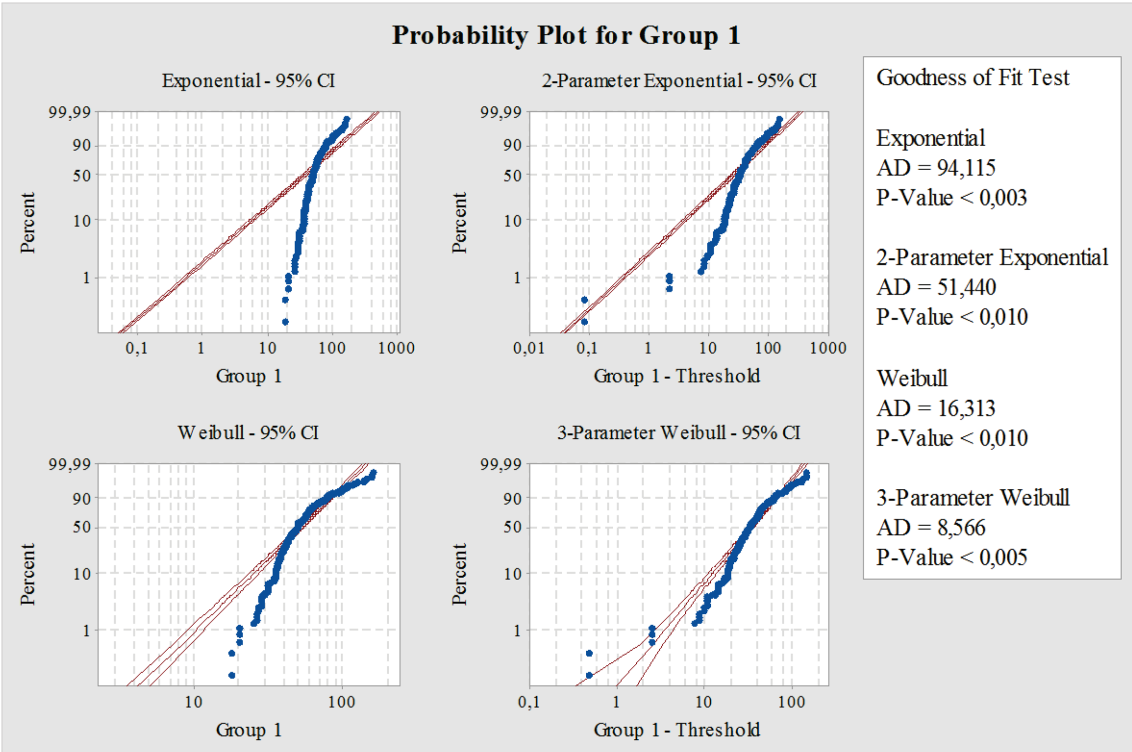


Figure 5.39. Exponential, 2-Parameter Exponential, Weibull, 3-Parameter Weibull distribution plots of Group 1

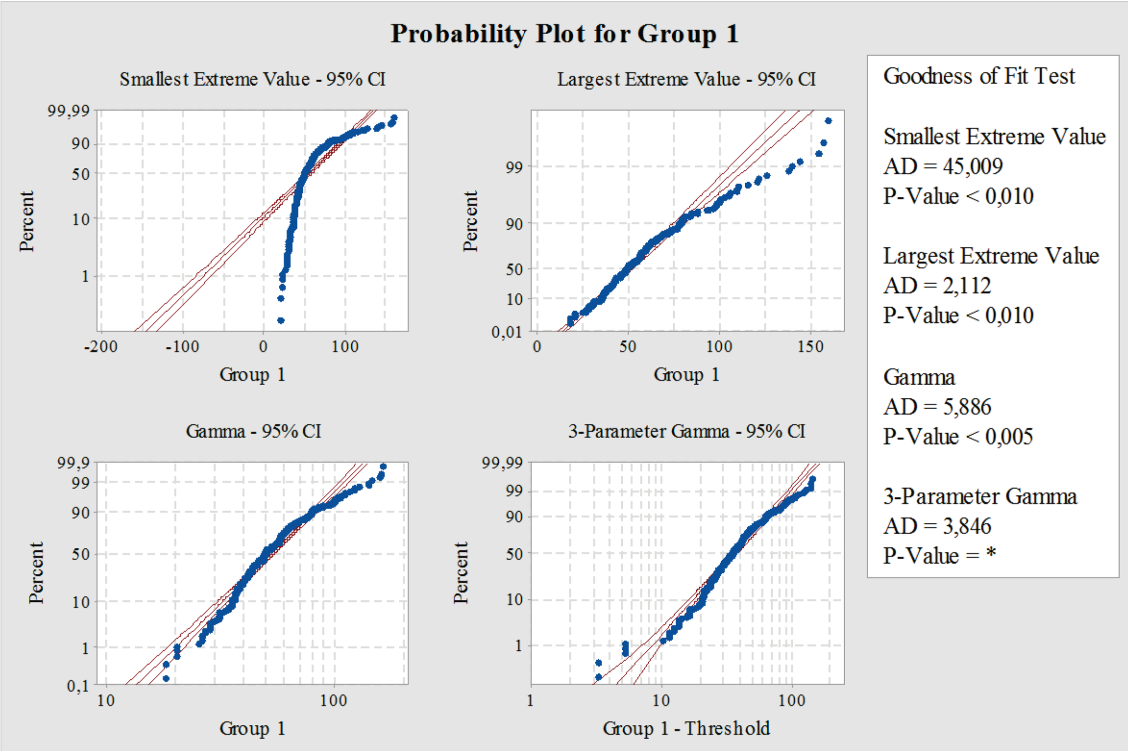


Figure 5.40. Smallest Extreme Value, Largest Extreme Value, Gamma, 3-Parameter Gamma distribution plots of Group 1

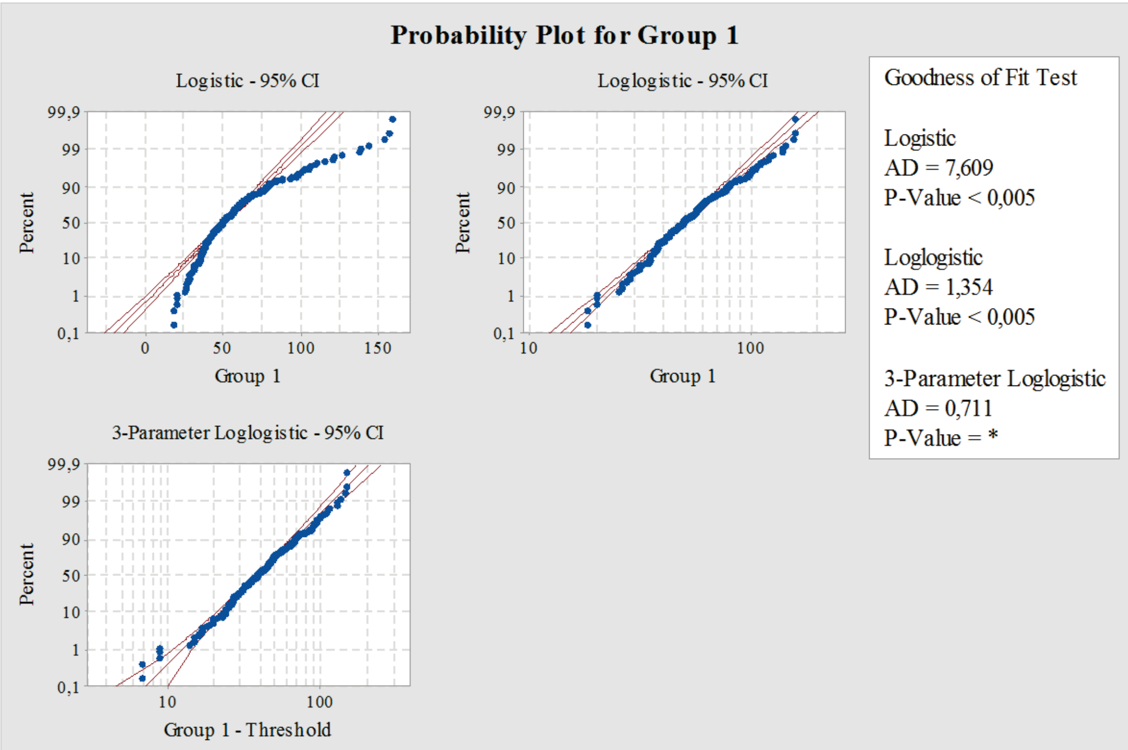


Figure 5.41. Logistic, Loglogistic, 3-Parameter Loglogistic distribution plots for Group 1

Table 5.23. Goodness of fit test results for Group 1

Distribution	**AD**	**P**	**LRT P**
Normal	16,365	<0,005	
Box-Cox Transformation	1,307	<0,005	
Lognormal	2,845	<0,005	
3-Parameter Lognormal	2,114	*	0,023
Exponential	94,115	<0,003	
2-Parameter Exponential	51,440	<0,010	0,000
Weibull	16,313	<0,010	
3-Parameter Weibull	8,566	<0,005	0,000
Smallest Extreme Value	45,009	<0,010	
Largest Extreme Value	2,112	<0,010	
Gamma	5,886	<0,005	
3-Parameter Gamma	3,846	*	0,000
Logistic	7,609	<0,005	
Loglogistic	1,354	<0,005	
3-Parameter Loglogistic	0,711	*	0,007

Table 5.24. ML estimates of distribution parameters for Group 1

Distribution	Location	Shape	Scale	Threshold
Normal*	53.88117		21.04926	
Box-Cox Transformation*	0.14258		0.02390	
Lognormal*	3.92447		0.34330	
3-Parameter Lognormal	3.74857		0.40650	7.63119
Exponential			53.88117	
2-Parameter Exponential			35.96180	17.91937
Weibull		2.58581	60.54324	
3-Parameter Weibull		1.83826	41.00824	17.54433
Smallest Extreme Value	65.96859		30.87981	
Largest Extreme Value	45.20401		14.30710	
Gamma		8.18801	6.58049	
3-Parameter Gamma		4.15592	9.41724	14.74389
Logistic	51.07578		10.32744	
Loglogistic	3.90882		0.18767	
3-Parameter Loglogistic	3.64405		0.24475	11.26846

Table 5.23 tabulate the results of the Goodness of fit test for Group 1. None of distribution has p-value greater than 0.05. Figure 5.42 illustrates the Box-Cox Plot of Group 1. The lower and upper confidence levels (CLs) display that the best results for normality were reached with Lambda values between -0.72 and -0.24. The estimated value for the optimal λ is -0.46 and, the rounded value for λ is -0.50.

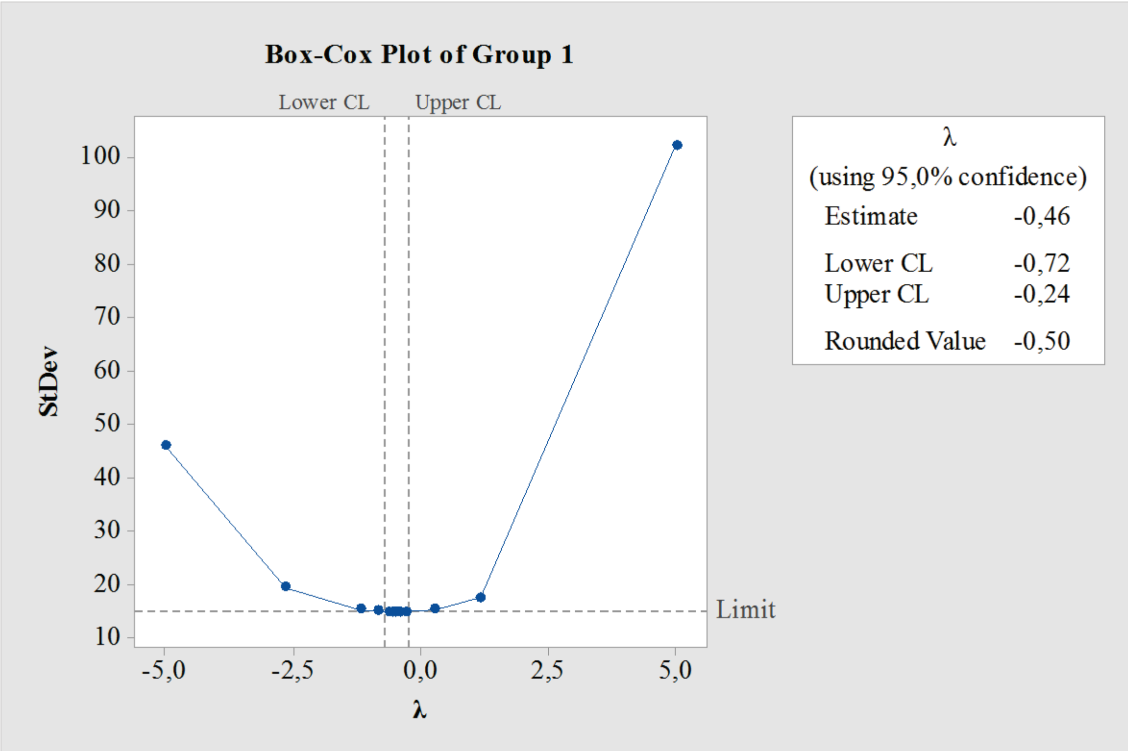


Figure 5.42. Box-Cox plot of Group 1

Figure 5.43 presents the process capability report of Group 1 using Box-Cox transformation. The histogram on the center of the report displays the histogram of the transformed data using Lambda= -0.5 According to the report, after the transformation, the data is more normally distributed. The statistics and capability indexes are calculated and summarized in the report. The upper left box in Figure 5.43 lists the statistics of the process data before and after the transformation.

The values of all capability indexes are lower than 1. So, the process is inadequate. The upper specification limit of 28 days is simultaneously transformed to 0,18, producing a DPMO of 973906.93. The change in the process capability index according to the days is shown in the Figure 5.44.

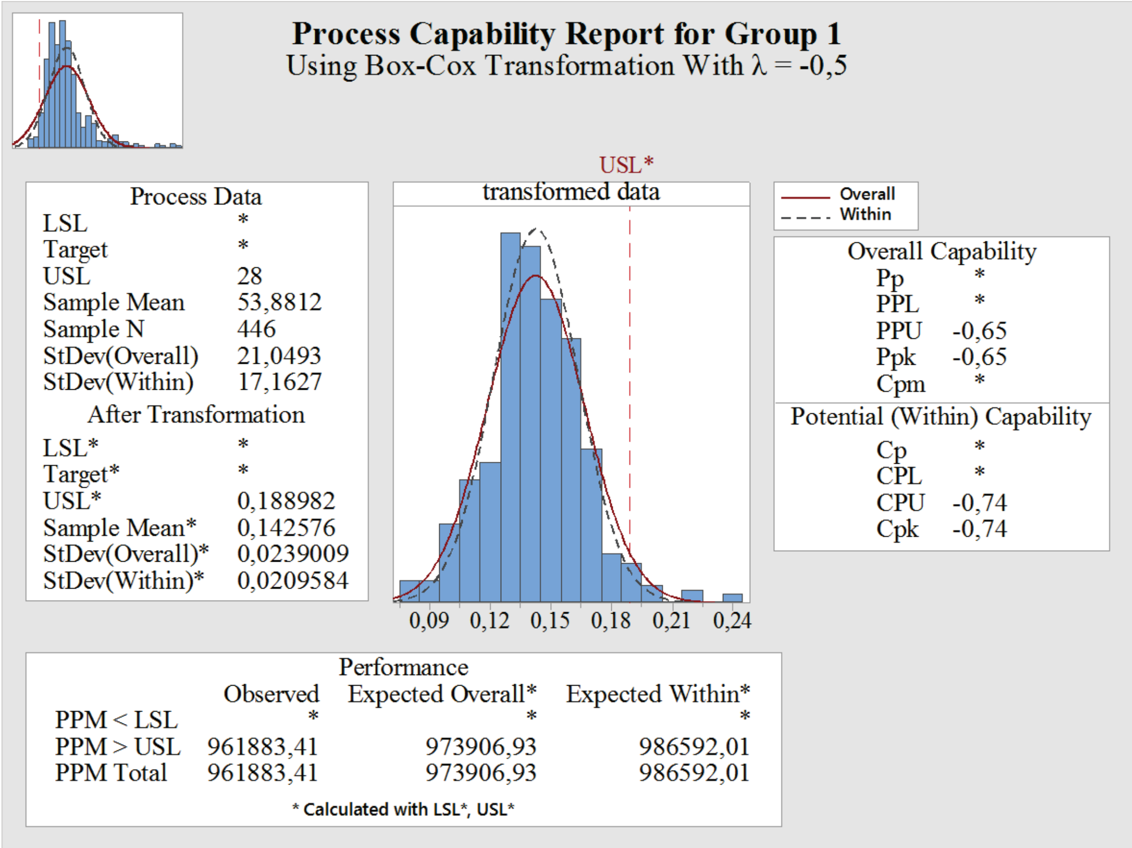


Figure 5.43. Process capability report for Group 1

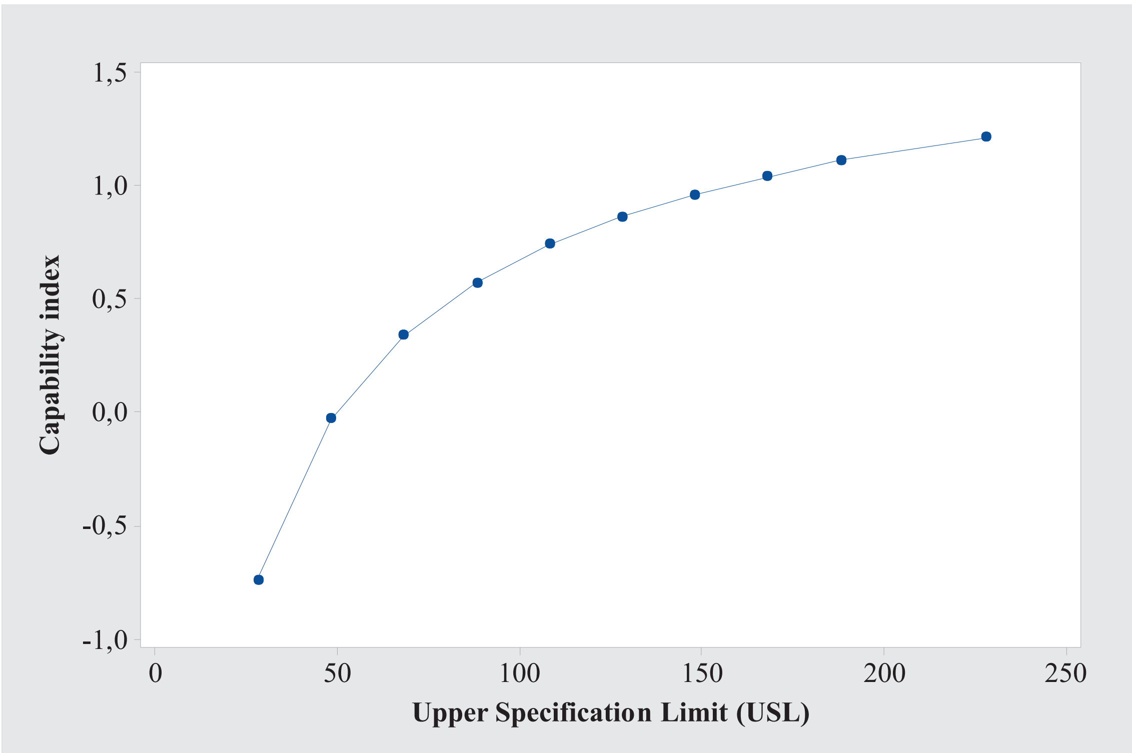


Figure 5.44. C_{PU} change by USL (day) in Group 1

5.3.3 Group 2

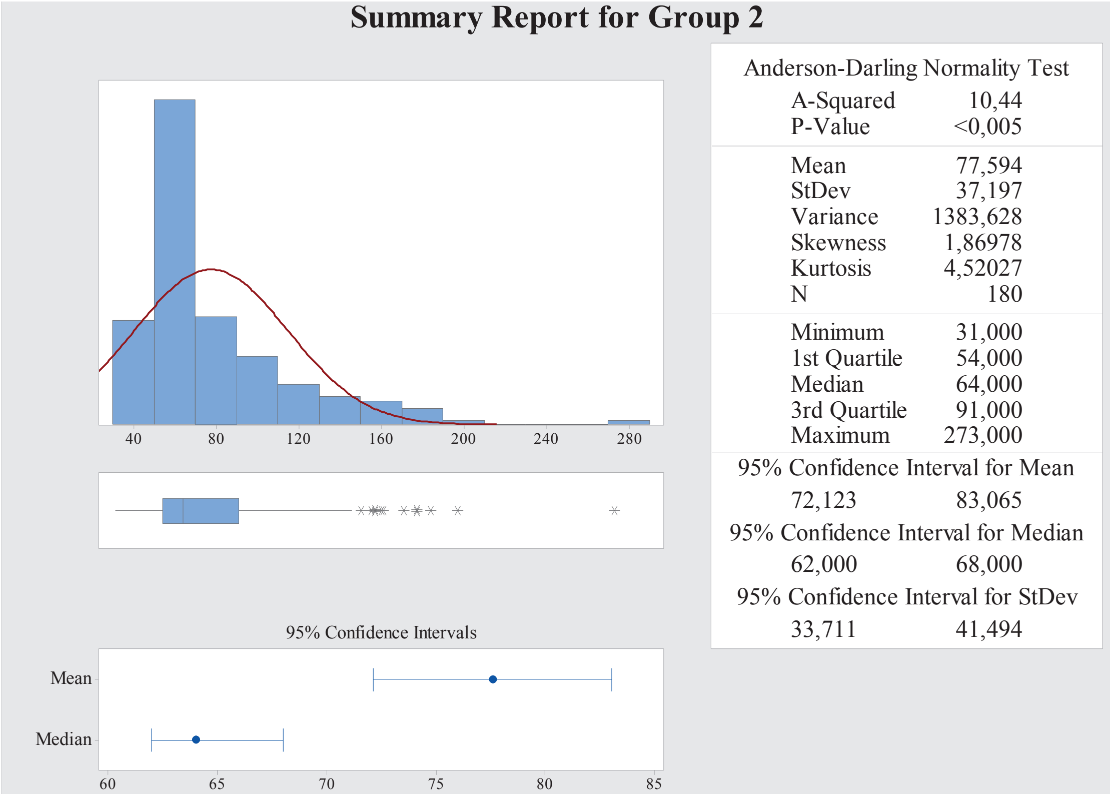


Figure 5.45. Frequency distribution graph and descriptive statistics for Group 2

In Figure 5.45, descriptive statistics and frequency distribution graph for Group 2 are indicated. In the histogram, data skewed to the left is observed. According to the histogram, Group 2 is not distributed normally. Table 5.25 and Table 5.26 tabulate the normality test results for Group 2.

Table 5.25. Shapiro Wilk normality test results for Group 2

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Group 2	0,200	180	0,000	0,817	180	0,000

Table 5.26. One- sample Kolmogorov-Smirnov test results of Group 2

	Group 2
N	180
Kolmogorov-Smirnov Z	2,678
Asymp. Sig. (2-tailed)	0,000

The mean, standard deviation, variance, minimum, maximum values, skewness, and kurtosis were given in the 95% confidence interval of the mean. Skewness is an indication of whether the data are distributed symmetrically. The skewness value of the symmetrically distributed data is 0. As stated in Figure 5.45 skewness value is 1.870 and the kurtosis value is 4.52 for Group 2. Since the skewness and kurtosis findings are not in the range of -1.5 <x <+1.5, it can be concluded that they are not distributed normally. According to Shapiro Wilk normality test results for Group 2 (see in Table 5.25), (KS = 0.200, df 180, p <0.05) and (SW =0.817, df 180, p <0.05), the data is not normally distributed. In addition, according to the Kolmogorov-Smirnov test results (see in Table 5.26), the p-value is 0.00. It is lower than the significance value (0.05). As a result, it can be said that the data is not distributed normally.

Figure 5.46 displays the normality plot of Group 2 obtained from MİNİTAB-18 statistical software. According to probability plot of Group 2, mean:77.59, standard deviation: 37.20, Anderson Darling test statics: 10.438 and p-value is less than 0.005. According to the results, normal distribution is not seen in Group 2.

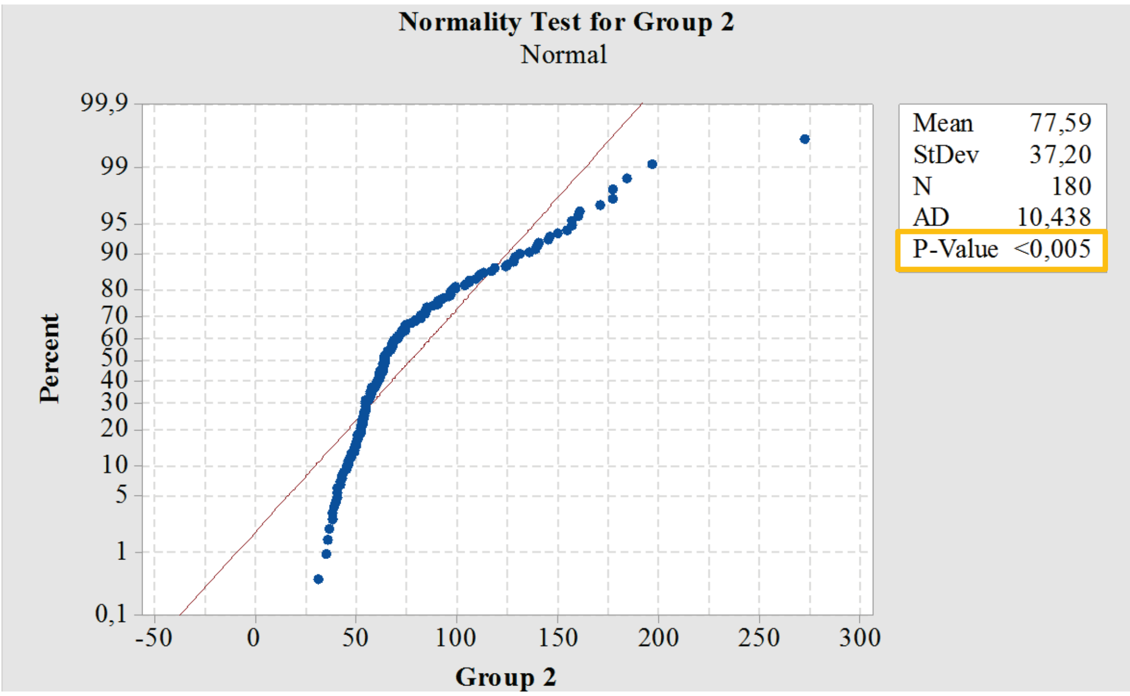


Figure 5.46. Normality plot of Group 2

Uncontrolled variations in Group 2 are shown in Figure 5.47. According to the I-MR chart of Group 2, many uncontrolled points were determined, and these points were marked in red in the graph. Totally, six points are detected. However, the three major variables, which distort the symmetry of the graph, were excluded from the calculations.

The results of the individual distribution identification for Group 2 are illustrated in Figure 5.48-51. The p-value of each distribution is quite small. The most suitable distribution for this group could not be determined.

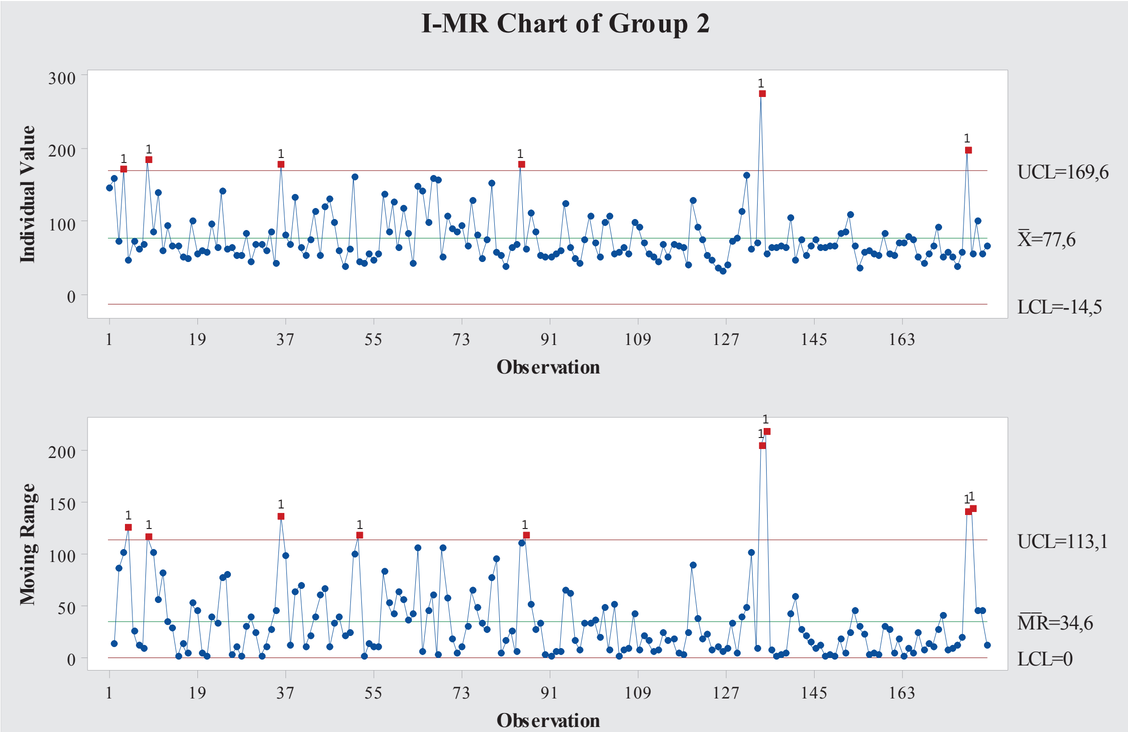


Figure 5.47. I-MR chart of Group 2

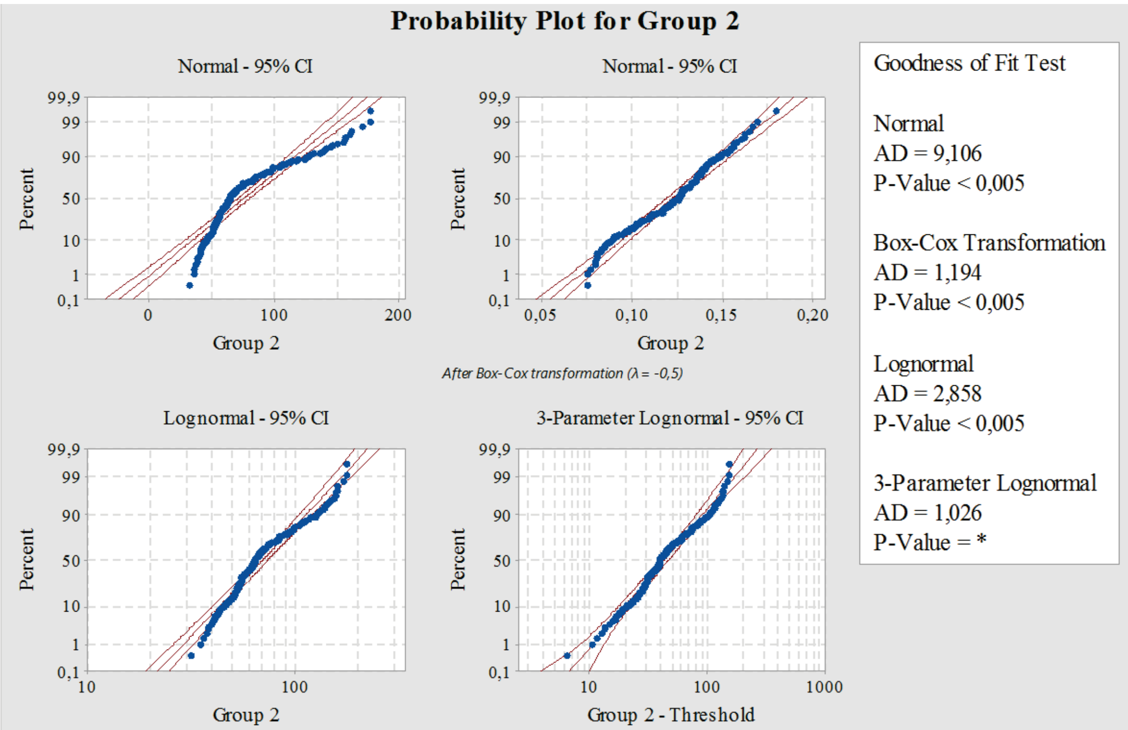


Figure 5.48. Normal, Box-Cox Transformation, Lognormal, 3-Parameter Lognormal distribution plots for Group 2

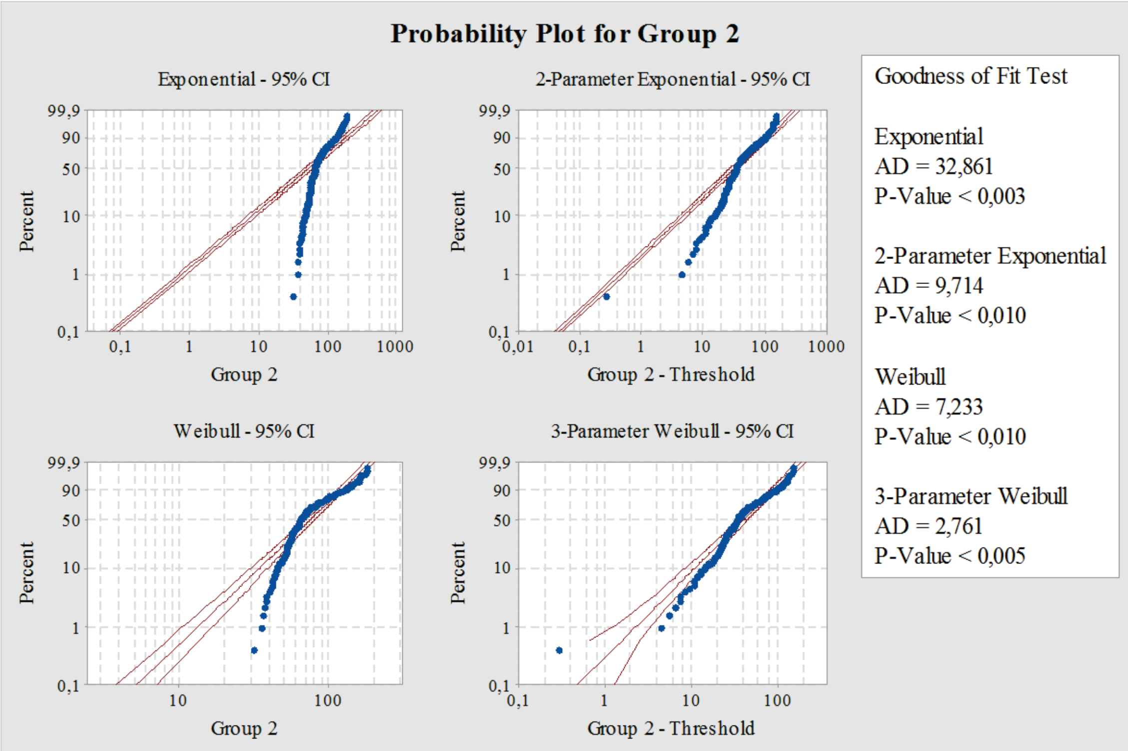


Figure 5.49. Exponential, 2-Parameter Exponential, Weibull, 3-Parameter Weibull distribution plots of Group 2

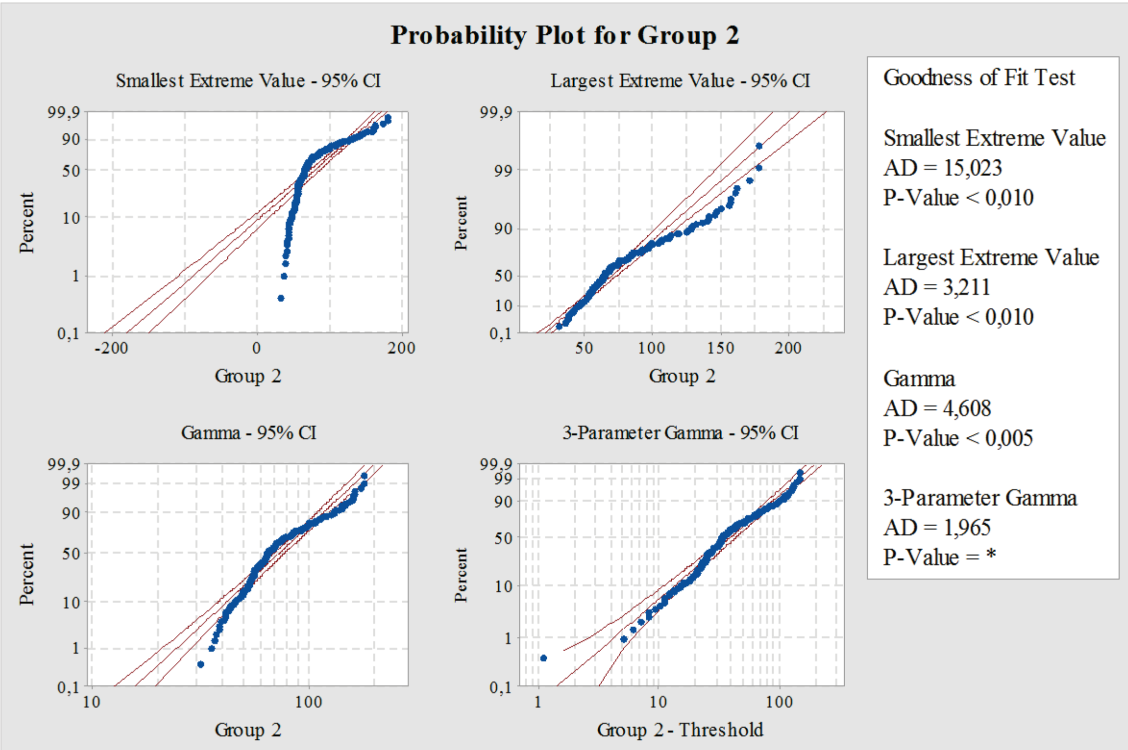


Figure 5.50. Smallest Extreme Value, Largest Extreme Value, Gamma, 3-Parameter Gamma distribution plots of Group 2

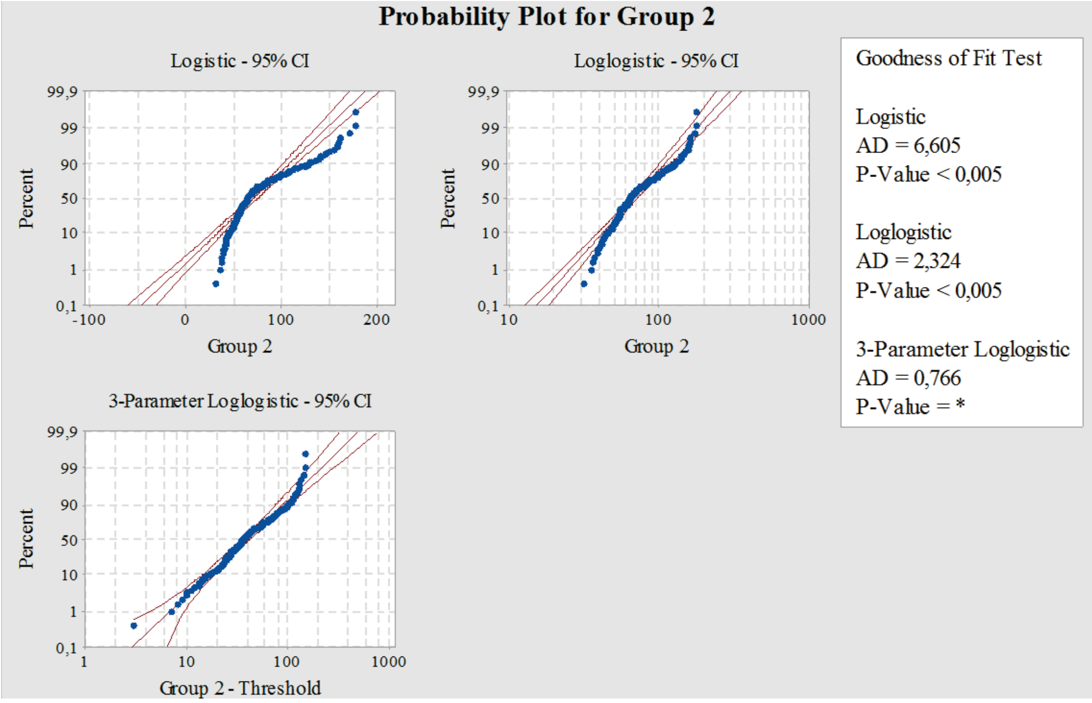


Figure 5.51 Logistic, Loglogistic, 3-Parameter Loglogistic distribution plots for Group 2

Table 5.27 presents the results of the Goodness of fit test for Group 2. Distribution which fit Group 2 enough was not determined. All have smaller p values than 0.05.

Table 5.27. Goodness of fit test results for Group 2

Distribution	**AD**	**P**	**LRT P**
Normal	9.106	<0.005	
Box-Cox Transformation	1.194	<0.005	
Lognormal	2.858	<0.005	
3-Parameter Lognormal	1.026	*	0.000
Exponential	32.861	<0.003	
2-Parameter Exponential	9.714	<0.010	0.000
Weibull	7.233	<0.010	
3-Parameter Weibull	2.761	<0.005	0.000
Smallest Extreme Value	15.023	<0.010	
Largest Extreme Value	3.211	<0.010	
Gamma	4.608	<0.005	
3-Parameter Gamma	1.965	*	0.000
Logistic	6.605	<0.005	
Loglogistic	2.324	<0.005	
3-Parameter Loglogistic	0.766	*	0.000

Table 5.28. ML estimates of distribution parameters for Group 2

Distribution	**Location**	**Shape**	**Scale**	**Threshold**
Normal*	75.21469		32.23703	
Box-Cox Transformation*	0.12190		0.02194	
Lognormal*	4.24355		0.37972	
3-Parameter Lognormal	3.74138		0.59985	24.74067
Exponential			75.21469	
2-Parameter Exponential			44.46590	30.74878
Weibull		2.45828	85.04061	
3-Parameter Weibull		1.47789	49.46329	30.71040
Smallest Extreme Value	93.09452		39.64800	
Largest Extreme Value	61.57450		21.21019	
Gamma		6.67338	11.27085	
3-Parameter Gamma		2.22587	20.34154	29.93709
Logistic	70.04470		16.87126	
Loglogistic	4.21137		0.21480	
3-Parameter Loglogistic	3.63512		0.37482	28.06746

** Scale: Adjusted ML estimate*

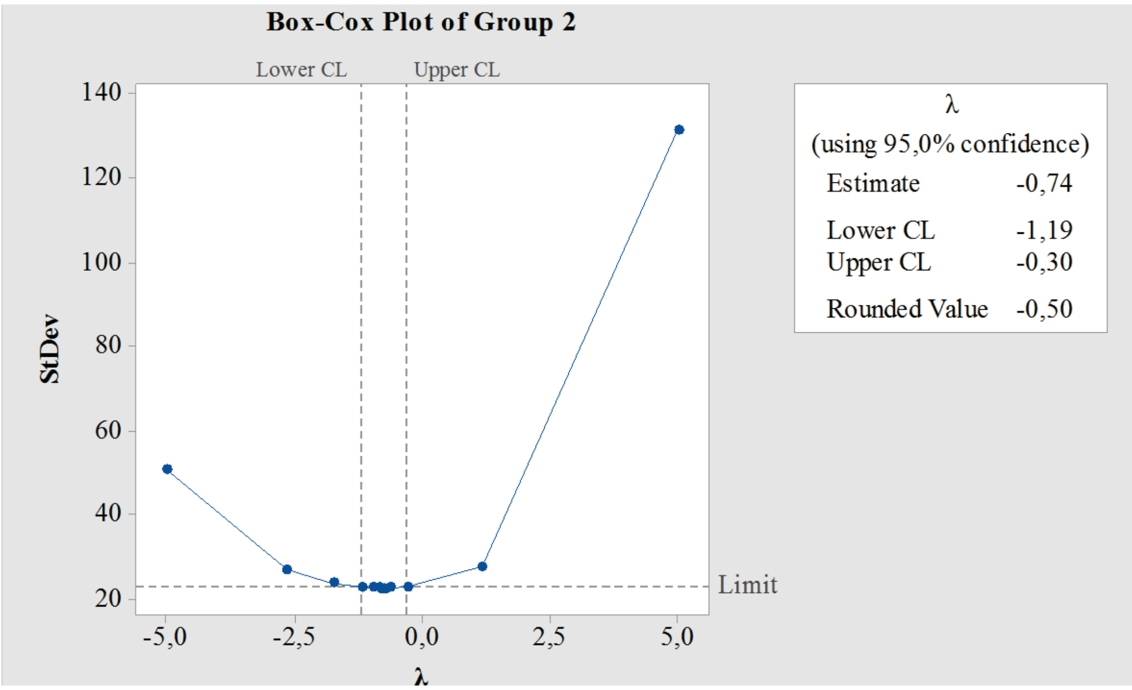


Figure 5.52. Box-Cox plot of Group 2

The Box-Cox Plot of Group 2 is demonstrated in Figure 5.52. The lower and upper confidence levels (CLs) show that the best results for normality are reached with Lambda values between -1.19 and -0.30. The estimated value for the optimal λ is -0.74 and, the rounded value for λ is -0.50.

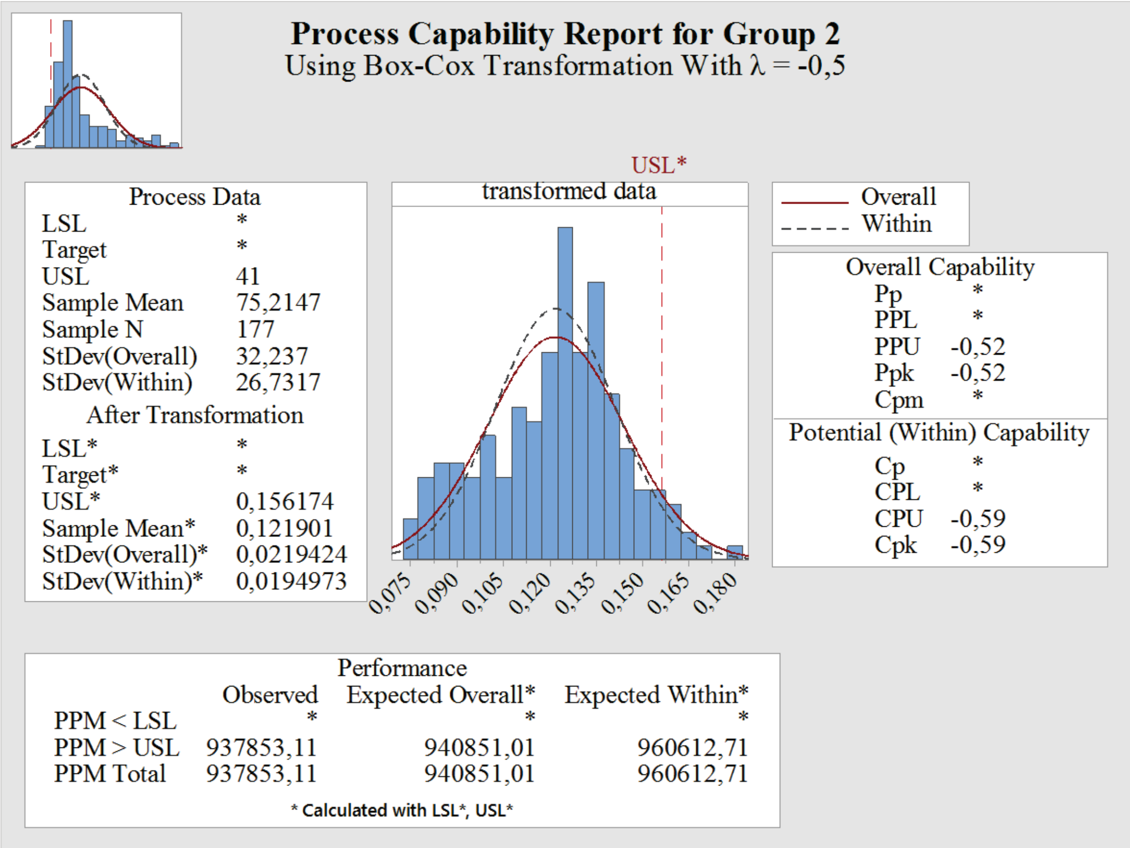


Figure 5.53. Process capability report for Group 2

Process capability report of Group 2 using Box-Cox transformation is presented in Figure 5.53. The histogram on the center of the report displays the histogram of the transformed data using Lambda= -0.5 According to the report, after the transformation, the data is more normally distributed.

The statistics and capability indexes are calculated and summarized in Figure 5.53. The upper left box in the report provides the statistics of the process data before and after the transformation. The values of all capability indexes are lower than 1. So, the process is inadequate. The upper specification limit of 41 days is simultaneously transformed to 0.15, producing a DPMO of 940851.01. The change in the process capability index according to the days is shown in the Figure 5.54.

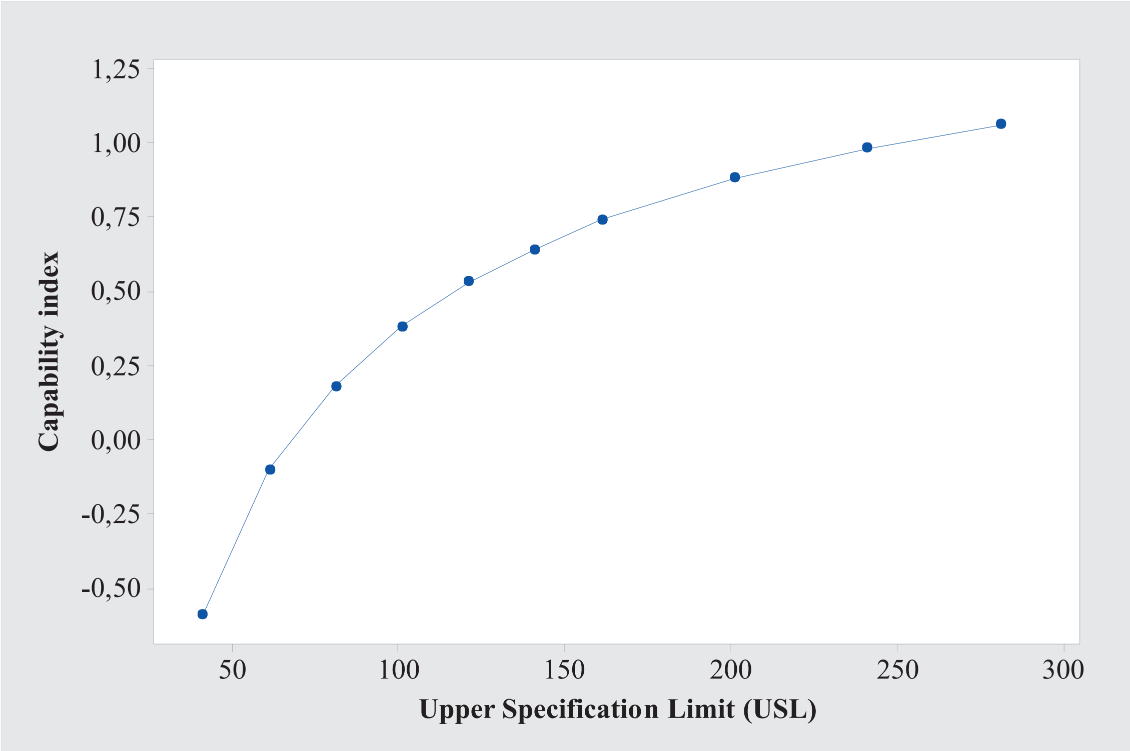


Figure 5.54. C_{PU} change by USL (day) in Group 2

5.3.4 Group 3

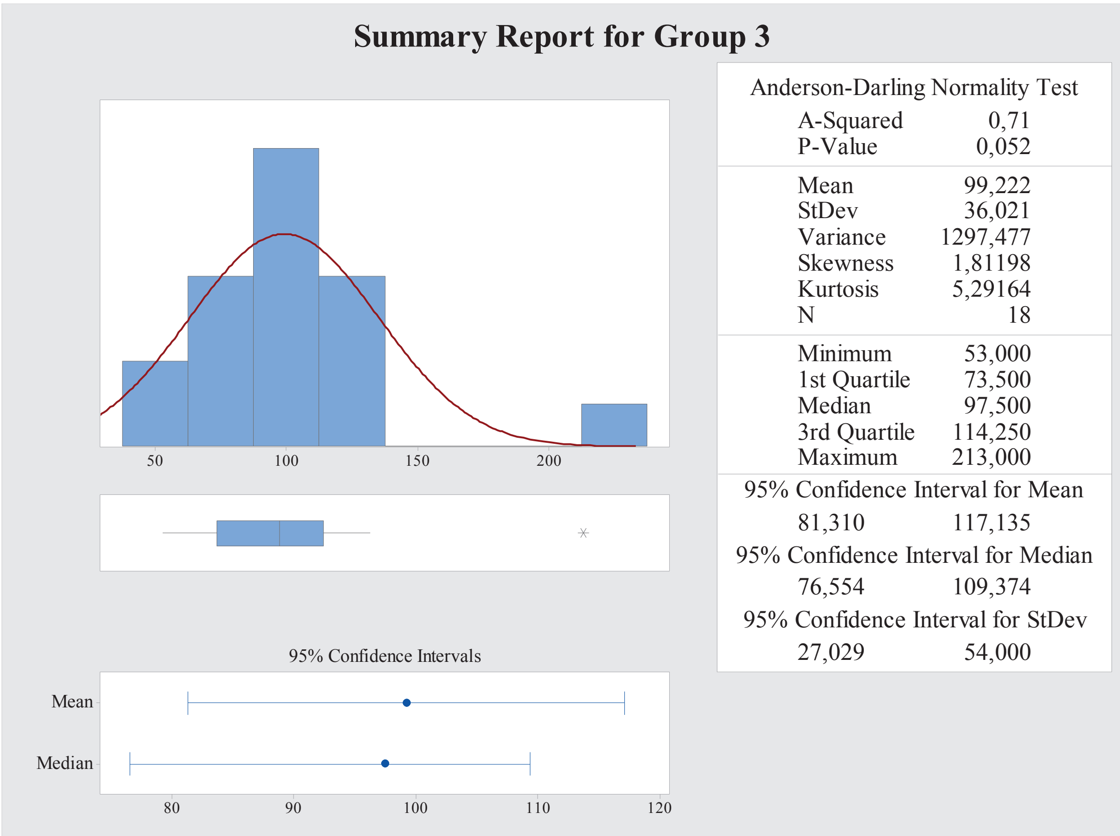


Figure 5.55. Frequency distribution graph and descriptive statistics for Group 3

The histogram in Figure 5.55 illustrates frequency distribution of Group 3. In the histogram, negative skewness is observed, as a result, Group 3 do not follow normal distribution. Normality test results for Group 3 are presented in Table 5.29-30.

Table 5.29. Shapiro Wilk normality test results for Group 3

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Group 3	0.152	18	0.200*	0.850	18	0.009

Table 5.30. One- sample Kolmogorov-Smirnov test results of Group 3

	Group 3
N	18
Kolmogorov-Smirnov Z	0.647
Asymp. Sig. (2-tailed)	0.797

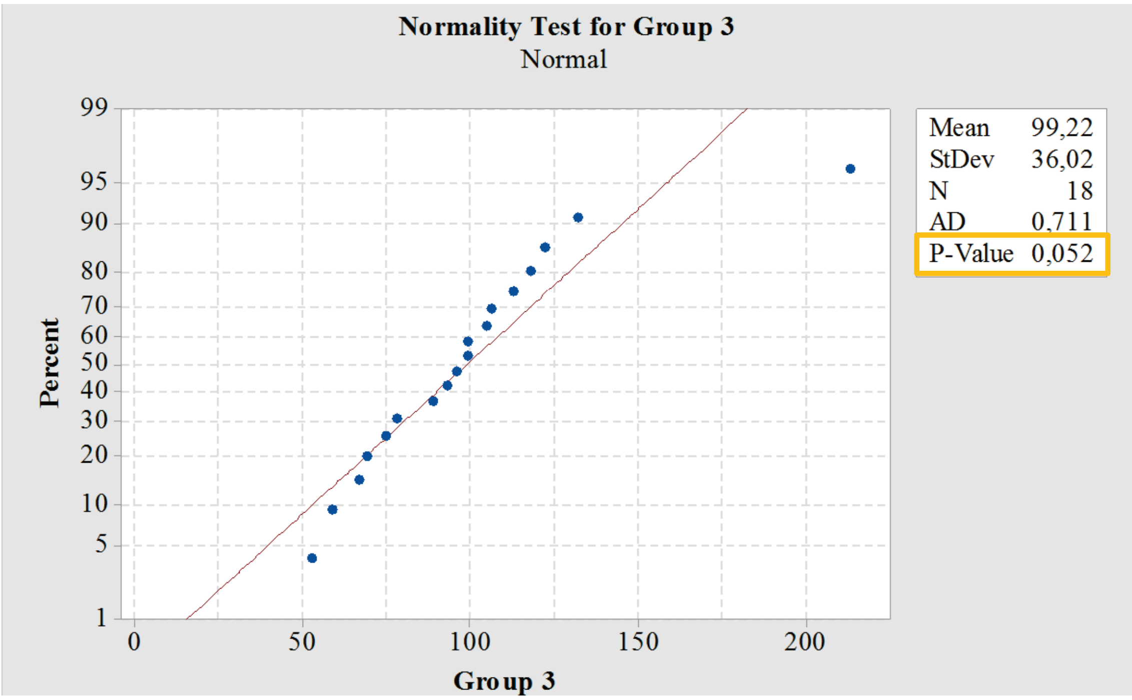


Figure 5.56. Normality plot of Group 3

The mean, standard deviation, variance, minimum, maximum values, skewness, and kurtosis were given in the 95% confidence interval of the mean. Skewness is an indication of whether the data are distributed symmetrically. The skewness value of the symmetrically distributed data is 0. As shown in Figure 5.55, the skewness value is 1.812

and the kurtosis value is 5.292 for Group 3. Since the skewness and kurtosis findings are not in the range of -1.5 <x <+1.5, it can be concluded that they are not distributed normally. According to Shapiro Wilk normality test results for Group 3 (see in Table 5.29), (KS = 0.152, df 18, p >0.05) and (SW = 0.850, df 18, p <0.05), the data follow normal distribution. Additionally, according to the Kolmogorov-Smirnov test results (see in Table 5.30), the p-value is 0.797. It is greater than the significance value (0.05). As a result, it can be said that the data follow normal distribution.

Figure 5.56 illustrates the normality test results of MİNİTAB-18 statistical software for Group 3. According to normality test results, mean:99.22, standard deviation:36.02 Anderson Darling test statics: 0.711 and p-value is 0.052. P-value is very close to limit level 0.05.

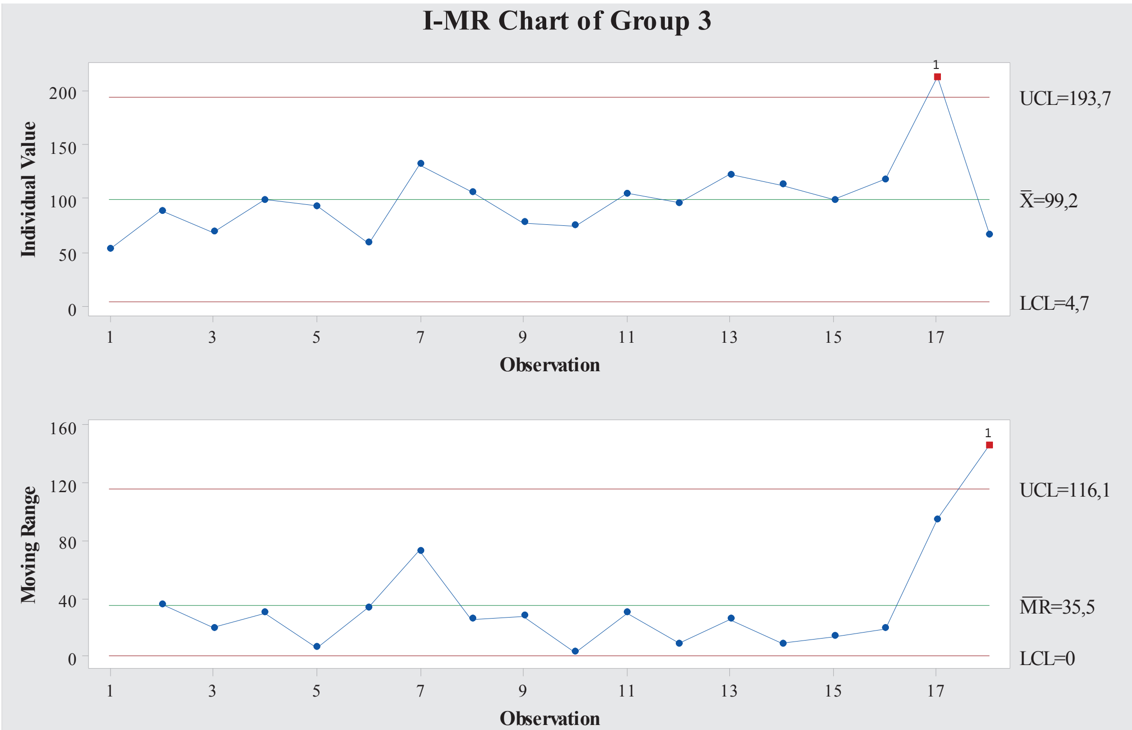


Figure 5.57. I-MR chart of Group 3

With I-MR chart it was controlled that process mean of Group 3 is in the control or not. Red points in Figure 5.57 show the uncontrolled variation in Group 3. For Group 3, only one uncontrolled variation was detected, and this variation was omitted from the calculations.

The results of the individual distribution identification for Group 3 are illustrated in Figure 5.58-61. The highest p-value are found from normal distribution (p= 0.894) and box-cox transformation (p=0.751). But in normality test result p-value was close to significance value (0.05). Therefore, using the box-cox transformation which has second high p-value is better to examine process capability for Group 3.

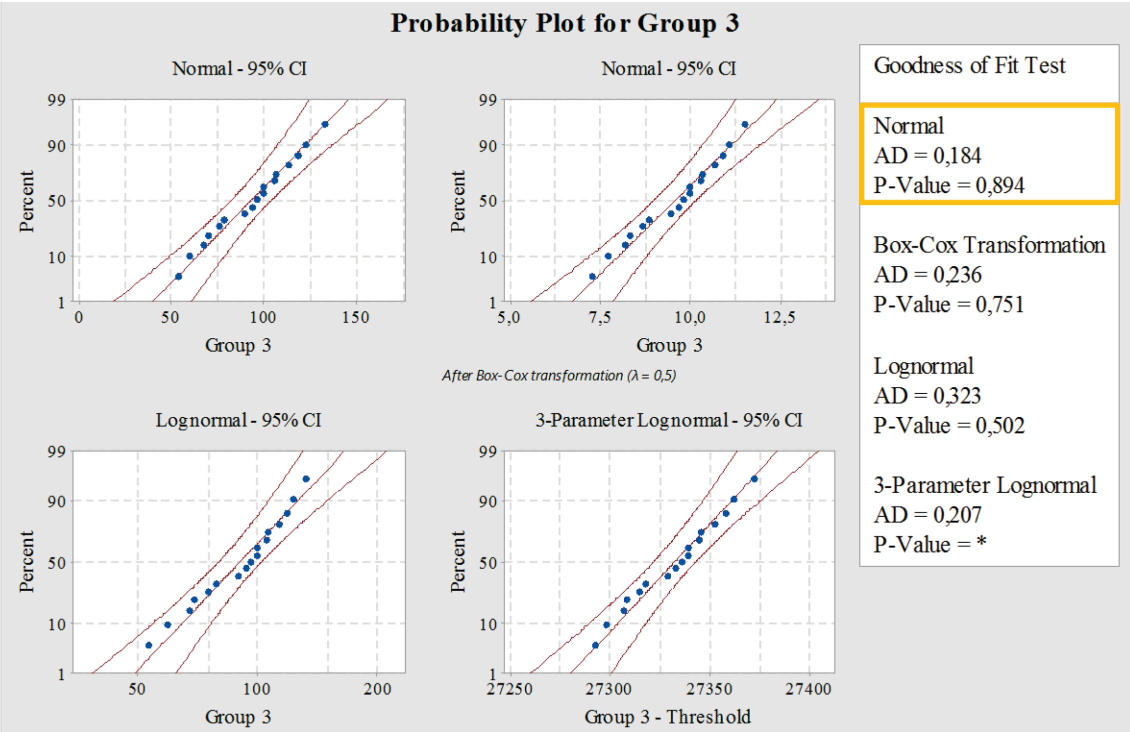


Figure 5.58. Normal, Box-Cox Transformation, Lognormal, 3-Parameter Lognormal distribution plots for Group 3

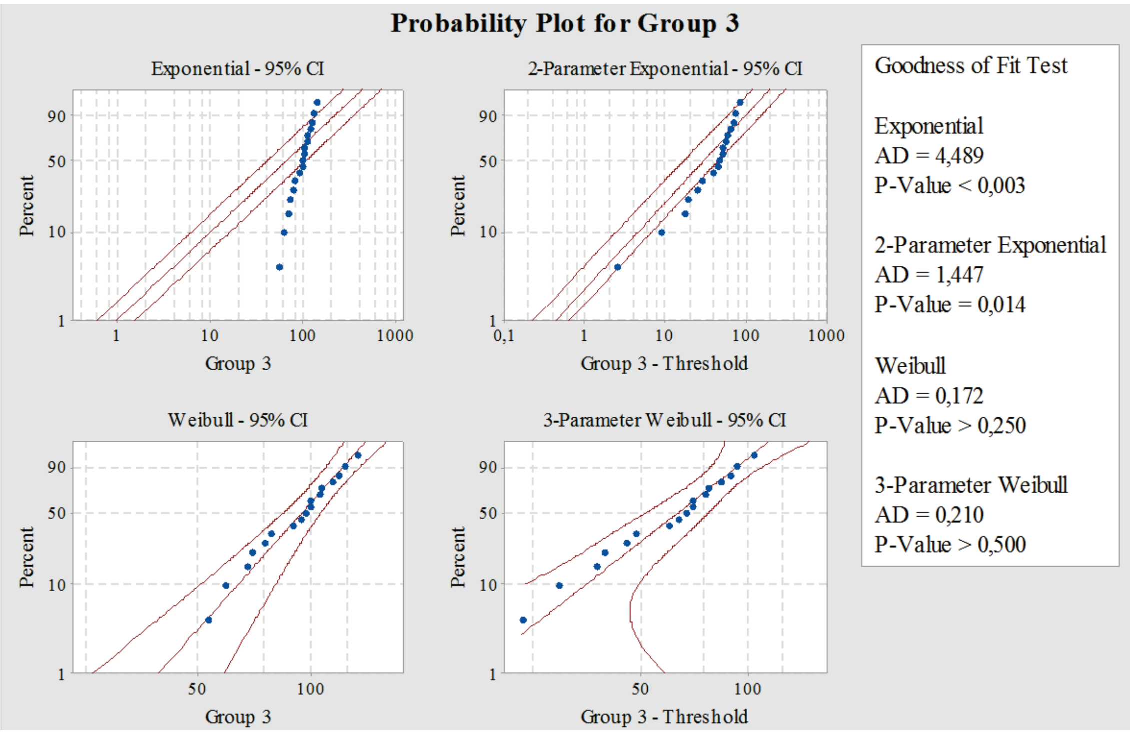


Figure 5.59. Exponential, 2-Parameter Exponential, Weibull, 3-Parameter Weibull distribution plots of Group 3

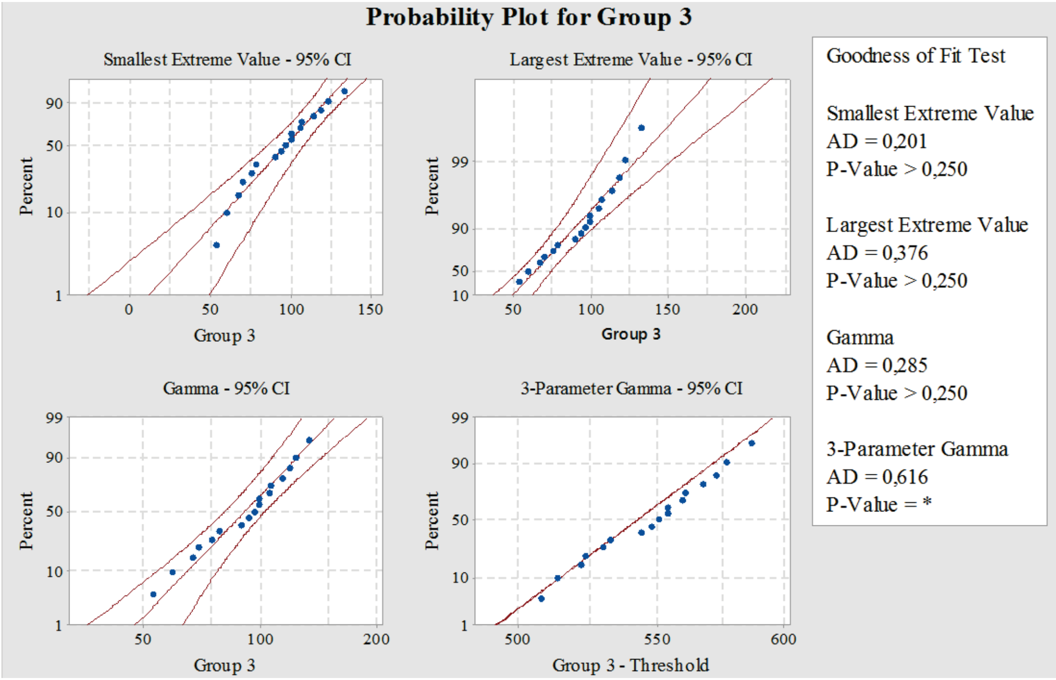


Figure 5.60. Smallest Extreme Value, Largest Extreme Value, Gamma, 3-Parameter Gamma distribution plots of Group 3

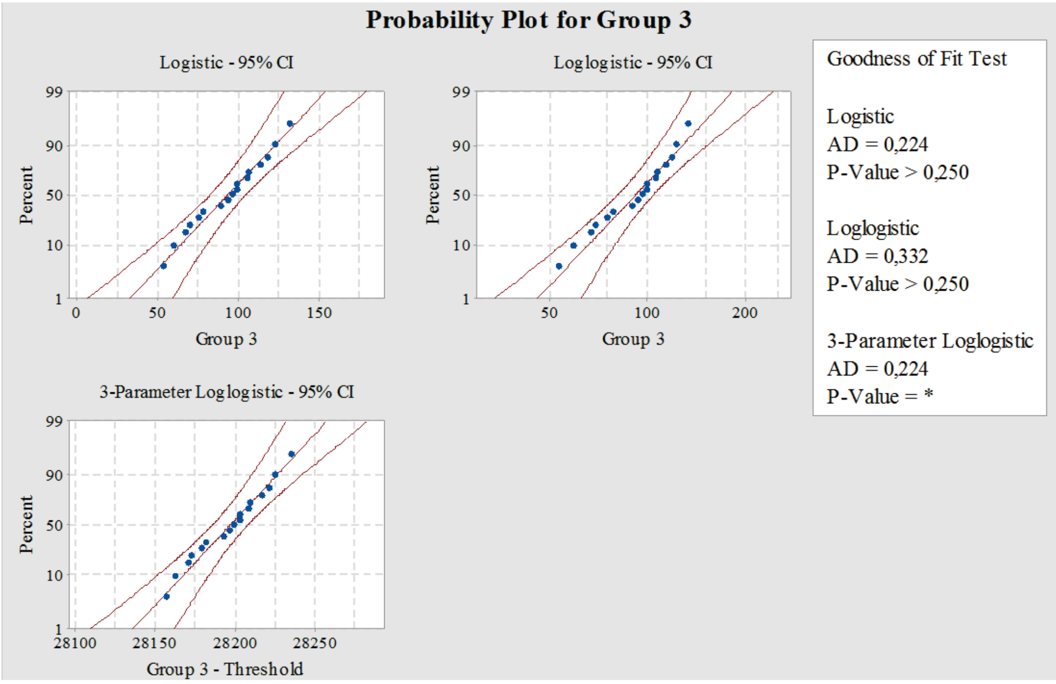


Figure 5.61. Logistic, Loglogistic, 3-Parameter Loglogistic distribution plots of Group 3

Table 5.31 lists the results of the Goodness of fit test for Group 3. Normal, Box-cox transformation, Lognormal, 2-Parameter Exponential, 3-Parameter Weibull distribution, have p-value greater than 0.05 for Group 3. These are effective in transforming the data to follow a normal distribution. However, normal distribution (p = 0.894) have the largest p-values and appear to fit the data better than other distributions.

Table 5.31. Goodness of fit test results for Group 3

Distribution	AD	P	LRT P
Normal	0.184	0.894	
Box-Cox Transformation	0.236	0.751	
Lognormal	0.323	0.502	
3-Parameter Lognormal	0.207	*	0.291
Exponential	4.489	<0.003	
2-Parameter Exponential	1.447	0.014	0.000
Weibull	0.172	>0.250	
3-Parameter Weibull	0.210	>0.500	0.677
Smallest Extreme Value	0.201	>0.250	
Largest Extreme Value	0.376	>0.250	
Gamma	0.285	>0.250	
3-Parameter Gamma	0.616	*	1.000
Logistic	0.224	>0.250	
Loglogistic	0.332	>0.250	
3-Parameter Loglogistic	0.224	*	0.351

Table 5.32. ML estimates of distribution parameters for Group 3

Distribution	Location	Shape	Scale	Threshold
Normal*	92.52941		22.84491	
Box-Cox Transformation*	9.54650		1.21687	
Lognormal*	4.49641		0.26320	
3-Parameter Lognormal	10.21581		0,00081	-2.72393E+04
Exponential			92.52941	
2-Parameter Exponential			41.99950	50.52944
Weibull		4.80704	101.19670	
3-Parameter Weibull		3.20177	70.26067	29.76240
Smallest Extreme Value	103.44823		20.03907	
Largest Extreme Value	81.35918		20.90378	
Gamma		16.23274	5.70017	
3-Parameter Gamma		596.08035	0.90978	-454.38959
Logistic	93.05054		13.22520	
Loglogistic	4.51548		0.15035	
3-Parameter Loglogistic	10.24695		0.00047	-2.81033E+04

** Scale: Adjusted ML estimate*

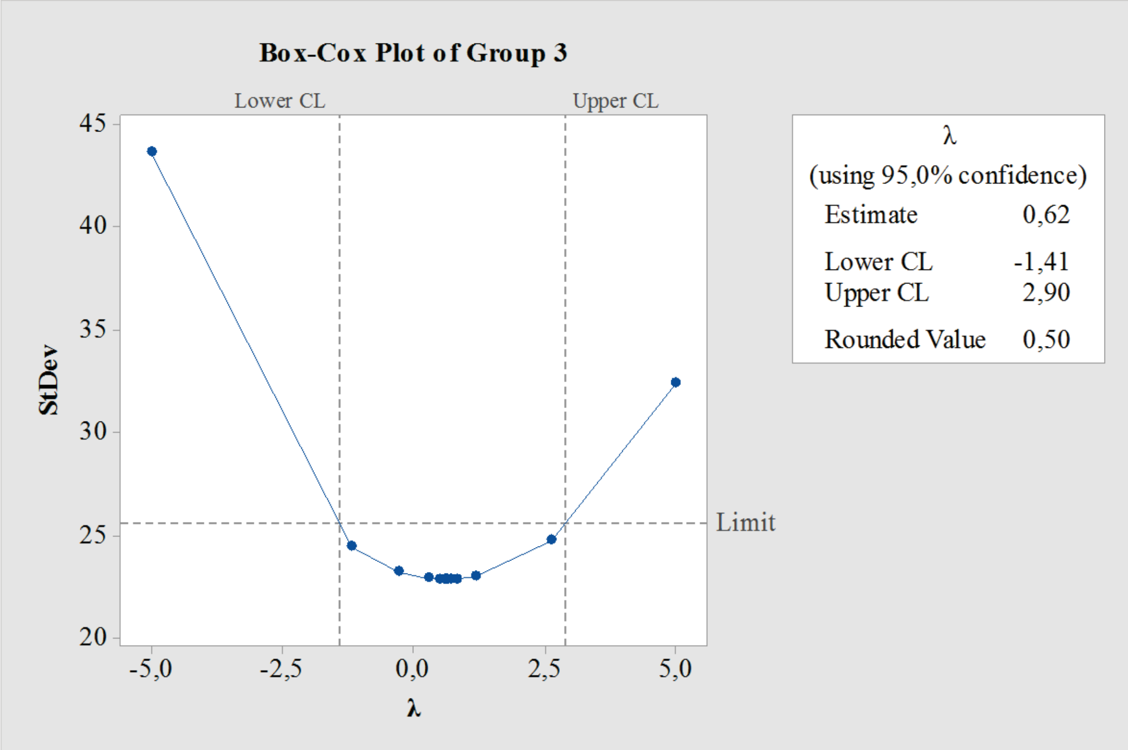


Figure 5.62. Box-Cox plot of Group 3

The Box-Cox Plot of Group 3 is shown in Figure 5.62. The lower and upper confidence levels (CLs) show that the best results for normality are reached with Lambda values between -1.41 and 2.90. The estimated value for the optimal λ is 0.62 and, the rounded value for λ is 0.50.

The process capability report of Group 3 using Box-Cox transformation is presented in Figure 5.63. The histogram on the center of the report shows the histogram of the transformed data using Lambda=0.5. According to the report, after the transformation, the data is more normally distributed. The statistics and capability indexes are calculated and summarized in the report.

The upper left box in Figure 5.63 provides the statistics of the process data before and after the transformation. The values of all capability indexes are lower than 1. So, the process is inadequate. The upper specification limit of 63 days is simultaneously transformed to 7.93, producing a DPMO of 906991.68.

The change in the process capability index according to the days is shown in the Figure 5.64.

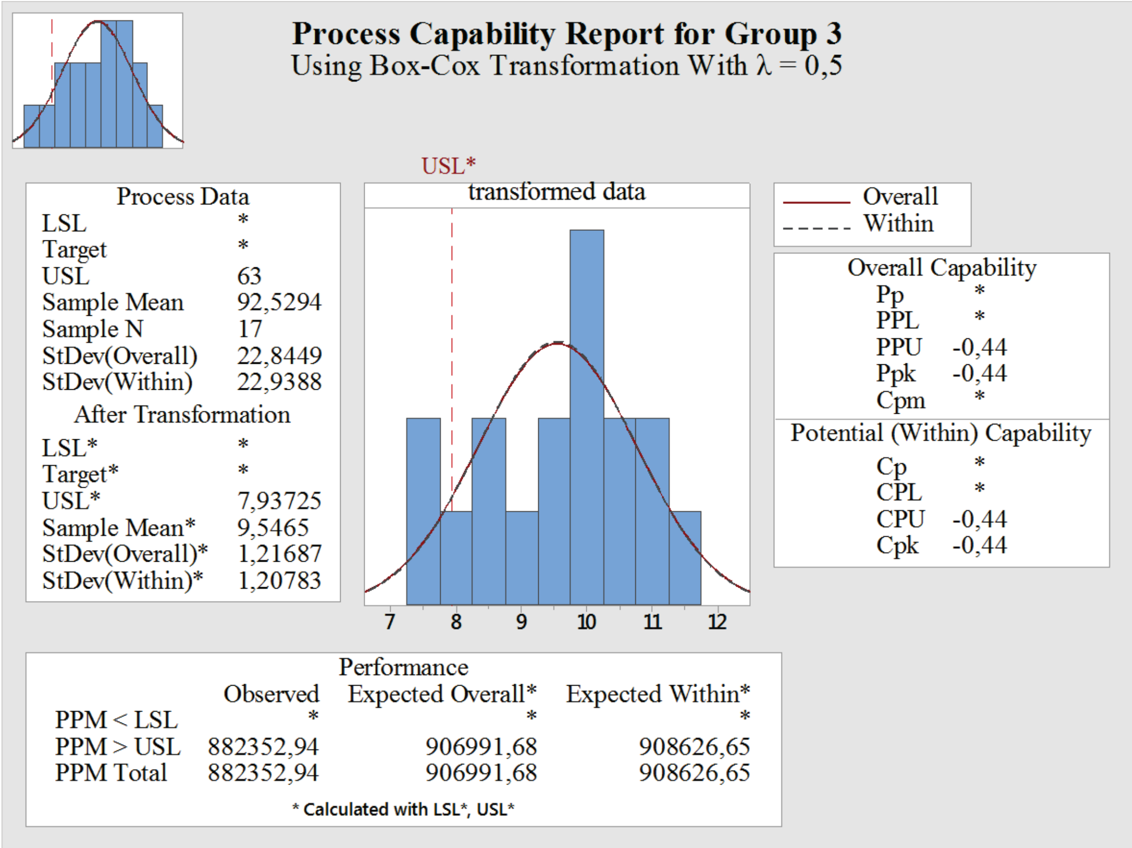


Figure 5.63. Process capability report for Group 3

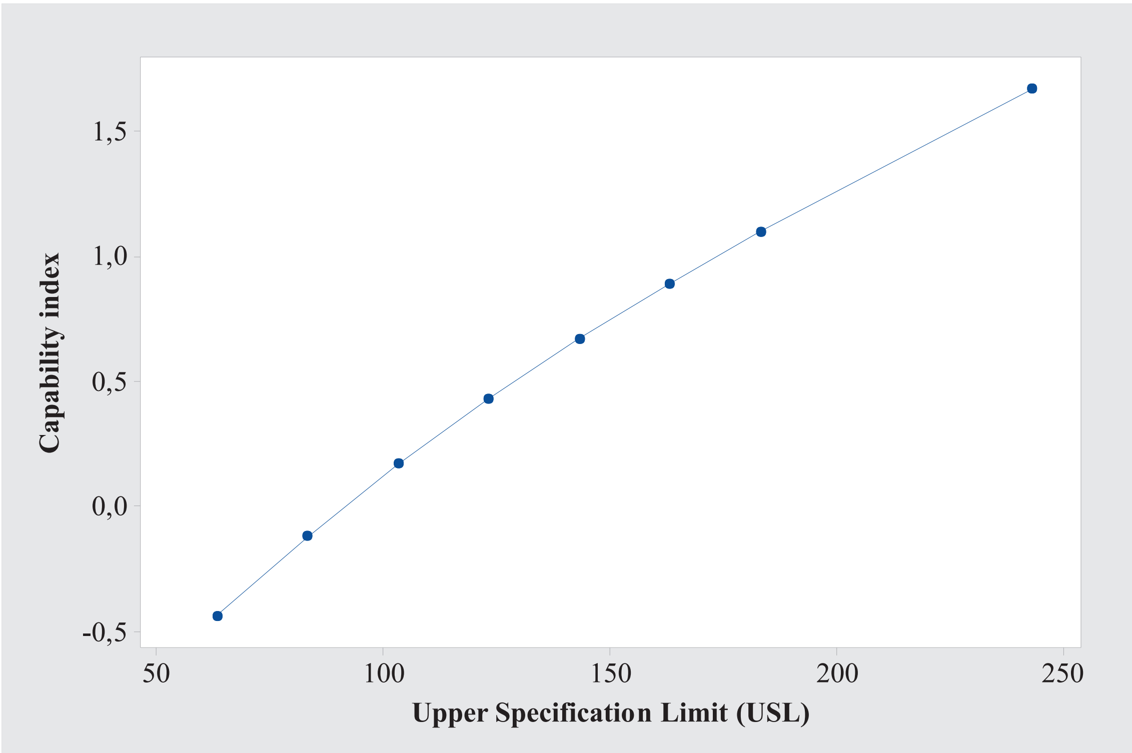


Figure 5.64 C_{PU} change by USL (day) in Group 3

5.4 Discussions

This thesis explores the process capabilities of tender evaluation process in public agencies. The research findings reveal that the variation in tender evaluation process duration is significantly high in public agencies. The presence of high variation in time required to complete tender evaluation process points out there is significant uncertainty about the ability of public agencies to complete the tender evaluation process on planned or targeted time frame. Uncertainty on time required to complete tender evaluation process can cause a chain of delays in managing construction projects and in turn inefficient and effective use limited public resources.

The research findings also reveal that the number of valid tenderer and estimated construction cost have negative impact on time required to complete tender evaluation process.

The process capability index of a good /desired process (e.g., tender evaluation process) should be greater than 1.33. The results suggest that the standard deviations of the time required to complete tender evaluation process for each group are significantly high and the process capabilities of tender evaluation process (i.e., processing time) for each group are significantly lower than the lower limit of 1.33. Overall results suggest that there is a significant need for process improvements in public agencies in order to ensure efficient and effective use limited public resources.

It should be also noted that process capability indices are sensitive to predefined target and upper specification limits (USL). For example, at initial process capability analysis stages, it was assumed that the 10-day period for each group would be sufficient for the tender evaluation duration, and the upper specification limit (USL) duration was calculated by adding 10 days to the preparation period and contract periods specified in the contract. However, obtained negative process capability indexes suggest that a 10-day period was a very short time for the evaluation of tenders. It is clear that the tender evaluation duration (i.e., processing time) is inefficient. For the examined groups, process capabilities greater than 1.33 were made possible by increasing the upper specification limit (USL), which was specified as the completion time. It is clear that as upper specification limit (i.e., processing time measured in days) increases, the value of the process capability index also increases. However, this is undesirable situation because increasing the number of days means that the tender evaluation process will be completed in a longer period. It is ideal to complete the tender evaluation process as soon as possible in order to ensure efficient and effective use of public resources. Different factors may have negative impact on time required to tender evaluation process (i.e., processing time). Yet the most widely mentioned factors which cause delays in tender evaluation process include:

- Deficiencies in documents and information
- Numbers of participants in a tender,
- Existing of abnormally low tenders,
- Qualification of tender (nature, complexity, size, type etc.),
- Experience and motivation of tender committee members and tenderers,
- Workload of the tender committee.

In order to improve tender evaluation process (i.e., reduce variation in processing time) in public agencies, managerial action plans should be developed and implemented. These managerial actions can be developed and implemented by following the general frameworks proposed by process improvement methods such as PDCA, DMAIC, Six sigma, Lean and Lean-Six Sigma. Processing time in tender evaluation and also uncertainty in processing time can be reduced by using the proposed general frameworks. The deficiencies of contract documents and information can be eliminated, motivation of the tender committee can be increased and workload can be balanced. However, the presentation of abnormally low tenders, the number of tenderer /participants, and the nature of the tender are cases beyond the control of management and are difficult to intervene.

In addition, amendments in the relevant articles of the Public Procurement Law 4734 such as the reduction of documentation and paper works in the process and specifying a targeted time frame for processing time can contribute to the shortening of the processing time in tender evaluation.

CHAPTER 6

CONCLUSIONS

This research explores the processing time (i.e., time required to complete tender evaluation) in tender evaluation of public agencies. The main conclusions that can be drawn from the this thesis are follows: (1) at macro level - the process capability index of public procurement process in Turkey based on processing time is poor, (2) at micro level - the process capability index of tender evaluation process (i.e., processing time) in public agencies operationalized, measured and analyzed with respect to the number of tenderer (NT) and estimated construction costs (ECC) are poor and (3) improving process capability at macro level requires changes in the Public Procure Law whereas improving process capability at micro level can be achieved by using process improvement methods.

The above conclusion should be approached with a caution that process capability index used in this thesis is "smaller is better" and it is sensitive to Upper Specification Limit (USL). Increasing or decreasing the upper specification limit (i.e., increasing target time) may result in increase or decrease in the process capability. Setting a "good enough" upper specification limit is the primary challenge in such research studies.

The unit of analysis in this thesis is construction department of public agencies. Using a larger sample size may ensure the validity and reliability of the research findings because the sample size of the research presented in thesis is only 647 public agencies. The research findings are based on a coarse analysis. Therefore, adopting a fine grained analysis approach – selecting single public agency as a unit of analysis, deeper insights can be gained about the tender evaluation process.

Future studies can explore how to reduce variation the processing time of tender evaluation and how to increase the process capability of processing time in public agencies. Process improvement methods and tools present promising answers to these challenging research questions.

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