IMPROVEMENT OF INDIVIDUAL LOAN PROCESS IN A PRIVATE PARTICIPATION BANK

(ÖZEL BİR KATILIM BANKASINDA BİREYSEL KREDİ SÜRECİNİN İYİLEŞTİRİLMESİ)

by

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Thesis

Submitted in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

in

INDUSTRIAL ENGINEERING

in the

GRADUATE SCHOOL OF SCIENCE AND ENGINEERING

of

GALATASARAY UNIVERSITY

Supervisor: Assoc. Prof. Dr. Mehtap DURSUN KARAHÜSEYİN

May 2025

ACKNOWLEDGEMENTS

First of all, I would like to thank my dear advisor, Assoc. Prof. Dr. Mehtap DURSUN KARAHÜSEYİN, for her patience, guidance, interest, always motivating me, and conveying her knowledge and experience. Her guidance has been supportive for me at all stages of my study.

I would also like to thank Assist. Prof. Dr. Esin MUKUL TAYLAN for her support.

I would also like to thank my family and friends who have always been with me on this journey. I have always felt their support.

Finally, I would also like to thank my dear fiance who has always been with me. He supported and motivated me in every sense on this journey.

May 2025
Fatma Nur DOĞAN

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LIST OF SYMBOLS

BPM **:** Business Process Management
DMAIC **:** Define, Measure, Analyze, Improve and Control
RPA **:** Robotic Process Automation
WoS **:** Web of Science

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ABSTRACT

In today's competitive financial sector, inefficient processes can lead to customer dissatisfaction and losses. Therefore, institutions should manage and improve their processes in an optimum way with a continuous improvement strategy. This study aims to improve the individual credit process that leads to customer complaints and losses in a private participation bank in Türkiye. A detailed analysis of the current situation is conducted with Six Sigma for process improvement. Process simulations are developed with Arena and Python programs and improvement points are determined. RPA integration is suggested for document control and approval steps are organized. In addition, after the improved process simulation, 2025 values are estimated with regression using 2023 and 2024 data, and a prediction is provided by simulating 2025 with these values. When the results are examined, it is observed that especially the approval numbers increased by an average of 9% in the improved model. More than 80% decrease in processing times and more than 90% decrease in waiting times are observed. This study has a unique position in the literature with the fact that it addresses a participation bank in Türkiye and the process improvement and simulation model are used together. It also contributes to the sector by providing a model that banks can use in their process improvement efforts.

ÖZET

Günümüzün rekabetçi finans sektöründe, verimsiz süreçler müşteri memnuniyetsizliğine ve kayıplara yol açabilir. Bu nedenle kurumlar sürekli iyileştirme stratejisiyle süreçlerini optimum bir şekilde yönetmeli ve iyileştirmelidirler. Bu çalışma Türkiye'de özel bir katılım bankasında müşteri şikayetlerine ve kayıplarına yol açan bireysel kredi sürecini iyileştirmeyi amaçlamaktadır. Süreç iyileştirme için Six Sigma ile mevcut durumun detaylı analizi yapılmıştır. Arena ve Python programları ile süreç simülasyonları yapılmış ve iyileştirme noktaları tespit edilmiştir. Belge kontrolü için RPA entegrasyonu önerilmiş ve onay adımları düzenlenmiştir. Ayrıca iyileştirilmiş süreç simülasyonundan sonra, 2023 ve 2024 verileri kullanılarak regresyon ile 2025 yılı değerleri tahminlenmiş, bu değerlerle 2025 yılı için de simülasyon yapılarak bir öngörü sağlanmıştır. Sonuçlara bakıldığında özellikle onay sayılarının iyileştirilmiş modelde ortalama %9 oranında arttığı gözlemlenmiştir. İşlem sürelerinde %80 den fazla azalma, bekleme sürelerinde ise %90'dan fazla azalma görülmüştür. Bu çalışma Türkiye'de bir katılım bankasını ele alması, süreç iyileştirme ve simülasyon modelinin beraber kullanılmasıyla literatürde özgün bir konuma sahiptir. Ayrıca bankaların süreç iyileştirme çalışmalarında kullanabileceği bir model sunulmasıyla da sektöre de katkı sağlamaktadır.

1. INTRODUCTION

In today's constantly evolving and changing business environment, institutions need to provide faster and customer-focused services in order to survive. In this intensely competitive environment, it is inevitable for banks and financial institutions that prioritize customer acquisition and satisfaction to develop process improvement Strategies. These institutions that adopt continuous improvement do not have difficulty adapting to changing conditions and constantly increase their efficiency.

In this study, process improvement is carried out in a private participation bank. The "individual loan process", which is the process that the bank receives the most complaints about in terms of customer satisfaction, is examined. This process consists of too many steps and takes a long time. This leads customers to prefer other banks.

The aim of the study is to improve the individual loan process. For this improvement study, the current situation will be analyzed first and bottlenecks will be determined. Then, improvement points will be determined and improvement performance will be measured with simulation. A forecast model will be made for the next year and suggestions will be presented.

The six sigma method is adapted to this study with the continuous improvement strategy. DMAIC stages are applied one by one for detailed analysis of the process. For the current scenario, firstly the simulation is performed with Arena program, however since there is a license restriction, Python simulation is suggested as an alternative. Since the 8-hour simulation results of both programs are consistent, the study is continued with Python. After the improved process is tested with the current data, in order to have a forecast for the next year, the 2025 periods is estimated with regression and the simulation is performed with these periods.

This study is unique in the literature as it is conducted in a participation bank in Türkiye. In addition, the fact that improvement points are presented in terms of both technical and process management makes the study unique. The rest of the study is organized as follows. Section 2 explains the process improvement in banking sector. Literature review is provided at Section 3. Section 4 explains materials and methods. Results are presented at Section 5. Discussions are provided at Section 6. Finally, Conclusions are given in the final section.

2. PROCESS IMPROVEMENT IN BANKING SECTOR

In this section, the first heading discusses the definition and importance of process management, and the second heading discusses the applications of process improvement in banking.

2.1 Definition and Importance of Process Management

In today's competitive business world, the management of processes for companies is of great importance for sustainable growth. If businesses structure and manage their processes correctly, they can keep their costs to a minimum by using their time and resources efficiently. For this reason, it is necessary for companies to manage business processes successfully and to identify the problems in the processes and to carry out continuous improvement studies.

Business process management (BPM) is a technique used to manage processes in an organization. BPM provides a variety of tools to define, analyze, execute, monitor, and modify business processes, thereby implementing the concept of continuous improvement (Davenport 1993). The goal of continuous improvement is to achieve customer satisfaction.

The most well-known BPM methods for optimizing business processes are Six Sigma, 5s, Kaizen and lean. As can be seen in the literature, Six Sigma is one of the most widely used BPM methods. The use of Six Sigma in the service sector has improved customer and employee satisfaction, process processing time and service provided (Aboelmaged, 2010).

Although Six Sigma has been adopted by many organizations around the world, the main areas in the service sector where Six Sigma is used the most are banking and financial services, healthcare, construction, supply chain management, accounting, customer relations, utilities, material procurement, education, libraries, order processing, the airline industry, security, and even government and non-profit organizations (Nakhai and Neves, 2009).

As a widely used BPM method, Six Sigma has proven its effectiveness in a variety of industries, especially banking. The next section focuses on the potential benefits of process improvement in the banking sector.

2.2 Applications of Process Improvement in Banking

Improving customer satisfaction is of great importance in all sectors, but especially in the service sector, banks and financial institutions are the most important economic sectors of societies that expand markets by facilitating fund transfers and trade exchanges (Gulati and Kumar, 2017). Most of the processes here directly affect the customer, and process improvements can save a lot of time and money.

For example, Islam & Ahmad (2012) reported a 50% reduction in processing time after redesigning a process in the credit card department of a multinational bank. In this way, the process is accelerated and customer satisfaction automatically increases as the length of the transactions decreases.

As identified in the following sections of this study, it has been determined that the process improvement studies are carried out in financial institutions, especially in Türkiye, are insufficient. In addition, when international studies are examined, it is striking that participation banks are not the subject of process improvement studies in the literature.

Individual credit processes, which are one of the basic activities in banking, are one of the processes that directly affect customer satisfaction. This study aims to improve individual credit processes in a participation bank in Türkiye. The process is analyzed

and restructured with Lean Six Sigma, one of the BPM methods. The extent of improvement is determined with simulation. This study aims to fill a major gap in the sector and literature.

3. LITERATURE REVIEW

This section is detailed with three subheadings. In 3.1, how the literature review is done is detailed and the PRISMA diagram is presented. In 3.2, the results of the review are shared and interpreted in detail. Finally, in 3.3, the bibliometric mapping analysis performed with the VOSviewer software is presented.

3.1 The Review Process

This study aims to improve the "Individual Loans" process of a participation bank in Turkey. The improvement will be carried out using the Lean Six Sigma method, and the results will be determined through simulation. To identify the existence of studies on this topic or the methods used in the sector, a review of the literature is conducted.

The literature review is carried out through the Web of Science (WoS) database.In the WoS database, the search is performed under the "Topic" category. The topics “Improvement” and “Financial Services” are used.

In order to identify highly relevant articles, this study is limited to the English language and excluded studies that is not related to the concept.

The study selection process is as shown in Figure 3.1. The WoS database searches yield 90 records. After English language selection and document type filtering, 65 studies remained and abstracts were screened for eligibility.

At this stage, 7 studies is excluded due to limited access, 1 study is excluded due to retracted publication and 36 studies are found to be less relevant to the aim of this paper. Finally, 21 studies are included in the final review.

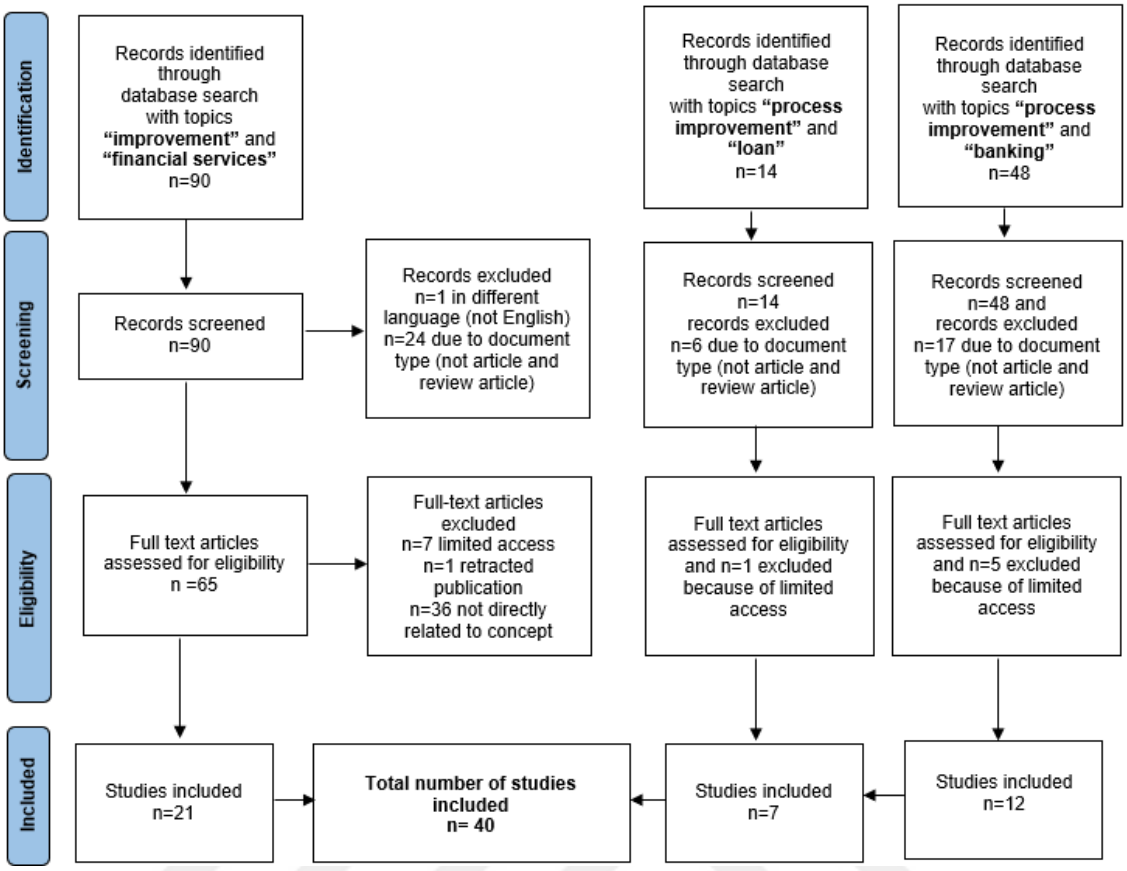

Figure 3.1: A Diagram of the PRISMA Review Process

In order to strengthen the study, a search is also conducted in the WoS database using different subject headings.

The keywords "process improvement" and "loan" are used. The search yields 14 sources. Articles is filtered as document type. 1 source is excluded due to restricted access. The remaining 7 studies are included because they are directly related to the scope of the study when examine in detail.

Finally, a search is conducted in the WoS database using "process improvement" and "banking". 48 sources are obtained. Articles are filtered by document type and 31 sources are obtained. 5 is not included due to limited access and 6 articles that are accessed in other searches. The remaining articles are examined in detail and 7 articles are found to be irrelevant to the topic, of which 13 articles are finally included in this study.

This means that a total of 41 articles have been included in this thesis.

3.2 Review Results

In this study, firstly "improvement" and "financial services", then "process improvement" and "loan" and finally "process improvement" and "banking" topics are searched and literature search is conducted in WoS database. The first and most comprehensive of these is given as PRISMA review as seen in Figure 3.1. The obtained results are given in two different tables (Table 3.1 and Table 3.2). Table 3.1 covers the topics of "improvement" and "financial services" (referred to as Search 1). Table 3.2 is created by combining the themes specifically focused on banking and loans ("process improvement", "loan" and "process improvement", "banking") (referred to as Search 2).

In this analysis section, the tables obtained are interpreted according to the country of application, the objective of the study, the methods used and the types of financial services.

Table 3.1: Papers Concerning "Improvement" and "Financial Services" (Search 1)

Year	Author	Aim of the Study	Article Type	Application Country	Used technology	Used methods	Financial Service Type	Participation Bank
2005	Akamavi	Analyzed and redesigned the operational process of opening a student bank account to improve efficiency and customer satisfaction.	Research Paper	United Kingdom	E-Process (Virtual Process)	Process Mapping (Flowchart)	Retail Banking (Student Accounts)	No
2009	Elmuti et al.	Examine the strategic application of customer relationship management (CRM) and its impact on organizational effectiveness in the financial services industry.	Research Paper	United States	-	Survey, Interviews, Comparative Analysis	Banking, Insurance, Investments	No
2011	Lu & Betts	Examine why process improvement training often fails and propose a conceptual framework for improving results.	Research Paper	United Kingdom	-	Mixed methods including surveys, interviews, comparative analysis, and framework development	-	-
2011	Pyon et al.	To propose a business process management framework using customer complaints (Voice of the Customer - VOC) to improve service in the financial services industry.	Research Paper	South Korea	-	Business Process Management (BPM), Data Cube Analysis, Summarization, Exception and Comparison Modules	Banking	No

Table 3.1 (cont'd): Papers Concerning "Improvement" and "Financial Services" (Search 1)

Year	Author	Aim of the Study	Article Type	Application Country	Used technology	Used methods	Financial Service Type	Participation Bank
2011	Croom & Betts	To explore the relationship between curriculum design and the impact on process improvement in frontline training.	Research Paper	United Kingdom	-	Forensic tools, action learning	Financial Service Operations	-
2012	Lokkerbol et al.	Create actionable knowledge and templates for financial services process improvement projects.	Research Paper	Netherlands	-	Lean Six Sigma	Banking	No
2014	Leyer & Hollmann	To demonstrate how Business Process Simulation (BPS) can predict the impact of electronic document implementation in banks.	Research Paper	Germany	-	Business Process Simulation (BPS), Conceptual Modelling	Banking	No
2016	Milner & Savage	Understand how service-based organizations create and sustain continuous performance improvement over time.	Research Paper	United Kingdom	-	Multi-qualitative methods, narrative inquiry, thematic analysis	General	-
2017	Hirzel et al.	To explore the role of empowering employees in implementing successful continuous improvement in financial services over time.	Research Paper	European Countries	-	Longitudinal case study, surveys, structural empowerment theory	General	-

Table 3.1 (cont'd): Papers Concerning "Improvement" and "Financial Services" (Search 1)

Year	Author	Aim of the Study	Article Type	Application Country	Used technology	Used methods	Financial Service Type	Participation Bank
2019	Zhao et al.	Develop and evaluate service innovation strategies in China's banking industry during the fintech revolution using a hybrid MCDM model.	Research Paper	China	Big Data, Cloud Computing, Blockchain, Smart Investment Management	Hybrid MCDM model (DEMATEL, DANP, Modified VIKOR)	Banking	Np
2019	Secchi & Camuffo	Explore why Lean implementation efforts in financial services organizations fail despite overcoming traditional barriers	Research Paper	European Countries	-	Quasi-experiment, abductive case research, interviews, thematic analysis	Banking	No
2020	Lameijer et al.	To explore the effects of organizational motivation and coordination on the success of continuous improvement (CI) projects.	Research Paper	European Countries	-	Continuous Improvement (Lean, Six Sigma, TQM, Kaizen), Structural Equation Modelling (SEM)	Banking	No
2020	Thomas	Explore the role of technological convergence and digital fusion in achieving competitive differentiation in banking.	Research Paper	India	Big Data, AI, Cloud Computing, Digital Convergence	Qualitative, Inductive Research, Case Study (SBI)	Banking	No

Table 3.1 (cont'd): Papers Concerning "Improvement" and "Financial Services" (Search 1)

Year	Author	Aim of the Study	Article Type	Application Country	Used technology	Used methods	Financial Service Type	Participation Bank
2020	Diener	Analyzing the changing operating cost structure and its impact on banks' operating income, with a focus on labor costs and digital transformation.	Research Paper	Germany	-	Principal Component Analysis (PCA), Mixed Method Approach	Banking	No
2021	Gao & Xiao	Analyze the role of big data credit reports in consumer credit risk management.	Research Paper	China	Big Data, Machine Learning	Logistic Regression, XGBoost	Banking	No
2021	Egala et al.	Investigating the impact of digital banking service quality on customer satisfaction and retention during COVID-19	Research Paper	Ghana	-	Structural Equation Modeling (PLS-SEM)	Banking	No
2021	Secchi & Camuffo	Explore the role of knowledge codification in mitigating the risk of failure in lean banking implementations.	Research Paper	European Countries	-	Longitudinal Case Study, Quasi-Experimental Design, Survey, Interview, Data Analysis	Banking	No
2022	Li &Fang	Improve financial shared services and promote process-based management of accounting systems.	Research Paper	China	-	Case analysis, Practical analysis	Advisory	No

Table 3.1 (cont'd): Papers Concerning "Improvement" and "Financial Services" (Search 1)

Year	Author	Aim of the Study	Article Type	Application Country	Used technology	Used methods	Financial Service Type	Participation Bank
2022	Edu	Explore how big data analytics (BDA) capabilities can be leveraged to improve financial services agility through IT capability development.	Research Paper	Ghana	Big Data Analytics	Survey and Partial Least Squares Structural Equation Modeling (PLS-SEM)	Banking	No
2024	Oke & Cavus	To analyze the integration and role of AI in financial services through bibliometric analysis, focusing on trends, key issues, and applications.	Research Paper	Not Country-Specific	Artificial Intelligence (AI)	Bibliometric Analysis	Banking, Investment, Insurance	No
2024	Lameijer et al.	To empirically demonstrate how Lean Six Sigma (LSS) can optimize the use of robotic process automation (RPA) in financial services operations, particularly in a digitized environment.	Research Paper	Netherlands	Robotic Process Automation (RPA), Industry 4.0	Lean Six Sigma	Banking	No

Table 3.2: Papers Concerning "Banking" and "Loans" (Search 2)

Year	Author	Aim of the Study	Article Type	Application Country	Used technology	Used methods	Financial Service Type	Participation Bank
2010	Trkman	Define the critical success factors and provide a theoretical framework for Business Process Management (BPM) in the banking industry.	Research Paper	Slovenia	-	Contingency Theory, Dynamic Capabilities, Task-Technology Fit	Banking	No
2012	Borner & Moormann	Analyze the effectiveness of role-playing in business process improvement training and highlight its benefits in improving Six Sigma methodologies.	Research Paper	Germany	-	Six Sigma methodology	Banking	No
2012	Moreno	Develop integrated workflows to improve interlibrary loan turnaround times and efficiency	Research Paper	Australia	-	Workflow Analysis, PRINCE2 project management	-	-
2012	Bortolotti & Romano	Explore the integration of lean management with process improvement and automation in banking services.	Research Paper	Italy	-	Process Mapping	Banking	No
2012	Oliya et al.	Using the Six Sigma methodology to study the improvement of marketing processes in the banking sector.	Research Paper	Iran	-	Six Sigma	Banking	Yes

Table 3.2 (cont'd): Papers Concerning "Banking" and "Loans" (Search 2)

Year	Author	Aim of the Study	Article Type	Application Country	Used technology	Used methods	Financial Service Type	Participation Bank
2012	Islam & Ahmed	Improve credit card processes and increase effectiveness.	Research Paper	-	-	SWOT Analysis, Fishbone Diagram, Process Flow Diagram	Banking	No
2015	Yousfi et al.	Implement decision-aware business processes to improve workflows with a focus on loan applications.	Research Paper	Morocco	-	Case study, Decision-Making Models	Banking	No
2015	Sunder M. & Antony	Applying Six Sigma to improve top-box customer satisfaction scores in a banking call center.	Research Paper	India	-	Six Sigma (DMAIC), Pareto analysis, Chi-square tests	Banking	No
2016	Ugoani & Ugoani	Examination of the impact of BPR on the efficiency of the Nigerian banking system.	Research Paper	Nigeria	-	Exploratory Research	Banking	No
2016	Sunder M.	Using Lean Six Sigma to Reduce Rejection Rates in the Bank Account Opening Process	Research Paper	India	-	Lean Six Sigma	Retail Banking	No
2016	Gupta et al.	To demonstrate how lean methodology is applied to the service sector and to examine the evolution of lean services through a detailed literature review.	Review Paper	-	-	Literature Review	Banking	No

Table 3.2 (cont'd): Papers Concerning "Banking" and "Loans" (Search 2)

Year	Author	Aim of the Study	Article Type	Application Country	Used technology	Used methods	Financial Service Type	Participation Bank
2021	Alnajem	Demonstrate how Lean principles can be taught and applied to improve a real bank lending process.	Research Paper	Kuwait	-	Lean A3, Gemba Walk, PDCA, Value Stream Mapping, Semi-Structured Interviews, Direct Observation	Banking	Yes
2021	Scott et al.	Exploring how to improve agile software development processes in a bank (LHV) to stay competitive with FinTech companies.	Research Paper	Estonia	Agile Software Development	Process Improvement	Banking	No
2021	SadrAbadi & Zanjirchi	The purpose of the present study was the improvement of the most effective processes of the supply chain of banking services of bank A in Iran.	Research Paper	Iran	-	DEMATEL-ISM	Banking	Yes
2023	Molnár et al.	Providing BPM patterns using blockchain technology, analyzing challenges, and implementing loan and insurance processes as web services.	Research Paper	-	Blockchain	Design Science Research, Software Case Study, Model-to-Programming (M2P)	Banking &Insurance	No

Table 3.2 (cont'd): Papers Concerning "Banking" and "Loans" (Search 2)

Year	Author	Aim of the Study	Article Type	Application Country	Used technology	Used methods	Financial Service Type	Participation Bank
2023	Edward et al.	To examine the success factors of peer-to-peer (P2P) lending for SMEs on Islamic fintech platforms in Indonesia.	Research Paper	Indonesia	Fintech, P2P Lending	OLS Regression	SME Financing, Islamic Financial Services	Yes?
2023	Oberle	Investigation of factors that influence process responsiveness in German banks, particularly in the residential mortgage loan application process.	Research Paper	Germany	Process Automation	Multi-method: Survey, Regression Analysis, Framework Development	Banking	No
2023	Mamede et al.	Explore the improvement of banking processes by combining RPA with lean techniques.	Research Paper	Portugal	Robotic Process Automation	Design Science Research, Field Study	Banking	No
2023	Sunder M. et al.	To explore the application of lean methodology in the service sector and to develop a dynamic capabilities framework for organizational learning.	Research Paper	-	-	Literature Review	-	No

3.2.1 Year and Article Type

The number of studies are obtained when searching with the topics “improvement” and “financial services” (Search 1) and “Banking” and “loans” (Search 2) are shown according to years in the Figure 3.2. According to the table, the earliest study identified in search 1 is conducted in 2005. The earliest study found in Search 2 is from 2010.

Both searches are dominated by research articles, with one review article each.

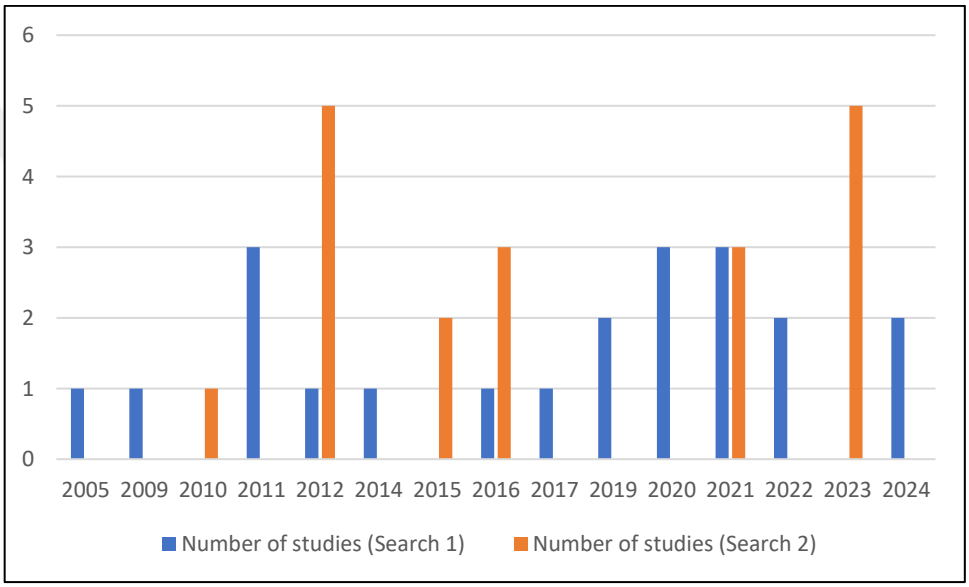

Figure 3.2: Number of Studies Comparison by Year

3.2.2 Application Country

The studies included in Table 3.1 are conducted in various countries such as United Kingdom, United States, South Korea, Netherlands, Germany, China, India and Ghana. Also some of the studies are implemented in European Countries which are not specified as names. As regards their distribution, four studies each are from United Kingdom and European countries, three from China, two studies each from Germany, Netherlands and Ghana and one from each remaining country.

Also the studies in the Table 3.2 are implemented in Kuwait, Indonesia, Germany, Australia, Morocco, Iran, Nigeria, India, Portugal, Italy, Estonia and Slovenia. As

regards their distribution, two studies each are from Germany, Iran and India. Also one from each remaining country.

3.2.3 Aim of the Study

The aims are interpreted according to two different article types.

There are 2 review papers. Oke & Cavus (2024) aimed to analyze the use of artificial intelligence in financial services and analyze the applications in the literature. Gupta et al. (2016) also conducted a detailed review of the literature but focused on the applications of Lean methodologies in the service sector.

Research articles are categorized according to "aim of the studies". Although the aims of the reviewed studies differ, there are studies that will contribute to the scope of this thesis. The studies are basically grouped under two main groups. The first is process improvement studies. The second group is the use of technology in financial services.

*Process improvement studies***:** The studies in this category aim to redesign and optimize processes. For example, Akamavi (2005) documented the current state of the bank account opening process for students with a flowchart and then identified the areas that needed improvement. He offered an improvement suggestion by restructuring the process. Pyon et al. (2011) conducted a process improvement study by taking into account customer complaints. Lameijer et al. (2024), who contributed to process improvement with a methodology that is popular today, contributed to the literature by optimizing Lean Six Sigma with Robotic Process Management. Similarly, Mamede et al. (2023) improved banking processes by using lean techniques and RPA together.

Use of Technology in Financial Services: Studies in this category aim to see the effects of using technologies and digitalization in financial services. In this context, it has been determined that the effects of artificial intelligence, blockchain and machine learning methods are generally examined in studies. For example, Thomas (2020) investigated the effects of technology to provide competitive advantage in the banking sector. Edward et al. (2023) focused on identifying the success factors of Islamic fintech

technologies on P2P lending. Gao & Xiao (2021) aimed to analyze the effects of big data on customer credit risk.

3.2.4 Used Technology

Digital technologies are found to be used more frequently in Search 1 than in Search 2. Mostly big data, machine learning and artificial intelligence technologies are found to be used. Zhao et al. (2019) proposed a hybrid multi-criteria decision-making method for evaluating China's banking services against the challenges brought by the Fintech revolution. In their study, big data was used to understand customer behavior, cloud computing for data management infrastructure, artificial intelligence and blockchain technologies were used for customer-specific financial analysis. As another example, Thomas (2020) focused on the integration of various technologies such as big data, cloud computing and artificial intelligence to provide competitive advantage in the banking sector. Gao and Xiao (2021) conducted a study on how big data can be used in risk management in consumer financing. In addition, Edu (2022) conducted a detailed study on how big data can be used for agility and improvement in financial services. As one of the most recent studies, Oke and Cavus (2024) focused on the use of artificial intelligence in financial services. Unlike these technologies, Akamavi (2005) analyzes the process of opening a bank account for students and proposes to eliminate bottlenecks through a restructured virtual process. Another technology identified in Search 1 is Robotic Process Automation (RPA). Lameijer et al. (2024) optimized financial service operations with RPA.

In the studies in Search 2, technologies such as Blockchain, Fintech and Robotic Process Automation (RPA) are used. Molnár et al. (2023) used blockchain technology for process optimization, aiming to increase transparency, security, and efficiency in financial processes such as loan applications. Edward et al. (2023) used Peer-to-Peer (P2P) Lending technology to offer an interest-free financing model. Mamede et al. (2023) studied the combination of Lean and RPA on three processes in a private bank in Portugal.

3.2.5 Used Methods

The methods used in Search 1 and Search 2 are evaluated together and categorized into five different categories as follows:

- *Process Modeling and Analysis Methods*: Studies in this category focus on mapping and analyzing models of processes. Methods such as flowchart, workflow analysis, value stream mapping, Lean A3 and Business Process Management (BPM) are included in this category. These methods are used alone to analyze the process in some studies, but in some studies they are supported by more than one method. For example, in a study by Alnajem (2021), credit processes in a Kuwaiti bank were analyzed, improved and redesigned using Lean A3 and PDCA (plan, do, check, act) methods.
- *Continuous Improvement:* These methods are applied to increase the efficiency of processes. In the studies evaluated within the scope of the literature review, methods such as Lean, Six Sigma, Total Quality Management and Kaizen are used for continuous improvement. Six Sigma is the most common method in the results obtained. For example, Sunder M. (2016) reduced transaction rejection rates by 30% with Lean Six Sigma method in a retail bank and achieved a great improvement. In addition, Oliya et al. (2012), who also used this method, improved marketing processes in a bank and greatly reduced costs.
- *Statistical Methods:* Studies in this category are articles that focus on the methods used to analyze and make sense of data. Methods found in the literature suitable for this category include Principal Component Analysis (PCA), Logistic Regression and OLS Regression can be given as examples.
- *Qualitative and Mixed Methods*: Studies in this category are articles that deal with methods created by combining qualitative or quantitative methods such as Surveys and Interviews. These methods are also encountered in the scanned studies, but it is seen that they are generally used together with different methods.
- *Research and Investigation Methods:* Articles that analyze the literature and discuss general research and investigation methods are included in this category. In the literature review conducted in this study, two review articles are found and Bibliometric Analysis and Exploratory Research methods are used.

3.2.6 Financial Service Type

In this study, financial service types are divided into categories such as Banking, Retail Banking, Insurance, Investment, SME Financing, Islamic Financial Services and Advisory. In both Search 1 and Search 2, the category with the largest number of studies is “Banking". The category with the least number of studies is Islamic Financial Services. It can be concluded that the literature should focus on this area.

3.2.7 Participation Bank

When the literature review is examined in detail, the type of banks in the studies conducted in the banking sector is generally not specifically stated. When the articles are evaluated within the scope of participation banks or Islamic finance applications, only three of them fit this scope.

It can be concluded that studies conducted on participation banks are lacking in the literature.

When the existing literature is examined in detail under the titles, several gaps are identified in the literature. There is no "Türkiye" in the countries where the examined studies are applied. This also emphasizes the lack of studies conducted in our country. In addition, the lack of applications conducted in participation banks is also noticeable.

This study will fill one of the most important gaps in the literature by implementing "individual credit processes", one of the most important processes in the banking field, in a participation bank in Türkiye with Lean Six Sigma and simulation applications.

3.3 Analysis of Bibliometric Mapping

VOSviewer is a software tool that developed for constructing and viewing bibliometric maps. (Van Eck & Waltman, 2009). VOSviewer (version 1.6.20) was used to examine

and analyze the studies obtained as a result of the literature review. In this part, all studies screened from WoS database examined with VOSviewer tool.

Firstly, a co-authorship analysis based on “country” is conducted. The minimum number of documents in countries is 3 to see clear collaboration networks. 17 countries where the studies are published are identified, and only 15 of these countries are linked to each other. The map in Figure 3.3 shows that Germany is the country with the most cooperation in co-authorship studies, followed by England and China, respectively. These countries form the core hubs of the network, with Germany and England showing strong multi-national collaboration across different clusters.

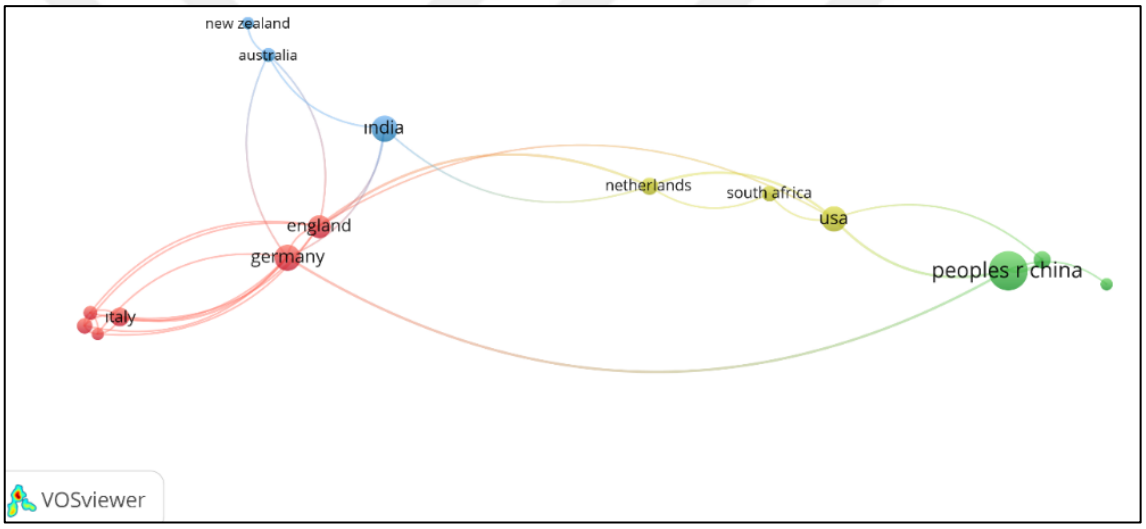

Figure 3.3: Co-authorship Network Based On Country

In addition, since journals are also prominent in scientific research, it is important to analyze these sources. Figure 3.4 is the co-citation density visualization based on source map.

The network map is created with 65 journals cited at least 10 times out of a total of 3340 journal citations. There are five clusters in the density map in Fig 3.4. The red cluster has 20 nodes, the green and the blue clusters have 16 each, the yellow cluster has 7, the purple cluster has 6 nodes. The densest cluster, shown in red, appears to have the highest number of connected journals, indicating a strong focus on related topics. On

the contrary, the loosest cluster, shown in purple, has fewer connections and a less tightly integrated.

Accordingly, Journal of Banking & Finance, Business Process Management Journal, Harvard Business Review and International Journal of Operations & Production Management are at the center of the network and represent the main streams of knowledge in the literature.

Figure 3.4: Co-citation Density Visualization Based on Source

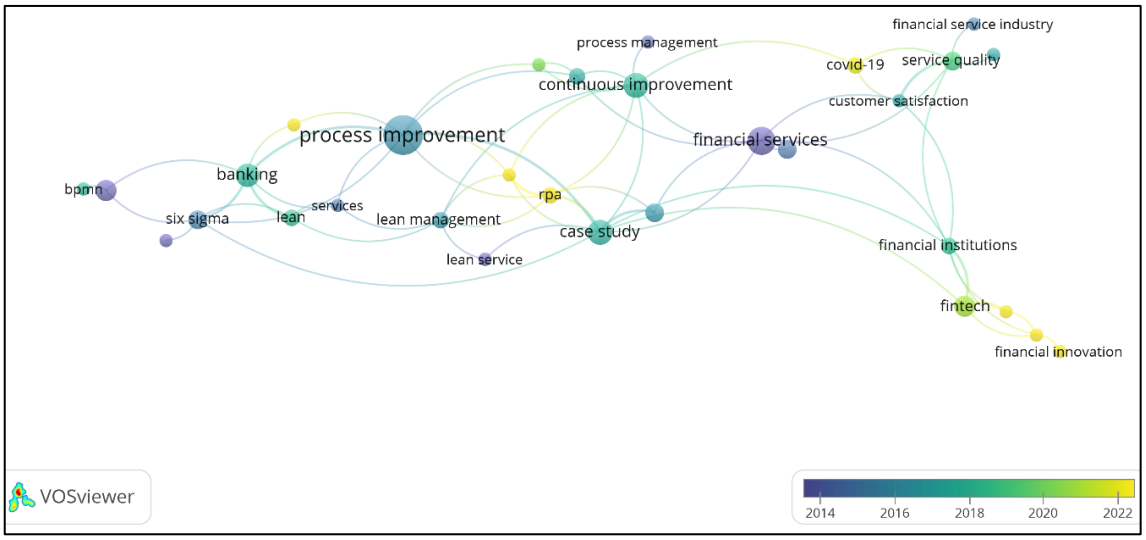

Figure 3.5: Co-occurrence Overlay Visualization Based on Author Keywords

Analyzing the keywords used by the author in the research is very important in understanding the content of the studies. The presence of related keywords in the articles shows the relationship between the studies. To analyze this relationship, co-occurrence analysis is performed based on author keywords to understand the scientific orientation of the articles. This analysis is shown in Figure 3.5 as an overlay visualization. From 547 keywords, minimum 2 occurances of a keyword were selected and 53 met the threshold. Some of the words eliminated so the final value is 31 which is mapped in Fig 4.

Historically, the nodes in yellow, which are the most recent concepts, indicate concepts that have been popular in the research field in recent years. Examples include “Fintech” and “Financial Innovation”. Concepts such as “Six Sigma”, “Lean”, and “Business Process Improvement” have been the subject of research since the past. Finally, “RPA” (Robotic Process Automation) has also been frequently encountered in recent years and is generally associated with case studies.In terms of methodology, it can be said that there are applied studies.

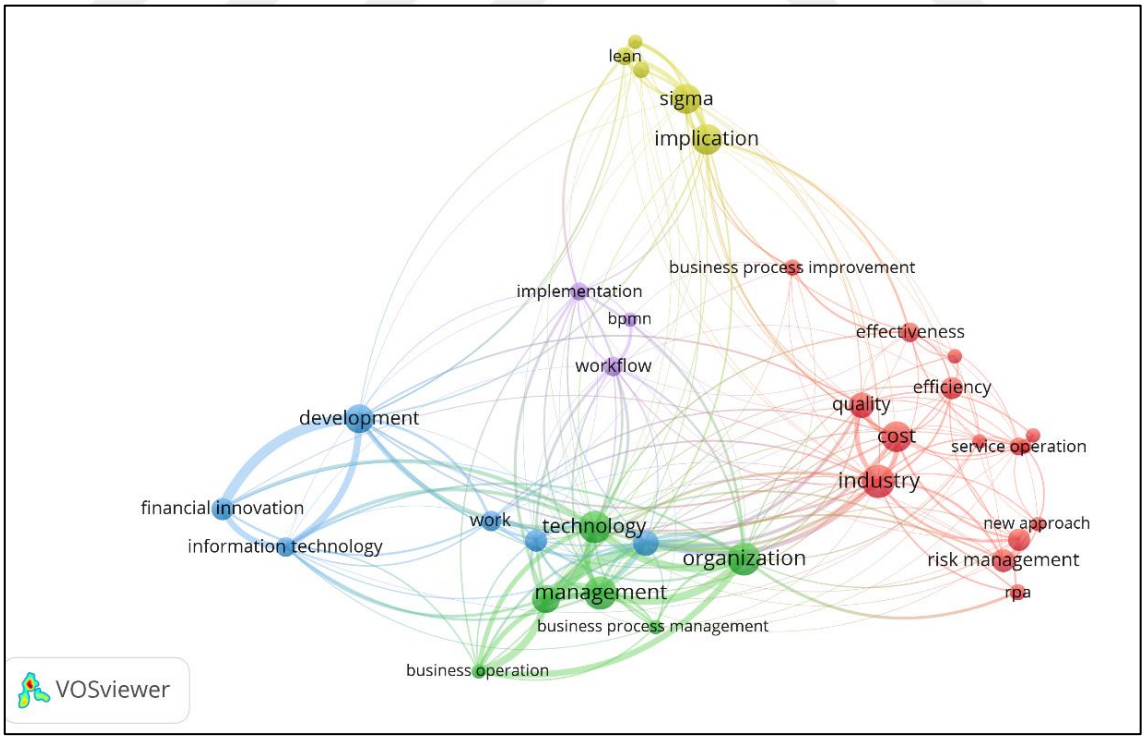

Figure 3.6: Co-occurrence Network With The Text Data

For a more detailed analysis, relevant keywords in the abstract sections of the study are mapped to the Co-occurrence network with the text data as shown in Figure 3.6. For a more comprehensive screening, full counting is performed with a minimum of 4 repetitions out of 1778 terms. From the 80 words are obtained, unnecessary concepts are manually removed and a map consisting of 35 items and 5 clusters is created as shown in Figure 3.6.

The red cluster constitutes a large part of the studies and focuses on the Business Process Improvement," "Cost," "Efficiency," "Quality," "Risk Management," "Service Operation." Also it has bonds with "Lean Implementation" and "RPA (Robotic Process Automation)" which shows the technological integration on the process improvement studies. The green cluster focuses on "Management," "Technology," "Organization," "Business Process Management.The blue cluster, on the other hand, emphasizes the concepts of financial innovation, information technology, and development. The yellow cluster focuses on "Lean" and "Sigma" methods. The term "Implication" refers to research on the results and effects of these methods. Finally, the purple cluster concentrates on "BPMN" and "workflow"

In this section, the studies scanned are in the Web of science database are evaluated with a bibliometric analysis. First, a co-authorship analysis based on “country” map is created and the links of country-based studies are analyzed. Then, a citation-based network based on document map is created and the links on citations are analyzed. The journals in which the studies were published are also examined and Co-citation density visualization based on source map is created. Afterwards, Co-occurrence overlay visualization based on author keywords map is created by emphasizing the importance of keywords. It is interpreted which keywords are used by authors and how they are distributed according to years. Finally, Co-occurrence network with the text data map is created with this software. In this analysis, VOSviewer examines the abstracts of the studies, finds the most frequently recurring terms and analyzes their links.
As a result, terms such as “Process Improvement”, “Lean”, “Six Sigma”, “Financial Innovation” and “RPA” have an important place in the literature both historically and currently. In the literature, it has been determined how the themes are related to each other in process improvement studies.

4. MATERIALS AND METHODS

In this section of the study, the steps seen in the flow chart in Figure 4.1 were followed. First, the problem is defined. In order to define the problem, the current process is modeled. Then, the necessary data is collected. In this section, six sigma is used. The simulation of the current process is done with Arena, then, due to various constraints, support is taken from Python as an alternative. After the improvement points are determined, the improved process is modeled and simulated. Finally, the estimated values for 2025 are determined and the simulation is done.

Figure 4.1: Method Flowchart

4.1 Six Sigma

Lean Six Sigma is a method widely used in process improvement studies in many sectors. The Six Sigma DMAIC (Define, Measure, Analyze, Improve and Control) methodology provides a basic roadmap for process improvement efforts. (Krishnan & Prasath, 2013)

4.1.1 Define

The definition phase is the first phase of DMAIC. Here, the main problem is defined. The functioning, importance and problems of the process to be improved are introduced. Thus, the first step of process improvement is completed.

In this study, the problem is first defined in the light of the Lean Six Sigma method. The most critical process in the banking sector is the credit service provided to customers. Loan disbursement processes directly affect customer satisfaction.

When this critical process is examined in a private participation bank where the study is conducted, it is more problematic compared to other banks. The long processing time and waiting time for loan processes prevent customers from preferring the bank. In addition, bank employees stated that they cannot provide credit service to their customers due to the complexity and length of the process.

In this context, the current status of the process is mapped and examined with a flow chart. Critical points for customers in the process were identified.

The current individual loan process flow chart is shown in Figure 4.2.

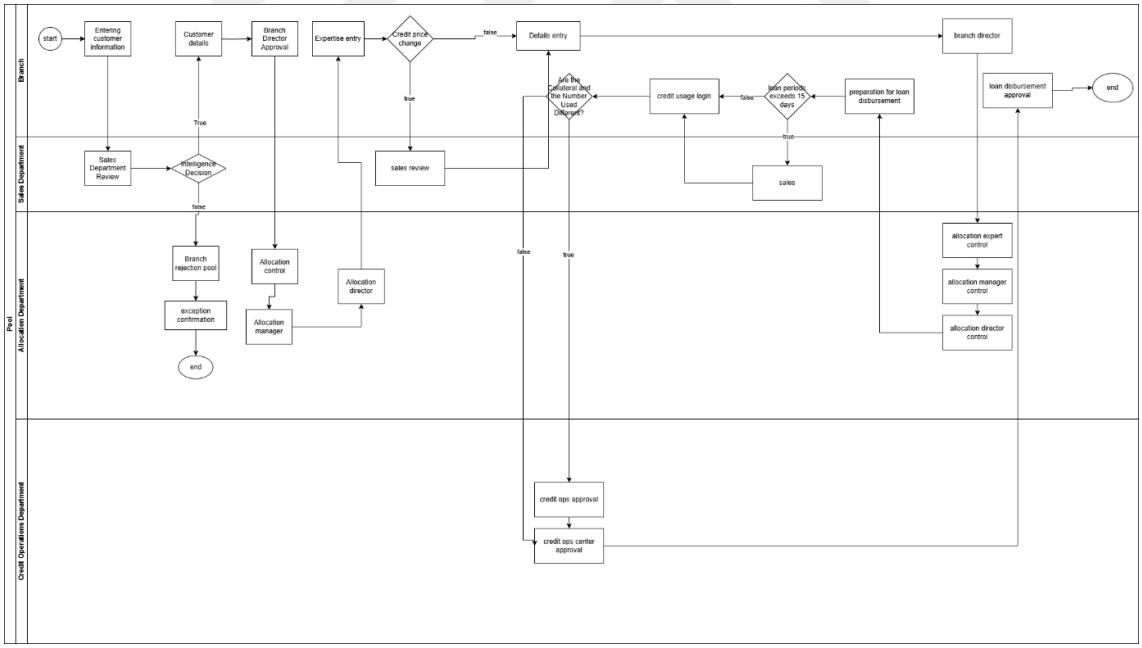

Figure 4.2: Loan Process Flowchart

4.1.2 Measurement

In the measurement phase, data regarding the process is collected. In the bank where the study is conducted, individual loan processes are carried out through an application belonging to the bank.

Data regarding the flow are obtained from log records. In order to analyze the current process, log records of the past 2 years (2023 & 2024) are examined. The logs are exported from the internal application used by bank. The number of employee working at each stage, transaction times, waiting times and return/rejection rates are determined. The number of branches operating in 2023 and 2024 is also determined at this stage. Also, the frequency of initiating the credit application flow through the system is determined. Based on transactions made throughout the year, it is determined that a new transaction is initiated through the system on average every 5 minutes.

During the data collection phase, a tolerance value of 5% is determined and processes that took too long or too short compared to normal (extreme points) are removed. Then, average values are obtained. In addition, average values as well as minimum and maximum times are determined for the process and waiting times in each step. After the filters are done, minimum, average and maximum times are obtained. Therefore, a triangular distribution is selected for modeling in the simulation phase. The final state of the obtained data is given in the tables below.

Table 4.1: Processing Time for Each Step in 2023 & 2024 (in Minutes)

Task name	2023			2024		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Entering customer information	2	5	18	2	4	10
Sales Department Review	0.16	0.34	1.33	0.16	0.26	1
Customer Details and Document Upload	4	16	79	2	13	39
Branch Director Approval	0.5	2	12	0.5	2	10
Allocation control	5	11.5	25	4	11.05	26
Approval of Allocation Manager	0.5	1.69	6	0.5	2.08	8.5
Expertise Entry	2.5	8.1	42.6	2.5	8.61	45.83
Approval of Allocation Director	0.5	1.71	5.6	0.5	2.8	11.5
Sales Department	0.16	0.34	1.33	0.16	0.26	1
Details Entry	4	16	79	2	13	39
Branch Director App	0.5	2	12	0.5	2	10
Allocation Expert Control	5	11.5	25	4	11.05	26
Manager	0.5	1.69	6	0.5	2.08	8.5
Director	0.5	1.71	5.6	0.5	2.8	11.5
Preparation for Loan Disbursement	2	15.6	112.5	2.5	15.7	91.5
Sales	0.16	0.34	1.33	0.16	0.26	1
Credit Usage Login	1	2.45	12.5	1.5	4.29	14.6
Credit Ops Approval	1	4.24	19.3	1	4.1	19.6
Credit Ops Center Approval	0.5	2.17	6.3	0.5	2.23	6
Loan Disbursement Approval	1	2.45	12.5	1.5	4.29	14.6
Branch Rejection Pool	0.16	0.64	4.33	0.16	0.77	6.83
Exception Confirmation	0.16	0.6	2.16	0.16	0.51	1.6

Table 4.1 shows the minimum, average and maximum values of processing times for 2023 and 2024 for each step in the individual loans process.

Table 4.2: Waiting Time for Each Step in 2023 & 2024 (in Minutes)

Task name	2023			2024		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Entering customer information	0.16	80	7390	0.16	26	387
Sales Department Review	0.83	12	52	0.5	7.85	37.5
Customer Details and Document Upload	0.5	69	1212	0.16	71	1144
Branch Director Approval	0.6	32	215	0,5	26	185
Allocation control	1.5	128	929	1.67	167	999
Approval of Allocation Manager	0.33	3.27	18.7	0.33	20.3	241
Expertise Entry	443.5	2802	11701	363	2223	6156
Approval of Allocation Director	1.17	38.5	140	1.3	53.1	182
Sales Department	0.85	11.4	64.2	0.5	8.12	34
Details Entry	1	63	1089	0.5	65	1200
Branch Director App	1	34	218	0.82	25	186
Allocation Expert Control	1.6	131	930	1.8	165	1000
Manager	0.35	3.4	19	0.4	21	250
Director	1.2	37	135,6	1.3	49.2	176
Preparation for Loan Disbursement	0.33	763	5101	0.33	1648	12643
Sales	1	13	49.6	0.5	7.9	41.5
Credit Usage Login	0.5	1794	12638	0.33	1648	12644
Credit Ops Approval	0.17	3.49	22	0.17	3.37	24
Credit Ops Center Approval	0.33	6.51	26.5	0.33	7.98	58
Loan Disbursement Approval	1	1685	11984	0.67	1492	12153
Branch Rejection Pool	0.33	82.3	1350	0.16	111.8	1352
Exception Confirmation	0.33	3.74	21.3	0.33	7.98	58

Table 4.2 shows the minimum, average and maximum values of waiting periods for 2023 and 2024 for each step in the individual loans process.

Table 4.3: Decide Rate (Percent true) in 2023 & 2024

	2023	2024
Change of the credit rate	33%	38%
Intelligence decision	75%	75%
Authority Control	5%	2%
Credit Price Change	25%	25%
Loan Period exceeds 15 days	25%	25%
Are the Collateral and the Number Used Different?	55%	43%
Did Sales Management Approve?	90%	90%
Did Branch Director Approve?	97%	97%
Did Allocation Approve?	86%	82%
Did Manager Approve?	90%	87%
Did branch approve?	90%	90%
Did allocation department approve?	85%	76%
Did Director Approve?	81%	77%
Did Sales Approve?	90%	90%
Branch director approve?	97%	97%
Expert control	80%	80%
Manager control	90%	90%
Director control	90%	90%
Sales approve?	90%	90%
credit ops decide	87%	91%
credit ops center decide	94%	92%

Table 4.3 shows the true percentage rates at decision points in the individual loans process.

Table 4.4: Number of Employees in 2023 & 2024

	2023	2024
Branch Employee	1198	1465
Allocation Employee	8	8
Allocation Manager	3	4
Allocation Director	1	1
Credit Operation Employee	12	12
Sales Department Employee	12	10
Branch Director	242	234
Number of Branches	242	234

Table 4.4 shows the number of employees are involved in the process in 2023 and 2024.

4.1.3 Analyze

In the analysis phase, the data collected during the measurement is analyzed and it can be clearly seen in which parts of the process improvements will be made.

4.1.3.1 Simulation Modeling

Arena Simulation Software is preferred for process analysis with simulation. The reason for choosing this program is that there are many sources in the literature with this application. First of all, the current state of the process is modeled in the Arena program. Here, unlike the flow diagram, assign and decide modules are used. With the Assign module, the assignment of the work to the branches where the customer who requested the loan applied is made. With the Decide modules, the decision points after each step are clearly seen. The true rates at each decision point are simulated using the measured real data. The flow of the current model in the Arena Simulation Software is shown in Figure 4.3.

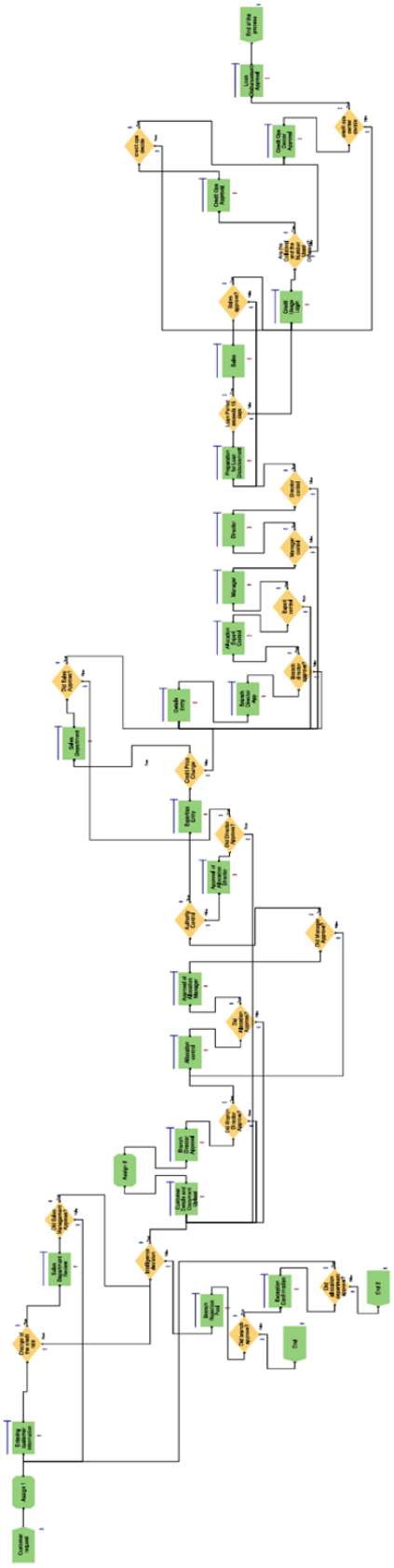

Figure 4.3: Diagram of the Loan Process in Arena Software

After modeling the current process and recording the actual data for 2023 into the simulation program, a simulation is performed. 480 minutes (1 day of work is 8 hours) are simulated with 3 replications. The results are given in the table below.

Table 4.5: Arena Simulation Software Results

	Arena (Avg Count)
Entering customer information	132.66
Sales Department Review	47.00
Customer Details and Doc Upload	116.33
Branch Director Approval	66.33
Allocation control	69.60
Approval of Allocation Manager	58.60
Approval of Allocation Director	50.00
Expertise Entry	42.00
Details Entry	45.00
Preparation for Loan Disbursement	15.33
Credit Usage Login	16.00
Credit Ops Approval	8.66
Credit Ops Center Approval	13.66
Loan Disbursement Approval	11.33
Branch Rejection Pool	33.00

After the simulation, a limitation is detected in the Arena program. Within the scope of this study, it is determined that there is a resource limitation in the Arena program used with a student license. Since the process is intended to be simulated with completely real data, no changes are made to the resources. Therefore, a maximum of 8 hours of simulation could be performed with the Arena program.

Since there is no time, replication or analysis limitation in order to analyze the process correctly in the study, simulation is attempted with Python. First, the current situations is visualized in Arena is written as code in the Python environment. Then, the data for the year 2023 is entered here and an 8-hour simulation is first performed with 3 replications.

The results are compared with the results obtained from Arena.

Table 4.6: Arena and Python Simulation Comparison

	Variable 1	Variable 2
Mean	48,162	48,35466667
Variance	501,0889457	1371,444755
Observation	15	15
Pearson Correlation	0,897028519	
Predicted Mean Difference	0	
df	14	
t Stat	-0,038015408	
P(T<=t) one-tailed	0,485106082	
t Critical one-tailed	1,761310136	
P(T<=t) two-tailed	0,970212164	
t Critical two-tailed	2,144786688	

A paired-sample t-test is performed to compare the Python model with Arena. Here, *t* Stat is –0.0380, indicating a statistically normal deviation. The two-tailed $P(T \leq t)$ value of 0.9702 indicates that the *p* value is above 0.05, indicating that there is no statistical difference between the Python and Arena results. Finally, the Pearson Correlation of 0.897 indicates that there is a strong positive relationship between the results of the two models. Considering these data, the Python model can be safely used instead of the Arena model.

Afterwards, the current process for the years 2023 and 2024 is coded to be simulated in the Python environment. The Python codes for 2023 and 2024 are included in the appendix.

Table 4.7: General Comparison Between 2023 and 2024

	2023	2024
Total Applications	24.992	25.023
Approved Applications	8137	7300

As seen in Table 4.7, as a result of the simulations, the total number of loan applications are 24,992 in 2023 and 25,023 in 2024. Despite the significant increase in applications, the number of approved applications is 8,137 in 2023 and 7,300 in 2024.

Table 4.8: Comparison of Step Counts in 2023 and 2024

Step Name	Count (2023)	Count (2024)	Difference (%)
Allocation Control	17.440	17.357	-0,5%
Approval of Allocation Director	12.770	12.127	-5,0%
Approval of Allocation Manager	15.004	14.217	-5,2%
Branch Director Approval	18.002	17.935	-0,4%
Branch Rejection Pool	5.990	6.061	1,2%
Credit Ops Approval	10.243	8.946	-12,7%
Credit Ops Center Approval	8.918	8.134	-8,8%
Credit Usage Login	10.243	8.947	-12,7%
Customer Details and Document Upload	18.014	17.944	-0,4%
Details Entry	10.647	9.429	-11,4%
Entering Customer Information	24.884	25.008	0,5%
Exception Confirmation	0	0	0,0%
Expertise Entry	10.664	9.443	-11,4%
Loan Disbursement Approval	8.137	7.300	-10,3%
Preparation for Loan Disbursement	10.523	9.177	-12,8%
Sales Department Review	8.200	9.464	15,4%

According to the Table 4.8, the number of transactions in most steps are decreased in 2024. The decreases in the credit steps indicate that fewer applications remain towards the end of the process.

The 10.3% decrease in the Credit Distribution Approval step supports the decrease in the number of customers who received credit approval.
The 0.5% increase in the Customer Information Entry step reflects a small increase in the total number of applications.

In general, the decrease in the number of transactions in many process steps indicates that applications are being eliminated at earlier stages of the process or fewer applications are reaching later stages.

Table 4.9: Comparison of Average Process Times for 2023 and 2024

Step Name	Avg Process Time (2023)	Avg Process Time (2024)	Difference (%)
Allocation Control	12,60	12,31	-2,30%
Approval of Allocation Director	2,15	3,86	79,53%
Approval of Allocation Manager	2,21	2,87	29,86%
Branch Director Approval	3,26	3,02	-7,36%
Branch Rejection Pool	1,1	1,51	37,27%
Credit Ops Approval	6,15	6,07	-1,30%
Credit Ops Center Approval	2,57	2,57	0,00%
Credit Usage Login	3,72	5,53	48,66%
Customer Details and Document Upload	24	15,4	-35,83%
Details Entry	24	15,4	-35,83%
Entering Customer Information	6,61	4,67	-29,35%
Exception Confirmation	0	0	0,00%
Expertise Entry	12,5	13,3	6,40%
Loan Disbursement Approval	3,72	5,54	48,92%
Preparation for Loan Disbursement	27,82	25,4	-8,70%
Sales Department Review	0,46	0,35	-23,91%

According to the table 4.9, while processing times are increased in some steps, they are decreased in others. The highest increase is in the Allocation Manager Approval step with 79.53%. This rate shows that the approval process is very slow in this step.

Table 4.10: Comparison of Average Waiting Times for 2023 and 2024

Step Name	Avg Wait Time (2023)	Avg Wait Time (2024)	Difference (%)
Allocation Control	229,65	272,04	18,46%
Approval of Allocation Director	49,13	65,8	33,93%
Approval of Allocation Manager	5	46,6	789,31%
Branch Director Approval	55,25	46,25	-16,29%
Branch Rejection Pool	220,78	258,57	17,12%
Credit Ops Approval	5,84	5,98	2,40%
Credit Ops Center Approval	8,81	14,32	62,54%
Credit Usage Login	3167,88	3026,03	-4,48%
Customer Details and Document Upload	192,68	189,85	-1,47%
Details Entry	173,97	185,34	6,54%
Entering Customer Information	512,16	66,86	-86,95%
Exception Confirmation	0	0	0,00%
Expertise Entry	3880,5	2542,35	-34,48%
Loan Disbursement Approval	2977,9	2833,35	-4,85%
Preparation for Loan Disbursement	1313,4	3030,36	130,73%
Sales Department Review	16,74	11,51	-31,24%

When we look at the Table 4.10, it is seen that the allocation manager approval step has increased by 789%. It seems that there is a problem that needs to be improved in this step.

In general, it is seen that the waiting rates are high in other steps as well. In particular, the 130% increase in the preparation for loan disbursement step is also noteworthy. This shows that customers are waiting too much.

As a result, while the total number of applications increased in 2024, the number of approved applications are decreased. It shows that the processing and waiting times in the allocation and loan preparation steps of the process are long and cause customer loss.

4.1.4 Improve

Following the problems identified during the analysis phase, 3 different improvement suggestions are presented.

The first is Resource planning. Increasing the number of personnel will improve the durations of steps with long waiting times. The second is simplification of process steps. Having too many approval steps in the process unnecessarily prolongs the process. Finally, automation and digitalization are suggested. Automatic document checks in the allocation step with the RPA solution will reduce both the process and waiting time.

Since the first improvement suggestion will directly affect resource planning, will cause recruitment processes and will not be realized in a short time, other improvement suggestions are evaluated.

The most effective way for process improvement is Options 2 and 3. If the complex structure of the process is organized here and digitalization solutions are produced in some steps, the process will progress much faster and customer satisfaction will increase.

The individual loan process in the participation bank examined has a long and complex structure. There are too many decision points and approval chains. When the simulation results are examined in detail, it is determined that there are 3 different control points in the allocation steps and that there are too many waiting and processing times in these

steps. Here, it is particularly noteworthy that the authorization control works after the allocation manager approval and then the allocation manager is in the approving role again.

After the discussions with the allocation unit, it is decided that the limits of this authority could be increased. It is also possible to remove the allocation manager step directly from the process and carry out this work with 2 approvers. If the process is organized in a way that the allocation manager is also authorized for the manager step, both the resource increase will occur in that step and a step will be removed from the process.

Another point to be improved will be to prevent the branch manager from approving after the customer details and document upload step. Here, the branch manager only gives approval, and the necessary documents are already reviewed in the allocation step. It would be beneficial to remove this step from the process.

In order to prevent document checks from taking long in the allocation steps, a robotic process automation solution can be offered. If the document checks are carried out automatically by robots, the process time and waiting time in the allocation step will also be reduced. The flow chart of the process after the improvements is as follows.

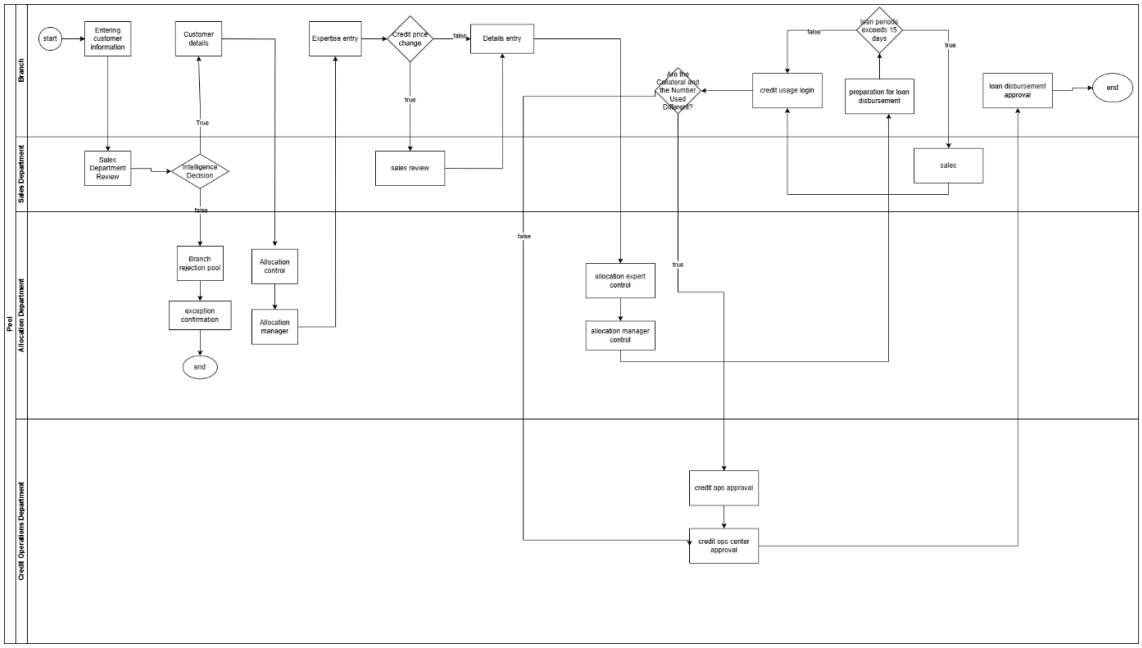

Figure 4.4: Improved Loan Process Flowchart

4.1.5 Control

Simulation is performed again to determine the performance of the improved process. The code written for the improvement is included in the appendix.

Processing time, waiting time and approval count are determined as the main performance indicators and these values are monitored in both the existing and improved processes

5. RESULTS

In this section, the findings obtained as a result of the simulation are presented. The results are listed under three subheadings. In the first section, the current and improved simulation results for 2023 are given. The results are compared within the scope of the main performance indicators, which are the number of approvals, processing time and waiting time. In the second section, analyses are given for 2024. In the last section, an estimate is made for the 2025 periods and the improved process is simulated with the 2025 values.

5.1 Comparison of Current and Improved Process - 2023 Simulation Results

Table 5.1 compares the current and improved simulation results of the process for the year 2023.

Table 5.1: 2023 Current vs Improved

Year	Scenario	Total Applications	Approved Applications	Approval Rate (%)
2023	Current Process	24.992	8137	32.56
2023	Improved Process	24.917	10.302	41.34

Table 5.2 compares the average processing times in the current and improved simulations for 2023.

Table 5.2: Comparison of Processing Times in 2023

Step Name	Avg Process Time (Current)	Avg Process Time (Improved)	Difference (%)
Allocation Control	12.60	2.15	82.94
Approval of Allocation Manager	2.21	2.20	0.45
Branch Rejection Pool	1.1	1.1	0
Credit Ops Approval	6.15	6.12	0.49
Credit Ops Center Approval	2.57	2.57	0
Credit Usage Login	3.72	3.72	0
Customer Details and Document Upload	24	24	0
Details Entry	24	24	0
Entering Customer Information	6.61	6.61	0
Exception Confirmation	0	0	0
Expertise Entry	12.5	12.47	0.24
Loan Disbursement Approval	3.72	3.72	0
Preparation for Loan Disbursement	27.82	27.82	0
Sales Department Review	0.46	0.46	0

Table 5.3 compares the average waiting times in the current and improved simulations for 2023.

Table 5.3: Comparison of Waiting Times in 2023

Step Name	Avg Wait Time (Current)	Avg Wait Time (Improved)	Difference (%)
Allocation Control	229.65	0.94	99.59
Approval of Allocation Manager	5	5.24	-4.8
Branch Rejection Pool	220.78	220.94	-0.07
Credit Ops Approval	5.84	5.84	0
Credit Ops Center Approval	8.81	8.84	-0.34
Credit Usage Login	3167.88	3150.06	0.56
Customer Details and Document Upload	192.68	192.47	0.11
Details Entry	173.97	174.18	-0.12
Entering Customer Information	512.16	512.20	-0.01
Exception Confirmation	0	0	0
Expertise Entry	3880.5	3865.06	0.4
Loan Disbursement Approval	2977.9	2989.46	-0.39
Preparation for Loan Disbursement	1313.4	1314.6	-0.09
Sales Department Review	16.74	16.7	0.24

5.2 Comparison of Current and Improved Process - 2024 Simulation Results

Table 5.4 compares the current and improved simulation results of the process for the year 2024.

Table 5.4: 2024 Current vs Improved

Year	Scenario	Total Applications	Approved Applications	Approval Rate (%)
2024	Current Process	25.023	7300	29.17
2024	Improved Process	25.008	9725	38.89

Table 5.5 compares the average processing times in the current and improved simulations for 2024.

Table 5.5: Comparison of Processing Time in 2024

Step Name	Avg Process Time (Current)	Avg Process Time (Improved)	Difference (%)
Allocation Control	12.31	2.15	82.53
Approval of Allocation Manager	2.87	2.87	0
Branch Rejection Pool	1.51	1.50	0.66
Credit Ops Approval	6.07	6.07	0
Credit Ops Center Approval	2.57	2.56	0.39
Credit Usage Login	5.53	5.53	0
Customer Details and Document Upload	15.4	15.4	0
Details Entry	15.4	15.4	0
Entering Customer Information	4.67	4.67	0
Exception Confirmation	0	0	0
Expertise Entry	13.3	13.3	0
Loan Disbursement Approval	5.54	5.54	0
Preparation for Loan Disbursement	25.4	25.4	0
Sales Department Review	0.35	0.35	0

Table 5.6 compares the average waiting times in the current and improved simulations for 2024.

Table 5.6: Comparison of Waiting Times in 2024

Step Name	Avg Wait Time (Current)	Avg Wait Time (Improved)	Difference (%)
Allocation Control	272.04	0.94	99.65
Approval of Allocation Manager	46.6	46.4	0.43
Branch Rejection Pool	258.57	258.3	0.1
Credit Ops Approval	5.98	5.9	1.34
Credit Ops Center Approval	14.32	14.3	0.14
Credit Usage Login	3026.03	3025.5	0.02
Customer Details and Document Upload	189.85	189.8	0.03
Details Entry	185.34	186.1	-0.41
Entering Customer Information	66.86	66.83	0.04
Exception Confirmation	0	0	0
Expertise Entry	2542.35	2544.4	-0.08
Loan Disbursement Approval	2833.35	2831.3	0.07
Preparation for Loan Disbursement	3030.36	3035.7	0
Sales Department Review	11.51	11.44	0.61

5.3 Simulation of Estimated Times for 2025

As part of the process improvement study, a simulation is also conducted for 2025 in order to determine the estimated performance of the current year and to identify possible improvement points. The 2025 transaction and waiting times to be used in the simulation are estimated with the regression model using the minimum, average and maximum values in 2023 and 2024. The code written for the estimation can be accessed from the Google colaboratory link in the attachments section.

Table 5.7: Estimated 2025 Times Calculated by Regression

Task name	Processing Times			Waiting Times		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Entering customer information	2	2	3	0.0	0.0	0.16
Sales Department Review	0.16	0.18	0.67	0.17	3.70	23
Customer Details and Document Upload	0.0	0.0	10	0.0	73	1076
Allocation control	1	2	4	0.0	1	2
Approval of Allocation Manager	0.5	2.47	11	0.33	37.3	463.3
Expertise Entry	2.5	9.12	49.06	282.5	611	1644
Details Entry	0.0	0.0	10	0.0	67	1311
Branch Rejection Pool	0.16	0.9	9.33	0.0	141.3	1354
Exception Confirmation	0.16	0.42	1.04	0.33	12.22	94.7
Preparation for Loan Disbursement	3	15.80	70.5	0.33	2533	20185
Credit Usage Login	2	6.13	16.7	0.16	1502	12650
Credit Ops Approval	1	3.96	19.9	0.17	3.25	26
Credit Ops Center Approval	0.5	2.29	5.7	0.33	9.45	89.5
Loan Disbursement Approval	2	6.13	16.7	0.34	1299	12322

Table 5.8: Comparison of 2023, 2024 and 2025

	2023 (Improved)	2024 (Improved)	2025 (Predicted)
Total Applications	24.917	25.008	25.095
Approved Applications	10.302	9725	9152
Approval Rate (%)	41.34%	38.89%	36.5%
Avg Processing Time (minutes)	9	7.75	5.35
Avg Waiting Time (minutes)	958.2	939.80	908.75

6. DISCUSSIONS

In the study, simulations are made for the current and improved processes by year and the results are shown in the results section. As seen in Table 5.1, the approval rate increased to 41.34% as a result of the improved scenario simulation in 2023. In Table x, the same comparison is shown for 2024. Here, it is seen that the approval rate increased to 38.89%. It is seen that the improved process increased the approved credit applications. In the last part, estimated periods are calculated with regression for 2025 and the improved process is simulated with this data. In Table 5.8, a comparative analysis is made for 2023, 2024 and 2025. Here, it is seen that although the total application increased, the approved application decreased. It is evaluated that this decrease is due to the increase in the number of applications and the stricter criteria applied in the decision steps. Therefore, it is recommended to evaluate the criteria especially at the decision points.

The changes in processing and waiting times are shown in Tables 5.2 and 5.3 for 2023. Here, the improvement in the allocation control step, where RPA development is suggested, is particularly noteworthy. 82.94% process time improved and 99.59% wait time improved. Similarly, as can be seen in Tables 5.5 and 5.6, 82.53% processing time and 99.65% waiting time improvements were determined in the allocation step for 2024. From here, it can be said that automation developments such as RPA have a great impact on the improvement.

When Avg Processing Time (minutes) and Avg Waiting Time (minutes) are examined in Table 5.6, it is seen that there is a positive decrease. Despite this, it is noteworthy that waiting times are still too high. Integrating solutions such as RPA into different steps of the process can support the improvement of waiting times.

These results indicated that the removed steps and RPA solution provided a significant improvement in application approval speed, processing times and waiting times.

7. CONCLUSIONS

Although process improvement studies are important in all sectors, they make a big difference especially in the banking and finance sectors. Customer satisfaction is the top priority in the banking sector. Evaluating the processes that are in direct contact with the customer with the ideology of continuous improvement ensures that institutions achieve optimum benefit. In this context, the most inefficient and customer loss-causing "individual loan process" is examined in a private participation bank in Türkiye. The current process was analyzed with the DMAIC stages of Six Sigma and improvement points are determined.

In the analysis phase of Six Sigma, the simulation modeling method is used. The current process is first simulated in the Arena program. Then, due to the simulation limitations in the arena, an alternative modeling is performed via Python. Since the results here are consistent, the simulation method is continued with Python. As a result of the simulation, the reduction of approval steps and RPA automation are suggested for the improvement of the process.

When the necessary actions is taken and the improved process is simulated, it is determined that there is an increase in the number of approved loans. The removal of a few steps in the current process directly affected the acceleration of the process. Especially in the allocation step where the RPA solution is introduced, a major change is observed in the processing and waiting times. The processing time decreased by approximately 82% and the waiting time decreased by 99.6%.

In the last part of the study, a forecasting model is developed for 2025. Based on the 2023 and 2024 data, the 2025 times are estimated with regression. Then, the improved

simulation runs with the 2025 data. The results of this simulation are also promising for 2025. However, it is seen that the number of approved applications decreased in 2025. This shows that the decision points should be re-evaluated and the process still needs improvement.

There are some limitations to this study. The simulations are based on average values. The model does not reflect that the decision criteria may change due to external factors. In addition, only the data of the last 2 years is used when estimating the 2025 values.

In future studies, this research can be examined with larger data sets. Various improvement scenarios can be tested. Studies should be carried out especially to reduce waiting times. Moreover, in future studies, testing the improved process in terms of customer satisfaction will also make a difference in this study.

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APPENDIX

Appendix A – Python Simulation Code

The following figures show the Python-based simulation model used in the study. The code was divided into parts for readability.

A.1 – 2023 Current State Simulation Code

```
#Current Simulation Model for 2023

!pip install simpy
!pip install pandas
!pip install matplotlib
import simpy
import random
import pandas as pd

# Parameters
random.seed(42)
NUM_BRANCHES = 242
TOTAL_BRANCH_EMPLOYEES = 1198
EMPLOYEES_PER_BRANCH = TOTAL_BRANCH_EMPLOYEES // NUM_BRANCHES  # =5
SIM_TIME = 124800  # 1 year
REPLICATIONS = 3

# Resources
class BankResources:
    def __init__(self, env):
        self.branch_employee = {branch_id: simpy.Resource(env, capacity=EMPLOYEES_PER_BRANCH) for branch_id in range(NUM_BRANCHES)}
        self.allocation_employee = simpy.Resource(env, capacity=8)
        self.allocation_manager = simpy.Resource(env, capacity=3)
        self.allocation_director = simpy.Resource(env, capacity=1)
        self.credit_operation_employee = simpy.Resource(env, capacity=12)
        self.sales_department_employee = simpy.Resource(env, capacity=12)
        self.branch_director = {branch_id: simpy.Resource(env, capacity=1) for branch_id in range(NUM_BRANCHES)}

# Process and waiting times
process_times = {
    "Entering Customer Information": {"process": (2, 5, 18), "wait": (0.16, 80, 7390)},
    "Sales Department Review": {"process": (0.16, 0.34, 1.33), "wait": (0.83, 12, 52)},
    "Customer Details and Document Upload": {"process": (4, 16, 79), "wait": (0.5, 69, 1212)},
    "Branch Director Approval": {"process": (0.5, 2, 12), "wait": (0.6, 32, 215)},
    "Allocation Control": {"process": (5, 11.5, 25), "wait": (1.5, 128, 929)},
    "Approval of Allocation Manager": {"process": (0.5, 1.69, 6), "wait": (0.33, 3.27, 18.7)},
    "Approval of Allocation Director": {"process": (0.5, 1.71, 5.6), "wait": (1.17, 38.5, 140)},
    "Expertise Entry": {"process": (2.5, 8.1, 42.6), "wait": (443.5, 2802, 11701)},
    "Details Entry": {"process": (4, 16, 79), "wait": (1, 63, 1089)},
    "Branch Rejection Pool": {"process": (0.16, 0.64, 4.33), "wait": (0.33, 82.3, 1350)},
    "Exception Confirmation": {"process": (0.16, 0.6, 2.16), "wait": (0.33, 3.74, 21.3)},
    "Preparation for Loan Disbursement": {"process": (2, 15.6, 112.5), "wait": (0.33, 763, 5101)},
    "Credit Usage Login": {"process": (1, 2.45, 12.5), "wait": (0.5, 1794, 12638)},
    "Credit Ops Approval": {"process": (1, 4.24, 19.3), "wait": (0.17, 3.49, 22)},
    "Credit Ops Center Approval": {"process": (0.5, 2.17, 6.3), "wait": (0.33, 6.51, 26.5)},
    "Loan Disbursement Approval": {"process": (1, 2.45, 12.5), "wait": (1, 1685, 11984)}
}

# Decision rates
decision_rates = {
    "Change of the Credit Rate": 0.33,
    "Intelligence Decision": 0.75,
    "Did Sales Management Approve?": 0.90,
    "Did Branch Approve?": 0.90,
    "Did Allocation Department Approve?": 0.85,
    "Did Branch Director Approve?": 0.97,
    "Did Allocation Approve?": 0.86,
    "Did Manager Approve?": 0.90,
    "Did Director Approve?": 0.81,
    "Authority Control": 0.05,
    "Credit Ops decide": 0.87,
    "credit ops center decide": 0.94
}
```

```python
# Statistics
def initialize_statistics():
    return {step: {"count": 0, "process_time": 0, "wait_time": 0} for step in process_times}

total_applications = 0
approved_applications = 0

# Decision function
def decision(name):
    return random.random() < decision_rates.get(name, 0.5)

# Process step
def process_step(env, name, resource, statistics):
    wait_min, wait_mode, wait_max = process_times[name]["wait"]
    wait_time = random.triangular(wait_min, wait_mode, wait_max)
    yield env.timeout(wait_time)

    start = env.now
    with resource.request() as req:
        yield req
        process_min, process_mode, process_max = process_times[name]["process"]
        process_time = random.triangular(process_min, process_mode, process_max)
        yield env.timeout(process_time)

    duration = env.now - start
    statistics[name]["count"] += 1
    statistics[name]["process_time"] += process_time
    statistics[name]["wait_time"] += wait_time

# Customer process
def customer(env, name, resources, statistics, application_tracker):
    application_tracker["total"] += 1
    branch_id = random.randint(0, NUM_BRANCHES - 1)

    yield env.process(process_step(env, "Entering Customer Information", resources.branch_employee[branch_id], statistics))

    if decision("Change of the Credit Rate"):
        yield env.process(process_step(env, "Sales Department Review", resources.sales_department_employee, statistics))
        if not decision("Did Sales Management Approve?"):
            return

    if not decision("Intelligence Decision"):
        yield env.process(process_step(env, "Branch Rejection Pool", resources.branch_employee[branch_id], statistics))
        if decision("Did Branch Approve?") and decision("Did Allocation Department Approve?"):
            return
        return

    yield env.process(process_step(env, "Customer Details and Document Upload", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Branch Director Approval", resources.branch_director[branch_id], statistics))
    if not decision("Did Branch Director Approve?"):
        return

    yield env.process(process_step(env, "Allocation Control", resources.allocation_employee, statistics))
    if not decision("Did Allocation Approve?"):
        return

    yield env.process(process_step(env, "Approval of Allocation Manager", resources.allocation_manager, statistics))
    if not decision("Did Manager Approve?"):
        return

    if not decision("Authority Control"):
        yield env.process(process_step(env, "Approval of Allocation Director", resources.allocation_director, statistics))
        if not decision("Did Director Approve?"):
```

```
    yield env.process(process_step(env, "Customer Details and Document Upload", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Branch Director Approval", resources.branch_director[branch_id], statistics))
    if not decision("Did Branch Director Approve?"):
        return

    yield env.process(process_step(env, "Allocation Control", resources.allocation_employee, statistics))
    if not decision("Did Allocation Approve?"):
        return

    yield env.process(process_step(env, "Approval of Allocation Manager", resources.allocation_manager, statistics))
    if not decision("Did Manager Approve?"):
        return

    if not decision("Authority Control"):
        yield env.process(process_step(env, "Approval of Allocation Director", resources.allocation_director, statistics))
        if not decision("Did Director Approve?"):
            return

    yield env.process(process_step(env, "Expertise Entry", resources.allocation_employee, statistics))
    yield env.process(process_step(env, "Details Entry", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Preparation for Loan Disbursement", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Credit Usage Login", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Credit Ops Approval", resources.credit_operation_employee, statistics))

    if decision("Credit Ops decide"):
        yield env.process(process_step(env, "Credit Ops Center Approval", resources.credit_operation_employee, statistics))
        if decision("credit ops center decide"):
            yield env.process(process_step(env, "Loan Disbursement Approval", resources.branch_employee[branch_id], statistics))
            application_tracker["approved"] += 1

# Customer generator
def customer_generator(env, resources, statistics, application_tracker):
    customer_id = 0
    while True:
        yield env.timeout(random.expovariate(1.0 / 5))
        customer_id += 1
        env.process(customer(env, f"Customer {customer_id}", resources, statistics, application_tracker))

# Simulation runner
def run_simulation():
    env = simpy.Environment()
    statistics = initialize_statistics()
    application_tracker = {"total": 0, "approved": 0}
    resources = BankResources(env)
    env.process(customer_generator(env, resources, statistics, application_tracker))
    env.run(until=SIM_TIME)
    return statistics, application_tracker

# Execute replications
results = []
application_results = []

for i in range(REPLICATIONS):
    stats, application_tracker = run_simulation()
    for step, data in stats.items():
        results.append({
            "Replication": i + 1,
            "Step": step,
            "Count": data["count"],
            "Process Time": data["process_time"],
            "Wait Time": data["wait_time"]
        })
    application_results.append(application_tracker)

# Results DataFrame
df = pd.DataFrame(results)
summary = df.groupby("Step").agg({
    "Count": "mean",
    "Process Time": "mean",
    "Wait Time": "mean"
}).reset_index()

summary["Avg Process Time"] = summary["Process Time"] / summary["Count"]
summary["Avg Wait Time"] = summary["Wait Time"] / summary["Count"]
```

A.2 – 2024 Current State Simulation Code

```
#Current Simulation Model for 2024
#2024 simulation
!pip install simpy
!pip install pandas
!pip install matplotlib
import simpy
import random
import pandas as pd

# Parameters
random.seed(42)
NUM_BRANCHES = 234
TOTAL_BRANCH_EMPLOYEES = 1465
EMPLOYEES_PER_BRANCH = TOTAL_BRANCH_EMPLOYEES // NUM_BRANCHES  # =6
SIM_TIME = 124800  # 1 year
REPLICATIONS = 3

# Resources
class BankResources:
    def __init__(self, env):
        self.branch_employee = {branch_id: simpy.Resource(env, capacity=EMPLOYEES_PER_BRANCH) for branch_id in range(NUM_BRANCHES)}
        self.allocation_employee = simpy.Resource(env, capacity=8)
        self.allocation_manager = simpy.Resource(env, capacity=4)
        self.allocation_director = simpy.Resource(env, capacity=1)
        self.credit_operation_employee = simpy.Resource(env, capacity=12)
        self.sales_department_employee = simpy.Resource(env, capacity=10)
        self.branch_director = {branch_id: simpy.Resource(env, capacity=1) for branch_id in range(NUM_BRANCHES)}

# Process and waiting times
process_times = {
    "Entering Customer Information": {"process": (2, 4, 10), "wait": (0.16, 26, 387)},
    "Sales Department Review": {"process": (0.16, 0.26, 1), "wait": (0.5, 7.85, 37.5)},
    "Customer Details and Document Upload": {"process": (2, 13, 39), "wait": (0.16, 71, 1144)},
    "Branch Director Approval": {"process": (0.5, 2, 10), "wait": (0.5, 26, 185)},
    "Allocation Control": {"process": (4, 11.05, 26), "wait": (1.67, 167, 999)},
    "Approval of Allocation Manager": {"process": (0.5, 2.08, 8.5), "wait": (0.33, 20.3, 241)},
    "Approval of Allocation Director": {"process": (0.5, 2.8, 11.5), "wait": (1.3, 53.1, 182)},
    "Expertise Entry": {"process": (2.5, 8.61, 45.83), "wait": (363, 2223, 6156)},
    "Details Entry": {"process": (2, 13, 39), "wait": (0.5, 65, 1200)},
    "Branch Rejection Pool": {"process": (0.16, 0.77, 6.83), "wait": (0.16, 111.8, 1352)},
    "Exception Confirmation": {"process": (0.16, 0.51, 1.6), "wait": (0.33, 7.98, 58)},
    "Preparation for Loan Disbursement": {"process": (2.5, 15.7, 91.5), "wait": (0.33, 1648, 12643)},
    "Credit Usage Login": {"process": (1.5, 4.29, 14.6), "wait": (0.33, 1648, 12644)},
    "Credit Ops Approval": {"process": (1, 4.1, 19.6), "wait": (0.17, 3.37, 24)},
    "Credit Ops Center Approval": {"process": (0.5, 2.23, 6), "wait": (0.33, 7.98, 58)},
    "Loan Disbursement Approval": {"process": (1.5, 4.29, 14.6), "wait": (0.67, 1492, 12153)}
}

# Decision rates
decision_rates = {
    "Change of the Credit Rate": 0.38,
    "Intelligence Decision": 0.75,
    "Did Sales Management Approve?": 0.90,
    "Did Branch Approve?": 0.90,
    "Did Allocation Department Approve?": 0.76,
    "Did Branch Director Approve?": 0.97,
    "Did Allocation Approve?": 0.82,
    "Did Manager Approve?": 0.87,
    "Did Director Approve?": 0.77,
    "Authority Control": 0.02,
    "Credit Ops decide": 0.91,
    "credit ops center decide": 0.92
}
```

```python
# Statistics
def initialize_statistics():
    return {step: {"count": 0, "process_time": 0, "wait_time": 0} for step in process_times}

total_applications = 0
approved_applications = 0

# Decision function
def decision(name):
    return random.random() < decision_rates.get(name, 0.5)

# Process step
def process_step(env, name, resource, statistics):
    wait_min, wait_mode, wait_max = process_times[name]["wait"]
    wait_time = random.triangular(wait_min, wait_mode, wait_max)
    yield env.timeout(wait_time)

    start = env.now
    with resource.request() as req:
        yield req
        process_min, process_mode, process_max = process_times[name]["process"]
        process_time = random.triangular(process_min, process_mode, process_max)
        yield env.timeout(process_time)

    duration = env.now - start
    statistics[name]["count"] += 1
    statistics[name]["process_time"] += process_time
    statistics[name]["wait_time"] += wait_time

# Customer process
def customer(env, name, resources, statistics, application_tracker):
    application_tracker["total"] += 1
    branch_id = random.randint(0, NUM_BRANCHES - 1)

    yield env.process(process_step(env, "Entering Customer Information", resources.branch_employee[branch_id], statistics))

    if decision("Change of the Credit Rate"):
        yield env.process(process_step(env, "Sales Department Review", resources.sales_department_employee, statistics))
        if not decision("Did Sales Management Approve?"):
            return

    if not decision("Intelligence Decision"):
        yield env.process(process_step(env, "Branch Rejection Pool", resources.branch_employee[branch_id], statistics))
        if decision("Did Branch Approve?") and decision("Did Allocation Department Approve?"):
            return
        return

    yield env.process(process_step(env, "Customer Details and Document Upload", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Branch Director Approval", resources.branch_director[branch_id], statistics))
    if not decision("Did Branch Director Approve?"):
        return

    yield env.process(process_step(env, "Allocation Control", resources.allocation_employee, statistics))
    if not decision("Did Allocation Approve?"):
        return

    yield env.process(process_step(env, "Approval of Allocation Manager", resources.allocation_manager, statistics))
    if not decision("Did Manager Approve?"):
        return

    if not decision("Authority Control"):
        yield env.process(process_step(env, "Approval of Allocation Director", resources.allocation_director, statistics))
        if not decision("Did Director Approve?"):
            return
```

```
    yield env.process(process_step(env, "Expertise Entry", resources.allocation_employee, statistics))
    yield env.process(process_step(env, "Details Entry", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Preparation for Loan Disbursement", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Credit Usage Login", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Credit Ops Approval", resources.credit_operation_employee, statistics))

    if decision("Credit Ops decide"):
        yield env.process(process_step(env, "Credit Ops Center Approval", resources.credit_operation_employee, statistics))
        if decision("credit ops center decide"):
            yield env.process(process_step(env, "Loan Disbursement Approval", resources.branch_employee[branch_id], statistics))
            application_tracker["approved"] += 1

# Customer generator
def customer_generator(env, resources, statistics, application_tracker):
    customer_id = 0
    while True:
        yield env.timeout(random.expovariate(1.0 / 5))
        customer_id += 1
        env.process(customer(env, f"Customer {customer_id}", resources, statistics, application_tracker))

# Simulation runner
def run_simulation():
    env = simpy.Environment()
    statistics = initialize_statistics()
    application_tracker = {"total": 0, "approved": 0}
    resources = BankResources(env)
    env.process(customer_generator(env, resources, statistics, application_tracker))
    env.run(until=SIM_TIME)
    return statistics, application_tracker

# Execute replications
results = []
application_results = []

for i in range(REPLICATIONS):
    stats, application_tracker = run_simulation()
    for step, data in stats.items():
        results.append({
            "Replication": i + 1,
            "Step": step,
            "Count": data["count"],
            "Process Time": data["process_time"],
            "Wait Time": data["wait_time"]
        })
    application_results.append(application_tracker)

# Results DataFrame
df = pd.DataFrame(results)
summary = df.groupby("Step").agg({
    "Count": "mean",
    "Process Time": "mean",
    "Wait Time": "mean"
}).reset_index()

summary["Avg Process Time"] = summary["Process Time"] / summary["Count"]
summary["Avg Wait Time"] = summary["Wait Time"] / summary["Count"]

print(summary)

# Applications summary
applications_df = pd.DataFrame(application_results)
total_applications = applications_df["total"].mean()
approved_applications = applications_df["approved"].mean()

print(f"\nTotal Applications (Average): {total_applications}")
print(f"Approved Applications (Average): {approved_applications}")
```

A.3 – 2023 Improved Simulation Code

```python
#Improved simulation model for 2023
import simpy
import random
import pandas as pd


# Parameters
random.seed(42)
NUM_BRANCHES = 242
TOTAL_BRANCH_EMPLOYEES = 1198
EMPLOYEES_PER_BRANCH = TOTAL_BRANCH_EMPLOYEES // NUM_BRANCHES  # =5
SIM_TIME = 124800  # 1 year
REPLICATIONS = 3

# Resources
class BankResources:
    def __init__(self, env):
        self.branch_employee = {branch_id: simpy.Resource(env, capacity=EMPLOYEES_PER_BRANCH) for branch_id in range(NUM_BRANCHES)}
        self.allocation_employee = simpy.Resource(env, capacity=8)
        self.allocation_manager = simpy.Resource(env, capacity=4)  # Updated capacity to 4
        self.credit_operation_employee = simpy.Resource(env, capacity=12)
        self.sales_department_employee = simpy.Resource(env, capacity=12)
        self.branch_director = {branch_id: simpy.Resource(env, capacity=1) for branch_id in range(NUM_BRANCHES)}


# Process and waiting times (Allocation Director and Branch Director steps removed)
process_times = {
    "Entering Customer Information": {"process": (2, 5, 18), "wait": (0.16, 80, 7390)},
    "Sales Department Review": {"process": (0.16, 0.34, 1.33), "wait": (0.83, 12, 52)},
    "Customer Details and Document Upload": {"process": (4, 16, 79), "wait": (0.5, 69, 1212)},
    "Allocation Control": {"process": (1, 2, 4), "wait": (0, 1, 2)},
    "Approval of Allocation Manager": {"process": (0.5, 1.69, 6), "wait": (0.33, 3.27, 18.7)},
    "Expertise Entry": {"process": (2.5, 8.1, 42.6), "wait": (443.5, 2802, 11701)},
    "Details Entry": {"process": (4, 16, 79), "wait": (1, 63, 1089)},
    "Branch Rejection Pool": {"process": (0.16, 0.64, 4.33), "wait": (0.33, 82.3, 1350)},
    "Exception Confirmation": {"process": (0.16, 0.6, 2.16), "wait": (0.33, 3.74, 21.3)},
    "Preparation for Loan Disbursement": {"process": (2, 15.6, 112.5), "wait": (0.33, 763, 5101)},
    "Credit Usage Login": {"process": (1, 2.45, 12.5), "wait": (0.5, 1794, 12638)},
    "Credit Ops Approval": {"process": (1, 4.24, 19.3), "wait": (0.17, 3.49, 22)},
    "Credit Ops Center Approval": {"process": (0.5, 2.17, 6.3), "wait": (0.33, 6.51, 26.5)},
    "Loan Disbursement Approval": {"process": (1, 2.45, 12.5), "wait": (1, 1685, 11984)}
}



# Decision rates
decision_rates = {
    "Change of the Credit Rate": 0.33,
    "Intelligence Decision": 0.75,
    "Did Sales Management Approve?": 0.90,
    "Did Allocation Approve?": 0.86,
    "Did Manager Approve?": 0.90,
    "Authority Control": 0.05,
    "Credit Ops decide": 0.87,
    "credit ops center decide": 0.94

}

# Statistics initialization
def initialize_statistics():
    return {step: {"count": 0, "process_time": 0, "wait_time": 0} for step in process_times}
```

```python
# Decision function
def decision(name):
    return random.random() < decision_rates.get(name, 0.5)

# Process step function
def process_step(env, name, resource, statistics):
    wait_min, wait_mode, wait_max = process_times[name]["wait"]
    wait_time = random.triangular(wait_min, wait_mode, wait_max)
    yield env.timeout(wait_time)

    start = env.now
    with resource.request() as req:
        yield req
        process_min, process_mode, process_max = process_times[name]["process"]
        process_time = random.triangular(process_min, process_mode, process_max)
        yield env.timeout(process_time)

    statistics[name]["count"] += 1
    statistics[name]["process_time"] += process_time
    statistics[name]["wait_time"] += wait_time

# Customer process
def customer(env, name, resources, statistics, application_tracker):
    application_tracker["total"] += 1
    branch_id = random.randint(0, NUM_BRANCHES - 1)

    yield env.process(process_step(env, "Entering Customer Information", resources.branch_employee[branch_id], statistics))

    if decision("Change of the Credit Rate"):
        yield env.process(process_step(env, "Sales Department Review", resources.sales_department_employee, statistics))
        if not decision("Did Sales Management Approve?"):
            return

    if not decision("Intelligence Decision"):
        yield env.process(process_step(env, "Branch Rejection Pool", resources.branch_employee[branch_id], statistics))
        return

    yield env.process(process_step(env, "Customer Details and Document Upload", resources.branch_employee[branch_id], statistics))
    # Branch Director Approval is REMOVED here

    yield env.process(process_step(env, "Allocation Control", resources.allocation_employee, statistics))
    if not decision("Did Allocation Approve?"):
        return

    yield env.process(process_step(env, "Approval of Allocation Manager", resources.allocation_manager, statistics))
    if not decision("Did Manager Approve?"):
        return

    if not decision("Authority Control"):
        pass  # Allocation Director and related decision REMOVED

    yield env.process(process_step(env, "Expertise Entry", resources.allocation_employee, statistics))
    yield env.process(process_step(env, "Details Entry", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Preparation for Loan Disbursement", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Credit Usage Login", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Credit Ops Approval", resources.credit_operation_employee, statistics))

    if decision("Credit Ops decide"):
        yield env.process(process_step(env, "Credit Ops Center Approval", resources.credit_operation_employee, statistics))
        if decision("credit ops center decide"):
            yield env.process(process_step(env, "Loan Disbursement Approval", resources.branch_employee[branch_id], statistics))
            application_tracker["approved"] += 1
```

```python
# Customer generator
def customer_generator(env, resources, statistics, application_tracker):
    customer_id = 0
    while True:
        yield env.timeout(random.expovariate(1.0 / 5))
        customer_id += 1
        env.process(customer(env, f"Customer {customer_id}", resources, statistics, application_tracker))

# Simulation runner
def run_simulation():
    env = simpy.Environment()
    statistics = initialize_statistics()
    application_tracker = {"total": 0, "approved": 0}
    resources = BankResources(env)
    env.process(customer_generator(env, resources, statistics, application_tracker))
    env.run(until=SIM_TIME)
    return statistics, application_tracker

# Execute replications
results = []
application_results = []

for i in range(REPLICATIONS):
    stats, application_tracker = run_simulation()
    for step, data in stats.items():
        results.append({
            "Replication": i + 1,
            "Step": step,
            "Count": data["count"],
            "Process Time": data["process_time"],
            "Wait Time": data["wait_time"]
        })
    application_results.append(application_tracker)

# Results
df = pd.DataFrame(results)
summary = df.groupby("Step").agg({
    "Count": "mean",
    "Process Time": "mean",
    "Wait Time": "mean"
}).reset_index()

summary["Avg Process Time"] = summary["Process Time"] / summary["Count"]
summary["Avg Wait Time"] = summary["Wait Time"] / summary["Count"]

print(summary)

applications_df = pd.DataFrame(application_results)
print("\nTotal Applications (Average):", applications_df["total"].mean())
print("Approved Applications (Average):", applications_df["approved"].mean())
```

A.4 – 2024 Improved Simulation Code

```python
#Improved simulation moodel for 2024
import simpy
import random
import pandas as pd

# Parameters
random.seed(42)
NUM_BRANCHES = 234
TOTAL_BRANCH_EMPLOYEES = 1465
EMPLOYEES_PER_BRANCH = TOTAL_BRANCH_EMPLOYEES // NUM_BRANCHES
SIM_TIME = 124800  # 1 year
REPLICATIONS = 3

# Updated Resources
class BankResources:
    def __init__(self, env):
        self.branch_employee = {branch_id: simpy.Resource(env, capacity=EMPLOYEES_PER_BRANCH) for branch_id in range(NUM_BRANCHES)}
        self.allocation_employee = simpy.Resource(env, capacity=8)
        self.allocation_manager = simpy.Resource(env, capacity=5)  # Updated capacity to 5
        self.credit_operation_employee = simpy.Resource(env, capacity=12)
        self.sales_department_employee = simpy.Resource(env, capacity=10)
        self.branch_director = {branch_id: simpy.Resource(env, capacity=1) for branch_id in range(NUM_BRANCHES)}

# Process and waiting times (Allocation Director and Branch Director steps removed)
process_times = {
    "Entering Customer Information": {"process": (2, 4, 10), "wait": (0.16, 26, 387)},
    "Sales Department Review": {"process": (0.16, 0.26, 1), "wait": (0.5, 7.85, 37.5)},
    "Customer Details and Document Upload": {"process": (2, 13, 39), "wait": (0.16, 71, 1144)},
    "Allocation Control": {"process": (1, 2, 4), "wait": (0, 1, 2)},
    "Approval of Allocation Manager": {"process": (0.5, 2.08, 8.5), "wait": (0.33, 20.3, 241)},
    "Expertise Entry": {"process": (2.5, 8.61, 45.83), "wait": (363, 2223, 6156)},
    "Details Entry": {"process": (2, 13, 39), "wait": (0.5, 65, 1200)},
    "Branch Rejection Pool": {"process": (0.16, 0.77, 6.83), "wait": (0.16, 111.8, 1352)},
    "Exception Confirmation": {"process": (0.16, 0.51, 1.6), "wait": (0.33, 7.98, 58)},
    "Preparation for Loan Disbursement": {"process": (2.5, 15.7, 91.5), "wait": (0.33, 1648, 12643)},
    "Credit Usage Login": {"process": (1.5, 4.29, 14.6), "wait": (0.33, 1648, 12644)},
    "Credit Ops Approval": {"process": (1, 4.1, 19.6), "wait": (0.17, 3.37, 24)},
    "Credit Ops Center Approval": {"process": (0.5, 2.23, 6), "wait": (0.33, 7.98, 58)},
    "Loan Disbursement Approval": {"process": (1.5, 4.29, 14.6), "wait": (0.67, 1492, 12153)}
}

# Decision rates
decision_rates = {
    "Change of the Credit Rate": 0.38,
    "Intelligence Decision": 0.75,
    "Did Sales Management Approve?": 0.90,
    "Did Allocation Approve?": 0.82,
    "Did Manager Approve?": 0.87,
    "Authority Control": 0.02,
    "Credit Ops decide": 0.91,
    "credit ops center decide": 0.92
}

# Statistics initialization
def initialize_statistics():
    return {step: {"count": 0, "process_time": 0, "wait_time": 0} for step in process_times}

# Decision function
def decision(name):
    return random.random() < decision_rates.get(name, 0.5)

# Process step function
def process_step(env, name, resource, statistics):
    wait_min, wait_mode, wait_max = process_times[name]["wait"]
```

```
    wait_time = random.triangular(wait_min, wait_mode, wait_max)
    yield env.timeout(wait_time)

    start = env.now
    with resource.request() as req:
        yield req
        process_min, process_mode, process_max = process_times[name]["process"]
        process_time = random.triangular(process_min, process_mode, process_max)
        yield env.timeout(process_time)

    statistics[name]["count"] += 1
    statistics[name]["process_time"] += process_time
    statistics[name]["wait_time"] += wait_time

# Customer process
def customer(env, name, resources, statistics, application_tracker):
    application_tracker["total"] += 1
    branch_id = random.randint(0, NUM_BRANCHES - 1)

    yield env.process(process_step(env, "Entering Customer Information", resources.branch_employee[branch_id], statistics))

    if decision("Change of the Credit Rate"):
        yield env.process(process_step(env, "Sales Department Review", resources.sales_department_employee, statistics))
        if not decision("Did Sales Management Approve?"):
            return

    if not decision("Intelligence Decision"):
        yield env.process(process_step(env, "Branch Rejection Pool", resources.branch_employee[branch_id], statistics))
        return

    yield env.process(process_step(env, "Customer Details and Document Upload", resources.branch_employee[branch_id], statistics))
    # Branch Director Approval is REMOVED here

    yield env.process(process_step(env, "Allocation Control", resources.allocation_employee, statistics))
    if not decision("Did Allocation Approve?"):
        return

    yield env.process(process_step(env, "Approval of Allocation Manager", resources.allocation_manager, statistics))
    if not decision("Did Manager Approve?"):
        return

    if not decision("Authority Control"):
        pass  # Allocation Director and related decision REMOVED

    yield env.process(process_step(env, "Expertise Entry", resources.allocation_employee, statistics))
    yield env.process(process_step(env, "Details Entry", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Preparation for Loan Disbursement", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Credit Usage Login", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Credit Ops Approval", resources.credit_operation_employee, statistics))

    if decision("Credit Ops decide"):
        yield env.process(process_step(env, "Credit Ops Center Approval", resources.credit_operation_employee, statistics))
        if decision("credit ops center decide"):
            yield env.process(process_step(env, "Loan Disbursement Approval", resources.branch_employee[branch_id], statistics))
            application_tracker["approved"] += 1

# Customer generator
def customer_generator(env, resources, statistics, application_tracker):
    customer_id = 0
    while True:
        yield env.timeout(random.expovariate(1.0 / 5))
        customer_id += 1
        env.process(customer(env, f"Customer {customer_id}", resources, statistics, application_tracker))
```

```python
# Simulation runner
def run_simulation():
    env = simpy.Environment()
    statistics = initialize_statistics()
    application_tracker = {"total": 0, "approved": 0}
    resources = BankResources(env)
    env.process(customer_generator(env, resources, statistics, application_tracker))
    env.run(until=SIM_TIME)
    return statistics, application_tracker

# Execute replications
results = []
application_results = []

for i in range(REPLICATIONS):
    stats, application_tracker = run_simulation()
    for step, data in stats.items():
        results.append({
            "Replication": i + 1,
            "Step": step,
            "Count": data["count"],
            "Process Time": data["process_time"],
            "Wait Time": data["wait_time"]
        })
    application_results.append(application_tracker)

# Results
df = pd.DataFrame(results)
summary = df.groupby("Step").agg({
    "Count": "mean",
    "Process Time": "mean",
    "Wait Time": "mean"
}).reset_index()

summary["Avg Process Time"] = summary["Process Time"] / summary["Count"]
summary["Avg Wait Time"] = summary["Wait Time"] / summary["Count"]

print(summary)

applications_df = pd.DataFrame(application_results)
print("\nTotal Applications (Average):", applications_df["total"].mean())
print("Approved Applications (Average):", applications_df["approved"].mean())

overall_avg_process_time = summary["Avg Process Time"].mean()
print("Overall Avg Process Time:", round(overall_avg_process_time, 2))

overall_avg_wait_time = summary["Avg Wait Time"].mean()
print("Overall Avg Wait Time:", round(overall_avg_wait_time, 2))
```

A.5 – 2025 Estimated Time Calculation Code

```
from os import wait
import pandas as pd
from sklearn.linear_model import LinearRegression
import numpy as np

#Enter process data separately for each value type.
process_data = {
    "Task": [
        "Entering customer information", "Sales Department Review", "Customer Details and Document Upload",
       "Allocation control", "Approval of Allocation Manager", "Expertise Entry", "Details Entry",
       "Branch Rejection Pool", "Exception Confirmation", "Preparation for Loan Disbursement",
       "Credit Usage Login", "Credit Ops Approval", "Credit Ops Center Approval", "Loan Disbursement Approval"
    ],
    "2023_Min": [2, 0.16, 4, 1, 0.5, 2.5, 4, 0.16, 0.16, 2, 1, 1, 0.5 , 1],
    "2023_Avg": [5, 0.34, 16, 2, 1.69, 8.1 , 16, 0.64, 0.6 , 15.6, 2.45, 4.24, 2.17, 2.45],
    "2023_Max": [18, 1.33, 79, 4, 6, 42.6, 79, 4.33, 2.16, 112.5, 12.5, 19.3, 6.3, 12.5],
    "2024_Min": [2, 0.16, 2, 1, 0.5, 2.5, 2, 0.16, 0.16, 2.5, 1.5, 1, 0.5, 1.5],
    "2024_Avg": [4, 0.26, 13, 2, 2.08, 8.61, 13, 0.77, 0.51, 15.7, 4.29, 4.1, 2.23, 4.29],
    "2024_Max": [10, 1, 39, 4, 8.5, 45.83, 39, 6.83, 1.6, 91.5, 14.6, 19.6, 6, 14.6]
}

df_proc = pd.DataFrame(process_data)

#Enter wait data separately for each value type.

wait_data = {
    "Task": [
        "Entering customer information", "Sales Department Review", "Customer Details and Document Upload",
       "Allocation control", "Approval of Allocation Manager", "Expertise Entry", "Details Entry",
       "Branch Rejection Pool", "Exception Confirmation", "Preparation for Loan Disbursement",
       "Credit Usage Login", "Credit Ops Approval", "Credit Ops Center Approval", "Loan Disbursement Approval"
    ],
    "2023_Min": [0.16, 0.83, 0.5, 0, 0.33, 443.5, 1, 0.33, 0.33, 0.33, 0.5, 0.17, 0.33, 1],
    "2023_Avg": [80, 12, 69, 1, 3.27, 2802, 63, 82.3, 3.74, 763, 1794, 3.49, 6.51, 1685],
    "2023_Max": [7390, 52, 1212, 2, 18.7, 11701, 1089, 1350, 21.3, 5101, 12638, 22, 26.5, 11984],
    "2024_Min": [0.16, 0.5, 0.16, 0, 0.33, 363, 0.5, 0.16, 0.33, 0.33, 0.33, 0.17, 0.33, 0.67],
    "2024_Avg": [26, 7.85, 71, 1, 20.3, 2223, 65, 111.8, 7.98, 1648, 1648, 3.37, 7.98, 1492],
    "2024_Max": [387, 37.5, 1144, 2, 241, 6156, 1200, 1352, 58, 12643, 12644, 24, 58, 12153]
}

df_wait = pd.DataFrame(wait_data)
```

```
# Regression)


def predict(df, col_2023, col_2024):
    return df.apply(lambda row: max(0, LinearRegression().fit(
        [[2023], [2024]],
        [[row[col_2023]], [row[col_2024]]]
    ).predict([[2025]])[0][0]), axis=1)


def enforce_order(row):
    values = [row["2025_Min"], row["2025_Avg"], row["2025_Max"]]
    values_sorted = sorted(values)
    row["2025_Min"], row["2025_Avg"], row["2025_Max"] = values_sorted
    return row

# -------------------- Apply Predictions --------------------
for col_type in ["Min", "Avg", "Max"]:
    df_proc[f"2025_{col_type}"] = predict(df_proc, f"2023_{col_type}", f"2024_{col_type}")
    df_wait[f"2025_{col_type}"] = predict(df_wait, f"2023_{col_type}", f"2024_{col_type}")


df_proc = df_proc.apply(enforce_order, axis=1)
df_wait = df_wait.apply(enforce_order, axis=1)

# -------------------- Show --------------------
print("PROCESS DURATIONS")
print(df_proc[["Task", "2023_Min", "2024_Min", "2025_Min",
               "2023_Avg", "2024_Avg", "2025_Avg",
               "2023_Max", "2024_Max", "2025_Max"]])

print("\nWAIT DURATIONS")
print(df_wait[["Task", "2023_Min", "2024_Min", "2025_Min",
               "2023_Avg", "2024_Avg", "2025_Avg",
               "2023_Max", "2024_Max", "2025_Max"]])
```

```
decision_data = {
    "Decision": [
        "Change of the Credit Rate", "Intelligence Decision", "Did Sales Management Approve?",
        "Did Allocation Approve?", "Did Manager Approve?", "Authority Control",
        "Credit Ops decide", "Credit ops center decide"
    ],
    "2023": [0.33, 0.75, 0.90, 0.86, 0.90, 0.05, 0.87, 0.94],
    "2024": [0.38, 0.75, 0.90, 0.82, 0.87, 0.02, 0.91, 0.92],
}

import pandas as pd
from sklearn.linear_model import LinearRegression

df_dec = pd.DataFrame(decision_data)

def predict_rate(row):
    model = LinearRegression().fit([[2023], [2024]], [[row["2023"]], [row["2024"]]])
    pred = model.predict([[2025]])[0][0]
    return min(1.0, max(0.0, round(pred, 4)))

df_dec["2025"] = df_dec.apply(predict_rate, axis=1)

print(df_dec)
```

A.6 – 2025 Projected Simulation Code

```python
#2025 Estimated Simulatiom
import simpy
import random
import pandas as pd

# Parameters
random.seed(42)
NUM_BRANCHES = 223
TOTAL_BRANCH_EMPLOYEES = 1523
EMPLOYEES_PER_BRANCH = TOTAL_BRANCH_EMPLOYEES // NUM_BRANCHES
SIM_TIME = 124800  # 1 year
REPLICATIONS = 3

# Updated Resources
class BankResources:
    def __init__(self, env):
        self.branch_employee = {branch_id: simpy.Resource(env, capacity=EMPLOYEES_PER_BRANCH) for branch_id in range(NUM_BRANCHES)}
        self.allocation_employee = simpy.Resource(env, capacity=10)
        self.allocation_manager = simpy.Resource(env, capacity=5)
        self.credit_operation_employee = simpy.Resource(env, capacity=12)
        self.sales_department_employee = simpy.Resource(env, capacity=12)
        self.branch_director = {branch_id: simpy.Resource(env, capacity=1) for branch_id in range(NUM_BRANCHES)}

# Process and waiting times (Allocation Director and Branch Director steps removed)
process_times = {
    "Entering Customer Information": {"process": (2,2,3), "wait": (0, 0, 0.16)},
    "Sales Department Review": {"process": (0.16, 0.18, 0.67), "wait": (0.17, 3.70, 23)},
    "Customer Details and Document Upload": {"process": (0, 0, 10), "wait": (0, 73, 1076)},
    "Allocation Control": {"process": (1, 2, 4), "wait": (0, 1, 2)},
    "Approval of Allocation Manager": {"process": (0.5, 2.47, 11), "wait": (0.33, 37.3, 463.3)},
    "Expertise Entry": {"process": (2.5, 9.12, 49.06), "wait": (282.5, 611, 1644)},
    "Details Entry": {"process": (0, 0, 10), "wait": (0, 67, 1311)},
    "Branch Rejection Pool": {"process": (0.16, 0.9, 9.33), "wait": (0, 141.3, 1354)},
    "Exception Confirmation": {"process": (0.16, 0.42, 1.04), "wait": (0.33, 12.22, 94.7)},
    "Preparation for Loan Disbursement": {"process": (3, 15.80, 70.5), "wait": (0.33, 2533, 20185)},
    "Credit Usage Login": {"process": (2, 6.13, 16.7), "wait": (0.16, 1502, 12650)},
    "Credit Ops Approval": {"process": (1, 3.96, 19.9), "wait": (0.17, 3.25, 26)},
    "Credit Ops Center Approval": {"process": (0.5, 2.29, 5.7), "wait": (0.33, 9.45, 89.5)},
    "Loan Disbursement Approval": {"process": (2, 6.13, 16.7), "wait": (0.34, 1299, 12322)}
}

# Decision rates
decision_rates = {
    "Change of the Credit Rate": 0.43,
    "Intelligence Decision": 0.75,
    "Did Sales Management Approve?": 0.90,
    "Did Allocation Approve?": 0.78,
    "Did Manager Approve?": 0.84,
    "Authority Control": 0,
    "Credit Ops decide": 0.95,
    "credit ops center decide": 0.90
}

# Statistics initialization
def initialize_statistics():
    return {step: {"count": 0, "process_time": 0, "wait_time": 0} for step in process_times}

# Decision function
def decision(name):
    return random.random() < decision_rates.get(name, 0.5)
```

```python
# Process step function
def process_step(env, name, resource, statistics):
    wait_min, wait_mode, wait_max = process_times[name]["wait"]
    wait_time = random.triangular(wait_min, wait_mode, wait_max)
    yield env.timeout(wait_time)

    start = env.now
    with resource.request() as req:
        yield req
        process_min, process_mode, process_max = process_times[name]["process"]
        process_time = random.triangular(process_min, process_mode, process_max)
        yield env.timeout(process_time)

    statistics[name]["count"] += 1
    statistics[name]["process_time"] += process_time
    statistics[name]["wait_time"] += wait_time

# Customer process
def customer(env, name, resources, statistics, application_tracker):
    application_tracker["total"] += 1
    branch_id = random.randint(0, NUM_BRANCHES - 1)

    yield env.process(process_step(env, "Entering Customer Information", resources.branch_employee[branch_id], statistics))

    if decision("Change of the Credit Rate"):
        yield env.process(process_step(env, "Sales Department Review", resources.sales_department_employee, statistics))
        if not decision("Did Sales Management Approve?"):
            return

    if not decision("Intelligence Decision"):
        yield env.process(process_step(env, "Branch Rejection Pool", resources.branch_employee[branch_id], statistics))
        return

    yield env.process(process_step(env, "Customer Details and Document Upload", resources.branch_employee[branch_id], statistics))
    # Branch Director Approval is REMOVED here

    yield env.process(process_step(env, "Allocation Control", resources.allocation_employee, statistics))
    if not decision("Did Allocation Approve?"):
        return

    yield env.process(process_step(env, "Approval of Allocation Manager", resources.allocation_manager, statistics))
    if not decision("Did Manager Approve?"):
        return

    if not decision("Authority Control"):
        pass  # Allocation Director and related decision REMOVED

    yield env.process(process_step(env, "Expertise Entry", resources.allocation_employee, statistics))
    yield env.process(process_step(env, "Details Entry", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Preparation for Loan Disbursement", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Credit Usage Login", resources.branch_employee[branch_id], statistics))
    yield env.process(process_step(env, "Credit Ops Approval", resources.credit_operation_employee, statistics))

    if decision("Credit Ops decide"):
        yield env.process(process_step(env, "Credit Ops Center Approval", resources.credit_operation_employee, statistics))
        if decision("credit ops center decide"):
            yield env.process(process_step(env, "Loan Disbursement Approval", resources.branch_employee[branch_id], statistics))
            application_tracker["approved"] += 1
```

```python
# Customer generator
def customer_generator(env, resources, statistics, application_tracker):
    customer_id = 0
    while True:
        yield env.timeout(random.expovariate(1.0 / 5))
        customer_id += 1
        env.process(customer(env, f"Customer {customer_id}", resources, statistics, application_tracker))

# Simulation runner
def run_simulation():
    env = simpy.Environment()
    statistics = initialize_statistics()
    application_tracker = {"total": 0, "approved": 0}
    resources = BankResources(env)
    env.process(customer_generator(env, resources, statistics, application_tracker))
    env.run(until=SIM_TIME)
    return statistics, application_tracker

# Execute replications
results = []
application_results = []

for i in range(REPLICATIONS):
    stats, application_tracker = run_simulation()
    for step, data in stats.items():
        results.append({
            "Replication": i + 1,
            "Step": step,
            "Count": data["count"],
            "Process Time": data["process_time"],
            "Wait Time": data["wait_time"]
        })
    application_results.append(application_tracker)

# Results
df = pd.DataFrame(results)
summary = df.groupby("Step").agg({
    "Count": "mean",
    "Process Time": "mean",
    "Wait Time": "mean"
}).reset_index()

summary["Avg Process Time"] = summary["Process Time"] / summary["Count"]
summary["Avg Wait Time"] = summary["Wait Time"] / summary["Count"]

print(summary)

applications_df = pd.DataFrame(application_results)
print("\nTotal Applications (Average):", applications_df["total"].mean())
print("Approved Applications (Average):", applications_df["approved"].mean())
```

BIOGRAPHICAL SKETCH

Fatma Nur Doğan graduated from Yenidoğu High School located in Istanbul, Türkiye. She later graduated from the Istanbul Sabahattin Zaim University, Department of Industrial Engineering.