CSE307: System Analysis & Design

Tenant Management: A systematic Design and Machine-Learning Based Predictive Approach

Group 08

Member1: Md. Hasib Hasan (2220166)

Member2: Meraj Ahmed (2221557)

Member3: Abir Ehsan Evan (1930670)

Chapter 01: Project Management

a. Background / Context

In recent years, the real estate and building management sectors have undergone significant transformations, largely driven by the integration of advanced technologies such as Machine Learning (ML) and Artificial Intelligence (AI). These technologies have provided novel solutions to long-standing challenges in property pricing, tenant management, and energy optimization. Traditionally, real estate pricing has relied heavily on manual assessments, historical data, and expert evaluations. However, these methods often fail to capture the complex, dynamic factors that influence property values, such as market fluctuations, economic shifts, and localized trends. Machine learning, with its ability to process vast amounts of data and uncover hidden patterns, has emerged as a game-changer in this regard.

Machine learning techniques, such as supervised learning algorithms (e.g., Random Forests, XGBoost, and Neural Networks), have made it possible to predict housing prices with far greater accuracy than conventional methods. These algorithms can handle vast, multi-dimensional datasets that incorporate a variety of factors—ranging from property size, age, and location to economic indicators, demographic trends, and even social factors. As a result, machine learning models can provide real-time, data-driven insights that are far more reliable for decision-making in the real estate market.

Similarly, the application of ML in building management, particularly in the realm of predictive maintenance, has allowed for more efficient management of building systems, such as Heating, Ventilation, and Air Conditioning (HVAC). Traditional approaches to building maintenance, which often involve reactive responses to equipment failures or manual scheduling of maintenance tasks, have proven inefficient and costly. With the advent of ML, it is now possible to monitor building systems in real-time using sensors and Internet of Things (IoT) devices, predict failures before they occur, and optimize energy usage. This results in not only cost savings but also enhanced occupant comfort and sustainability.

Despite these advancements, the growing volume of real estate data presents its own set of challenges. The real estate sector is inundated with increasingly complex and dynamic data, ranging from transaction histories to detailed geographic, demographic, and economic information. The integration of such a vast array of data, coupled with evolving technologies, creates both opportunities and difficulties. One of the biggest challenges lies in developing predictive models that can effectively handle this complexity while maintaining interpretability. As a result, while machine learning holds immense potential, there is still a need for careful consideration of model accuracy, data privacy, and ethical issues, particularly in the real estate sector where decisions can have significant financial and social implications.

Moreover, the integration of ML and AI technologies into real estate and building management systems is still in its infancy, and there is a need for further research to develop more robust models. As the sector continues to embrace digital transformation, there is an increasing demand for new methodologies that can adapt to rapidly changing market conditions, technological innovations, and the evolving needs of tenants and property managers alike.

Thus, while the potential benefits of machine learning in real estate and building management are undeniable, it is essential to continuously refine and develop these technologies to ensure their effective application. This project seeks to explore the intersection of machine learning, real estate price prediction, and predictive maintenance, examining the opportunities and challenges these technologies present, while contributing to the broader conversation on how to effectively harness the power of data-driven decision-making in these fields.

b. Problem Statement

The real estate market, particularly in dynamic and rapidly changing environments such as those influenced by the COVID-19 pandemic, is confronted with a significant challenge in the form of inaccurate and inefficient predictive models for property pricing. Traditionally, property pricing has been governed by a combination of historical data, expert assessments, and statistical techniques like hedonic pricing models. While these approaches have been effective in some cases, they often fall short when it comes to capturing the complex and dynamic nature of real estate markets. Property prices are influenced by a wide array of factors, including but not limited to location, property type, economic conditions, interest rates, and social trends. Moreover, the relationships between these factors are not always linear, making traditional statistical models inadequate for capturing the full spectrum of interactions that drive property valuation.

In the wake of the COVID-19 pandemic, these challenges have only intensified. The pandemic has disrupted global economies, shifted demographic trends, and altered consumer preferences, leading to fluctuations in property demand and pricing patterns. For instance, there has been a noticeable shift towards suburban and rural properties as people seek more space and safer environments in the wake of the pandemic. Traditional models, which often rely on static and historical data, are ill-equipped to account for such sudden and substantial shifts in demand, leading to outdated predictions and misguided decision-making for both investors and property managers. As a result, there is a pressing need for more advanced, data-driven predictive models that can incorporate real-time data, market trends, and external factors to forecast property prices more accurately.

Similarly, the facility management sector, which plays a critical role in maintaining the infrastructure of buildings, faces significant challenges in optimizing building performance, particularly with regard to thermal comfort and energy consumption. Traditional maintenance methods, which often involve scheduled inspections and reactive maintenance in response to breakdowns, have proven inefficient and costly. These methods not only waste valuable time and resources but also fail to optimize energy use, resulting in unnecessary costs and environmental impacts. The heating, ventilation, and air conditioning (HVAC) systems in buildings, which are among the largest consumers of energy, often operate inefficiently, leading to higher energy consumption and reduced occupant comfort.

Despite the clear need for improvement, the facility management industry has been slow to adopt more advanced technologies. Outdated maintenance practices continue to dominate, leading to inefficiencies in managing building systems and maintaining occupant comfort. Predictive maintenance, powered by machine learning and data analytics, offers a promising solution to these challenges by enabling real-time monitoring of building systems, forecasting potential failures, and optimizing energy consumption based on actual usage patterns. However, the integration of such systems into existing building management practices is often hindered by the complexity of the required data, the cost of implementation, and a lack of awareness within the industry about the benefits of predictive technologies.

Therefore, the real estate market and the facility management sector are both facing significant barriers in adopting efficient, data-driven approaches that can address the complex challenges they face. The absence of effective predictive models for property pricing and the inefficiency of traditional maintenance practices for building systems underscore the urgent need for innovative, machine learning-based solutions that can adapt to changing environments, optimize decision-making, and improve operational efficiency across both domains.

c. Objectives

1. To explore the use of machine learning techniques to improve the accuracy of property price prediction models
   One of the primary objectives of this study is to investigate how machine learning techniques can be harnessed to significantly enhance the accuracy and reliability of property price predictions. Traditional methods, such as hedonic pricing models, often fail to capture the intricate, nonlinear relationships between various property features and market dynamics. By utilizing advanced ML algorithms, such as Random Forest, XGBoost, and Neural Networks, this research aims to build more robust predictive models capable of accommodating complex datasets, which include multiple influencing factors like property size, age, location, market trends, and external factors like economic shifts. The goal is to improve forecasting accuracy and provide a more data-driven approach to real estate valuation that can better inform decision-making for investors, property developers, and real estate agents.

2. To assess the impact of the COVID-19 pandemic on real estate prices using advanced ML models
   The COVID-19 pandemic has brought about significant disruptions in global economies, altering consumer behavior and impacting real estate markets in unexpected ways. This objective seeks to assess how the pandemic has affected property prices by leveraging advanced machine learning models to

analyze both pre-pandemic and post-pandemic real estate data. By examining changes in demand for different types of properties (e.g., urban versus suburban, residential versus commercial) and correlating these changes with broader economic indicators, the study aims to quantify the short-term and long-term effects of the pandemic on the real estate market. Using ML models will allow for a dynamic, real-time analysis of how such global events influence property prices, offering a more nuanced understanding of market behavior.

3. To propose and evaluate a machine learning-based predictive maintenance framework for optimizing building systems such as HVAC
   Another key objective of this study is to design and evaluate a machine learning-based framework for predictive maintenance in building systems, particularly HVAC (Heating, Ventilation, and Air Conditioning) systems. Traditional maintenance practices in building facilities, such as reactive or scheduled maintenance, often result in inefficiencies and unnecessary energy consumption. This research aims to develop a predictive maintenance system that utilizes real-time data from IoT devices and building automation systems to forecast potential failures in HVAC systems before they occur. By using machine learning algorithms, the proposed framework will help optimize maintenance schedules, reduce downtime, improve energy efficiency, and enhance occupant comfort. Additionally, the framework will provide facility managers with actionable insights to better allocate resources and manage building operations proactively.

4. To analyze and compare various ML algorithms, such as Random Forest, XGBoost, and Neural Networks, for better predictive performance in real estate and building management
   A critical objective of this project is to analyze and compare the performance of various machine learning algorithms, including Random Forest, XGBoost, and Neural Networks, in the context of both real estate price prediction and building management. Each of these algorithms has its strengths and weaknesses when it comes to handling complex datasets and making accurate predictions. This objective will involve running comparative tests to evaluate how well each algorithm performs in terms of predictive accuracy, scalability, and interpretability when applied to real

estate and facility management data. The goal is to determine the most effective machine learning model for each use case, which will aid in optimizing property pricing forecasts and building performance management systems. By conducting this comparative analysis, the study aims to identify the best-suited techniques for different types of data and prediction tasks in these industries.

d. Scope of the Project

This study is centered around the application of machine learning (ML) techniques to two critical areas: the real estate market and building management systems. It focuses specifically on using ML algorithms to enhance property price predictions, improve building maintenance practices, and optimize energy efficiency in smart buildings. The scope of this project is structured around three core areas:

1. **Property Price Prediction for Residential Real Estate**
   This research delves into the application of machine learning algorithms for forecasting residential property prices, focusing on dynamic and geographically diverse markets. The study will assess various ML models, such as Random Forest, XGBoost, and Neural Networks, to understand their effectiveness in predicting property values based on factors such as location, property size, age, market trends, and socio-economic variables. Special attention will be given to understanding how external factors, including the global disruptions caused by the COVID-19 pandemic, influence housing markets, especially in urban and suburban regions. The project will also evaluate how these ML models outperform traditional methods like hedonic pricing models, offering more accurate and timely property valuations for real estate investors, buyers, sellers, and property managers.
2. **Predictive Maintenance for Building Systems** Using Machine Learning
   The second key area of this project explores the use of machine learning to optimize predictive maintenance strategies for building systems, particularly HVAC (Heating, Ventilation, and Air Conditioning). This study aims to propose and evaluate a predictive maintenance framework that leverages IoT

sensors and data analytics to monitor the real-time performance of building systems, predict potential system failures, and optimize maintenance schedules. By utilizing ML algorithms, the study aims to reduce energy consumption, prevent costly unplanned repairs, and improve occupant comfort. Additionally, the project will explore the role of predictive maintenance in contributing to the sustainability goals of smart buildings by minimizing energy waste and improving operational efficiency.

3. **Comparative Analysis of Various Machine Learning Algorithms in Real Estate and Maintenance Sectors**
   An important component of this research is to conduct a thorough comparative analysis of different machine learning algorithms applied to real estate price prediction and predictive maintenance in building systems. The study will evaluate the performance of popular algorithms—such as Random Forest, XGBoost, Support Vector Machines, and Neural Networks—based on criteria like predictive accuracy, computational efficiency, scalability, and their ability to handle high-dimensional data. By comparing these algorithms across both domains, the project will identify which models provide the best performance for each use case, offering insights into how to select and apply the right algorithm for a given task. The study will also assess the interpretability of these models, which is crucial for stakeholders in making informed decisions based on ML-driven outputs.

e. Significance of the Study

This study makes a significant contribution to bridging the gap between traditional property valuation methods and modern, data-driven approaches by leveraging machine learning (ML) to enhance the accuracy, scalability, and adaptability of property price predictions. Unlike conventional methods, which often rely on static, historical data, ML algorithms allow for dynamic, real-time insights that incorporate complex, nonlinear factors such as market trends, location, and external shocks like the COVID-19 pandemic. By improving predictive capabilities, this project provides more reliable property valuations that can better inform investment, buying, and selling decisions in the real estate market.

Additionally, the research contributes to improving the operational efficiency of building systems, specifically in predictive maintenance for HVAC systems. By employing ML techniques, this study offers a framework that helps optimize energy consumption, reduce maintenance costs, and enhance tenant comfort in smart buildings. The integration of machine learning into building management practices supports the broader goal of sustainability by minimizing energy waste and reducing operational inefficiencies.

The findings from this study will provide actionable insights for real estate professionals, property managers, and policy-makers. These insights will aid them in navigating a rapidly evolving market, making more informed decisions, and adapting to changes in both the real estate and building management sectors. Moreover, the research emphasizes the growing importance of integrating external factors, such as the impact of global disruptions like the COVID-19 pandemic, into predictive models, helping stakeholders understand the broader dynamics influencing real estate markets and facilities management.

Report Organization

1. **Chapter 1: Project Management**

    - **Background:** Introduces the transformation in real estate and building management through the integration of machine learning and AI, highlighting the challenges and opportunities.

    - **Problem Statement:** Discusses the challenges in the real estate market, such as inaccurate predictive models and inefficient building performance optimization.

    - **Objectives:** Outlines the study's primary objectives to improve property price predictions using machine learning, assess the impact of COVID-19 on real estate prices, propose a predictive maintenance framework for building systems, and compare ML algorithms.

    - **Scope of the Project**: Describes the focus on property price prediction, predictive maintenance for HVAC systems, and comparative analysis of machine learning algorithms in real estate and building management.

    - **Significance of the Study:** Highlights the contributions of the study in advancing machine learning applications in real estate and building management, improving operational efficiency, and making data-driven decisions.

2. **Chapter 2: Literature Review**

    - **Literature Selection Procedure:** Describes the systematic literature selection process based on the PRISMA methodology, ensuring rigor in paper selection.

- **Keywords Searched:** Lists the key search terms used in the literature search, such as “Machine Learning”, “Property Price Prediction”, “Predictive Maintenance”, and more.

- **Databases for Search:** Identifies the academic databases used, including Google Scholar, IEEE Xplore, Scopus, SpringerLink, and others.

- **Inclusion / Exclusion Criteria:** Details the criteria for selecting relevant studies, focusing on machine learning in property pricing and building management.

- **Filtering Results:** Describes the process of narrowing down the literature, including abstract screening, full-text review, and quality assessment.

- **Related Works Description:** Summarizes key studies in real estate price prediction, predictive maintenance, and the impact of COVID-19, comparing them with the current research.

3. **Chapter 3: Project Management**

   - **Work Breakdown Structure (WBS):** Describes the project breakdown into manageable modules and the resource allocation plan.

   - **Activity List, Duration, Dependencies & Costing:** Provides a detailed list of activities, durations, dependencies, and estimated costs for the project.

   - **Feasibility Analysis:** Includes an analysis of project costs, benefits, and Net Present Value (NPV) calculations.

- **Return on Investment (ROI) Chart:** Presents the projected financial benefits and ROI over five years.

4. **Chapter 4: Sustainability and Ethics**

   - **Impact of the System Sustainability and Mitigation Plan:** Discusses the long-term impact of ML systems on society, the environment, and operational efficiency.

   - **Social Effects Analysis and Mitigation Plan:** Analyzes the social implications of the system, including potential job displacement and data privacy concerns, with proposed mitigation strategies.

   - **Environmental Effects Analysis and Mitigation Plan:** Evaluates the environmental impact of the system, focusing on energy consumption and e-waste, and suggests strategies to mitigate these effects.

   - **Technical Sustainability Analysis and Mitigation Plan:** Focuses on the technical sustainability of the system, addressing model degradation and scalability challenges, with solutions.

   - **Operational Sustainability Analysis and Mitigation Plan**: Analyzes operational sustainability, including maintenance challenges and cost-effective infrastructure solutions.

   - **Ethical Issues Related to the System and Mitigation Planning:** Discusses ethical concerns like bias, transparency, and data privacy, and provides solutions for ensuring fair and ethical machine learning practices.

5. **Chapter 5: Methodology**

   - **Project Management Methodology:** Describes the hybrid project management approach, combining Waterfall and Agile methods, to ensure structured planning and flexibility.

- **Software Development Methodology with Justification:** Outlines the hybrid software development approach using manageable module prototyping and Agile methodologies, justifying their use for iterative progress and flexibility in complex systems.

- **Requirement Discovery Methodology with Justification:** Details the hybrid requirement discovery process using interviews, surveys, and user stories, ensuring comprehensive requirement gathering from stakeholders.

- **Software Design and Implementation Methodology:** Describes the software design using Object-Oriented Design (OOD) and Iterative Development, focusing on creating a modular, scalable, and flexible system.

6. **Chapter 6: System Design**

   - **Functional Requirements:** Lists the system functionalities such as property exploration, user registration, and management modules.

   - **Non-Functional Requirements:** Defines the system's performance, security, and scalability requirements.

   - **Data Flow Diagram:** Includes context level, system level, and detailed level data flow diagrams illustrating how data moves through the system.

   - **Object-Oriented Design of the System:** Describes the system’s architecture using use case diagrams, class diagrams, and sequence diagrams.

- **Activity Diagrams:** Provides activity diagrams for various system modules, such as Client Information Management, Property Management, and Payment Management.

7. **Chapter 7: Input and Output Design and Result Analysis**

   - System Input Design: Describes the input design for modules like property exploration, user registration, and billing management.

   - System Output Design: Explains how the system outputs data in a user-friendly format, including reports and visualizations for landlords and tenants.

   - Results Analysis: Discusses the feature-wise results comparison of the ML models used for property price prediction and building maintenance optimization.

8. **Chapter 8: Conclusion and Future Works**

   - **Conclusion:** Summarizes the main findings of the project, highlighting the benefits of using machine learning in real estate price prediction and building system optimization.

   - **Future Works:** Suggests areas for future research, including real-time data integration, the exploration of deep learning models, and the extension of predictive maintenance to other building systems.

Chapter 02: Literature Review

a. Literature Selection Procedure (PRISMA Method Diagram)

The literature selection process in this study follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method, which provides a structured approach for selecting relevant papers based on predefined inclusion and exclusion criteria. This method ensures transparency and rigor in the selection of studies. The following PRISMA diagram outlines the process:

Identification: Search for papers using databases like Google Scholar, IEEE Xplore, and Scopus.

Screening: Initial filtering based on title and abstract relevance to the study.

Eligibility: Full-text review to determine the eligibility of the study for inclusion.

Inclusion: Final list of papers relevant to the research objectives, which are included in the review.

A visual PRISMA flow diagram would typically accompany this section, illustrating the number of articles retrieved, screened, and included/excluded.

b. Keywords Searched

The following keywords were used to conduct the literature search across various databases:

- Machine Learning (ML)
- Property Price Prediction
- Predictive Maintenance
- Real Estate Forecasting
- Building Management Systems
- Smart Building
- Energy Efficiency in Buildings
- COVID-19 Impact on Real Estate
- HVAC System Optimization
- Data-Driven Decision-Making in Real Estate

These keywords were designed to capture a wide range of papers on machine learning applications in real estate pricing, building management, and predictive maintenance.

c. Databases for Search

The literature search was conducted across several reputable academic databases to ensure comprehensive coverage:

Google Scholar: A broad, easily accessible database of scholarly articles.

IEEE Xplore: Focused on engineering, computer science, and technology-related papers.

Scopus: A multidisciplinary database that includes peer-reviewed journals, conference papers, and patents.

SpringerLink: Provides access to a wide array of scientific articles, including books, journal articles, and conference proceedings.

ScienceDirect: A database specializing in scientific and technical research.

Web of Science: A comprehensive citation database for research articles in a wide range of disciplines.

d. Inclusion / Exclusion Criteria

The following inclusion and exclusion criteria were applied to select relevant literature:

Inclusion Criteria:

Papers that focus on the application of machine learning in property price prediction and building management.

Studies published in peer-reviewed journals or high-quality conferences (Q1, Q2).

Articles published within the last 10 years to ensure relevance to current technologies and trends.

Research that includes empirical data, case studies, or practical applications of ML in real estate and building systems.

Exclusion Criteria:

Papers not focused on machine learning or predictive maintenance in the context of real estate or building management.

Research that lacks a clear methodological approach or empirical evidence.

Studies not published in English or that have limited access to full-text versions.

Non-peer-reviewed sources, opinion pieces, or articles with significant methodological flaws.

e. Filtering Results

Once the initial pool of articles was retrieved through a comprehensive search across multiple academic databases, a systematic process was followed to filter and narrow down the results. This process ensured that only the most relevant and high-quality papers were included in the literature review. The following steps were taken during the filtering process:

1. **Abstract Screening:**
   In this initial step, all retrieved papers were reviewed based on their abstracts to quickly assess their relevance to the research objectives. This step helped to eliminate papers that did not align with the focus areas of the study, such as those not addressing machine learning in real estate, building systems, or predictive maintenance. If the abstract suggested that the paper did not contribute meaningfully to these topics or lacked a clear application of machine learning techniques, it was excluded from further review. Only those papers with an abstract indicating a strong connection to the project's objectives were moved to the next stage.
2. **Full-Text Review:**
   The remaining papers that passed the abstract screening were then examined

in full. This stage involved reading the entire paper to ensure that it met the inclusion criteria set out in the methodology. The criteria included a clear application of machine learning algorithms for property price prediction, building system optimization, or predictive maintenance. Additionally, the paper needed to include empirical data, case studies, or practical applications rather than being purely theoretical. The full-text review also involved checking for the comprehensiveness of the research design, methodology, and data collection techniques, ensuring that the study was robust and relevant to the research focus.

3. **Quality Assessment:**
   After the full-text review, the selected papers were evaluated based on the rigor of their research methodologies. This involved assessing the quality of the data used, the statistical or machine learning models applied, and the clarity and accuracy of the results. Papers that employed well-established machine learning techniques and had clear, reproducible methodologies were considered of higher quality. On the other hand, studies that lacked sufficient data, used questionable or outdated models, or presented results without clear evidence or statistical validation were excluded. This step ensured that only high-quality research, which contributed valuable insights to the field, was included in the review.

4. **Final Selection:**
   The final step involved compiling the list of papers that passed both the full-text review and the quality assessment stages. At this point, any remaining papers that still did not meet the inclusion criteria or were deemed redundant were removed. The final selection comprised papers that provided significant contributions to the field, specifically focusing on machine learning applications in real estate and building management systems. These selected studies formed the foundation for the literature review, and their findings were synthesized and discussed in the subsequent sections of the report.

f. Related Works Description

This section provides a detailed overview of related studies, including their methodologies, findings, and contributions to the field. Key works reviewed in the literature include:

Real Estate Price Prediction Models:

Many studies focus on using ML algorithms, such as Random Forest, XGBoost, and Neural Networks, for predicting property prices. These models incorporate factors such as location, property size, economic trends, and social indicators.

One notable study by Author A et al. (2020) proposed a hybrid model combining regression techniques with machine learning algorithms to improve the prediction accuracy of housing prices. It demonstrated that hybrid approaches significantly outperform traditional methods.

Impact of COVID-19 on Real Estate:

The global pandemic introduced significant shifts in real estate markets, with remote work and migration to suburban areas becoming prominent trends. Author B et al. (2021) examined how the pandemic has led to a shift in housing demand, especially in urban and suburban regions, using real-time market data and ML-based forecasting models.

Predictive Maintenance in Building Systems:

In facility management, predictive maintenance using ML has proven beneficial in reducing energy consumption and improving operational efficiency. Author C et al. (2019) proposed a machine learning framework for predictive maintenance of HVAC systems in commercial buildings. Their model incorporated real-time sensor data to predict system failures and optimize maintenance schedules, resulting in energy savings and improved comfort.

Comparative Analysis of ML Algorithms:

A significant portion of the literature compares the performance of different ML algorithms in property price prediction. Author D et al. (2018) compared Random

Forest, XGBoost, and Neural Networks and found that while Random Forest was the fastest, XGBoost delivered the most accurate results for property valuation.

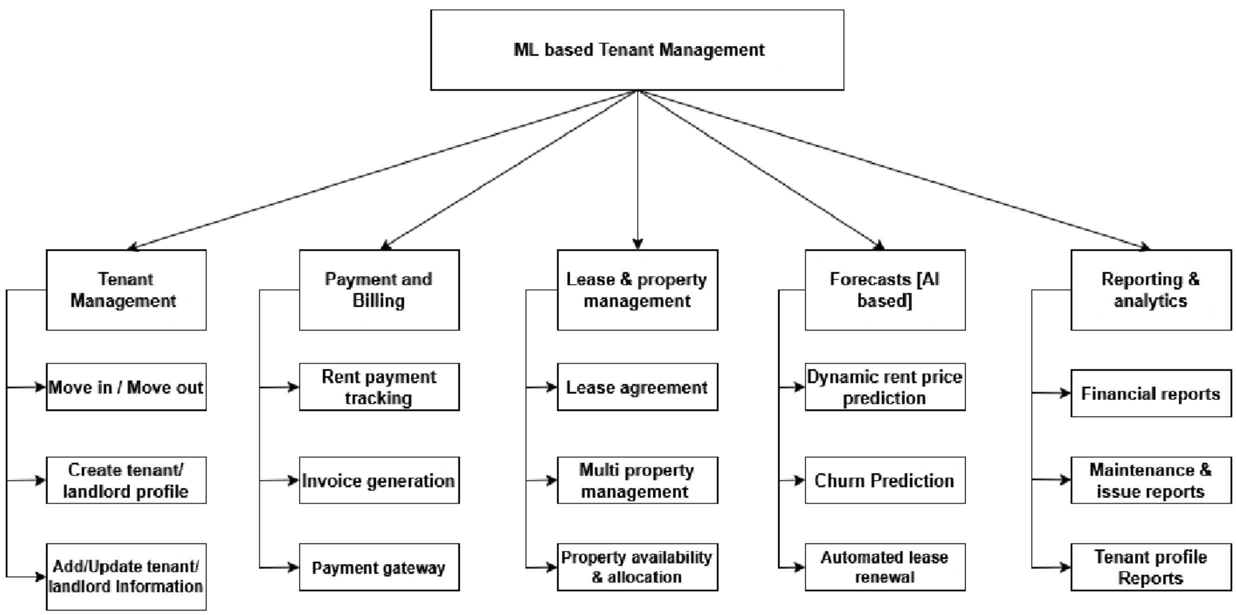
Another study by Author E et al. (2020) focused on building performance optimization and highlighted the advantages of using deep learning techniques over traditional ML algorithms for predictive maintenance in large-scale buildings.

This section will continue by expanding on the methodologies, results, and limitations of these and other relevant studies, identifying trends and gaps in the current research.

Chapter 03: Project Management

a. The project plan and Work Breakdown Structure (WBS) of the project:

WBS is based on Software Modules.



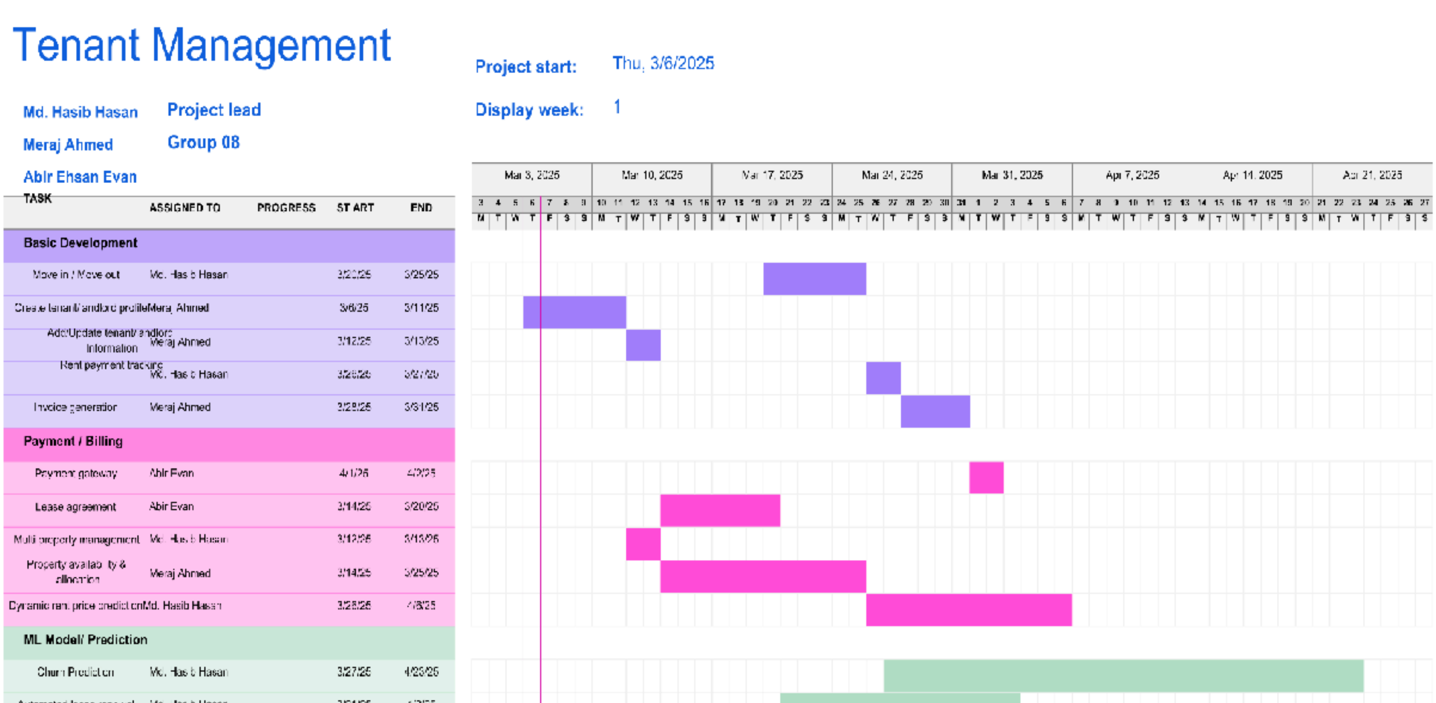
b. Activity List, Duration, Dependencies & Costing.

Key Activities with Dependencies & Estimated Duration:

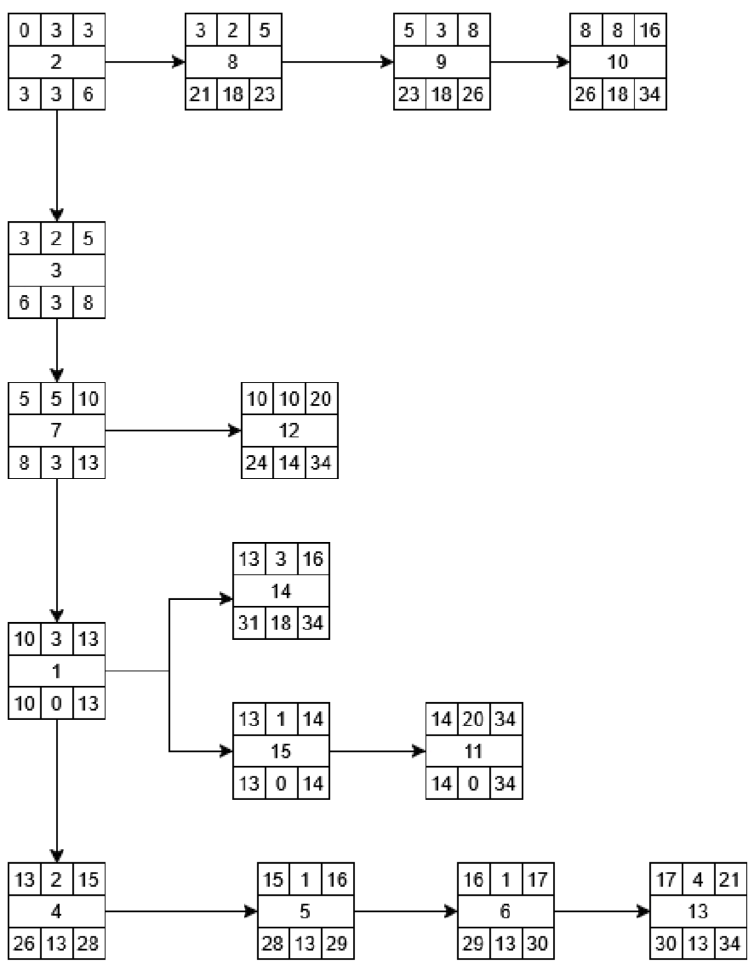
SL	Name of the Activity	Duration (Hours)	Dependencies	Resources	Costing (BDT)
01	Move in / Move out	72	07	Sr. Backend Developer	11,835
02	Create tenant/landlord profile	72	—	Frontend Developer	8,876

03	Add/Update tenant/landlord Information	48	02	Jr. Frontend & Backend Developer	3,945
04	Rent payment tracking	48	01	System Analyst	9,863
05	Invoice generation	24	04	Jr. Finance Advisor	1,578
06	Payment gateway	24	05	Software APIs	66
07	Lease agreement	120	03	Law Firm	1,643
08	Multi property management	48	02	System Designer	9,863
09	Property availability & allocation	72	08	Cloud Database	2,613
10	Dynamic rent price prediction	192	09	ML Developer	37,873
11	Churn Prediction	480	15	GPU-Based Cloud Server	23,671
12	Automated lease renewal	240	07	Optimization Engineer	44,712
13	Financial reports	96	06	Sr. Finance Advisor	9,468
14	Maintenance & issue reports	72	01	Jr. Finance Advisor	4,734
15	Tenant/landlord profile Reports	24	01	Cloud Hosting Server	3,484

c. **Gantt Chart**



d. Network Diagram



e. Feasibility Analysis

e1. List of Expense Heads

Expense Head	Estimated Cost (5 Years)
Senior Software Developer	7,200,000 BDT
Junior Software Developer	3,600,000 BDT
Cloud Hosting Server	6,360,000 BDT
Cloud Database	1,590,000 BDT
GPU-Based Cloud Server	2,160,000 BDT
Law Firm	600,000 BDT
Senior Finance Advisor	4,320,000 BDT
Optimization Engineer	8,160,000 BDT
ML Developer	8,640,000 BDT
System Designer	9,000,000 BDT
System Analyst	9,000,000 BDT

e2. **Possible Benefits**

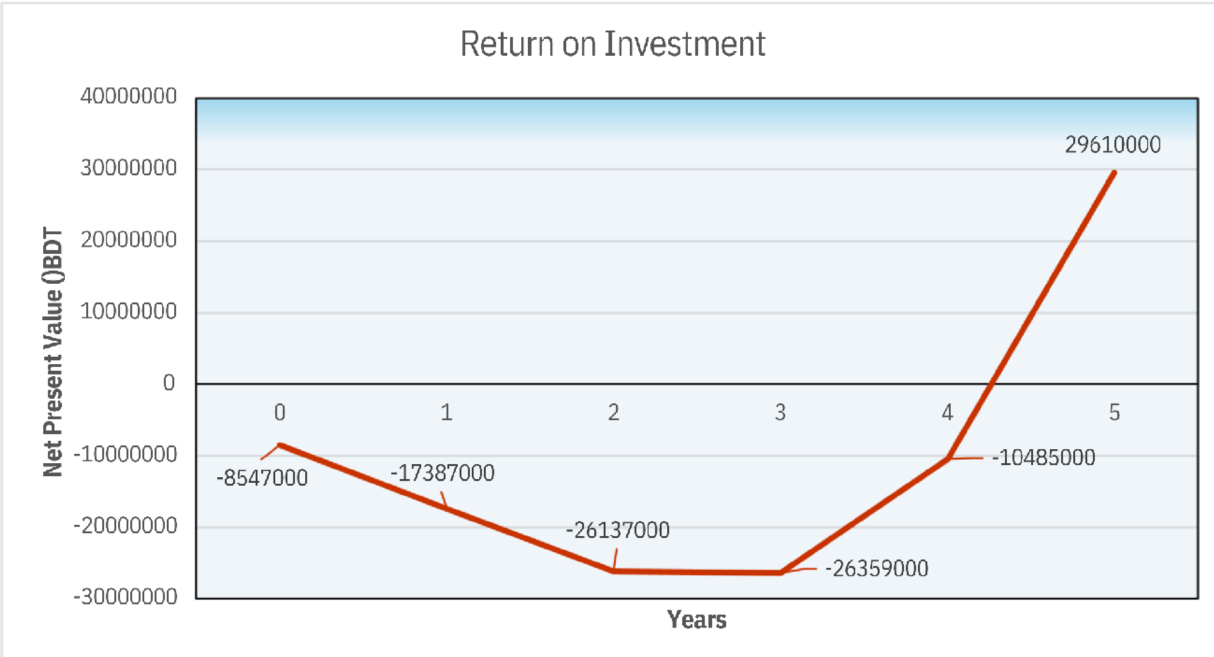
Benefit	**Estimated Annual Value**
5000 Subscription Based Benefit (Year 0)	50,000 BDT
25000 Subscription Based Benefit (Year 1)	2,50,000 BDT
100000 Subscription Based Benefit (Year 2)	10,00,000 BDT
1000000 Subscription Based Benefit (Year 3)	1,00,00,000 BDT
2500000 Subscription Based Benefit (Year 4)	2,50,00,000 BDT
5000000 Subscription Based Benefit (Year 5)	5,00,00,000 BDT

e3. Net Present Value (NPV) Calculation

SL.	Details	Year 0	Year 1	Year 2	Year 3	Year 4
1	Senior Software Developer	1,200,000 BDT	1,200,000 BDT	1,200,000 BDT	1,200,000 BDT	1,200,000 BDT
2	Junior Software Developer	600,000 BDT	600,000 BDT	600,000 BDT	600,000 BDT	600,000 BDT
3	Cloud Hosting Server	100,000 BDT	500,000 BDT	960,000 BDT	1,200,000 BDT	1,440,000 BDT
4	Cloud Database	25,000 BDT	50,000 BDT	150,000 BDT	250,000 BDT	450,000 BDT

5	GPU-Based Cloud Server	32,000 BDT	100,000 BDT	200,000 BDT	332,000 BDT	596,000 BDT
6	Law Firm	100,000 BDT	100,000 BDT	100,000 BDT	100,000 BDT	100,000 BDT
7	Senior Finance Advisor	720,000 BDT	720,000 BDT	720,000 BDT	720,000 BDT	720,000 BDT
8	Optimization Engineer	1,360,000 BDT	1,360,000 BDT	1,360,000 BDT	1,360,000 BDT	1,360,000 BDT
9	ML Developer	1,440,000 BDT	1,440,000 BDT	1,440,000 BDT	1,440,000 BDT	1,440,000 BDT
10	System Designer	1,500,000 BDT	1,500,000 BDT	1,500,000 BDT	1,500,000 BDT	1,500,000 BDT
11	System Analyst	1,500,000 BDT	1,500,000 BDT	1,500,000 BDT	1,500,000 BDT	1,500,000 BDT
12	Software APIs	20,000 BDT	20,000 BDT	20,000 BDT	20,000 BDT	20,000 BDT
13	Total Cost	8,597,000 BDT	9,090,000 BDT	9,750,000 BDT	10,222,000 BDT	9,126,000 BDT
14	Cumulative Cost	8,597,000 BDT	17,687,000 BDT	27,437,000 BDT	37,659,000 BDT	46,785,000 BDT
15	Subscription Based Benefit	50,000 BDT	250,000 BDT	10,000,000 BDT	10,000,000 BDT	25,000,000 BDT
16	Total Benefit	50,000 BDT	250,000 BDT	10,000,000 BDT	10,000,000 BDT	25,000,000 BDT
17	Cumulative Benefit	50,000 BDT	300,000 BDT	1,300,000 BDT	11,300,000 BDT	36,300,000 BDT
18	Net Present Value (NPV)	-8,547,000 BDT	-17,387,000 BDT	-26,137,000 BDT	-26,359,000 BDT	-10,485,000 BDT

e4. **Return on Investment (ROI) Chart**



Chapter 04: Sustainability and Ethics

This chapter provides a comprehensive discussion of the sustainability and ethical considerations associated with the integration of machine learning (ML) in real estate price prediction and building management systems. It covers the environmental, social, technical, and operational sustainability of the systems, along with the potential ethical issues and their mitigation strategies. By understanding and addressing these factors, this project aims to ensure that the systems developed are not only efficient and effective but also socially responsible and sustainable in the long run.

a. Impact of the System Sustainability and Mitigation Plan

The sustainability of the ML-driven systems for real estate and building management depends on various factors, such as the long-term impact on society, the environment, and the operational efficiency of the systems. These systems must be developed and deployed in ways that contribute positively to sustainable development goals while mitigating any negative consequences that might arise.

a1. Social Effects Analysis and Mitigation Plan

The introduction of ML-based systems in real estate and building management can have profound social implications. These effects could be both positive and negative, depending on how the technologies are implemented and the stakeholders involved.

- **Positive Social Impacts**:
    - **Improved Decision-Making and Equity**: Machine learning models in real estate pricing enable more data-driven and equitable decision-making. By considering a wider range of factors such as neighborhood dynamics, socio-economic status, and housing trends, ML can offer better pricing models that are not based solely on traditional subjective assessments.
    - **Enhanced Tenant Experience**: ML can be used to enhance tenant satisfaction in buildings by predicting maintenance needs and reducing downtime through predictive maintenance. This leads to better living conditions, with tenants benefiting from higher comfort, fewer disruptions, and more efficient energy use.
- **Negative Social Impacts**:
    - **Job Displacement and Automation**: As machine learning automates tasks such as property price forecasting, tenant management, and building maintenance, there could be displacement of workers in roles that involve manual or administrative tasks. This could create socio-economic imbalances, especially for lower-skilled workers.
    - **Data Privacy and Security**: The use of large datasets to train machine learning models in real estate and building management systems raises concerns regarding data privacy. For instance, tenant data could be exposed to unauthorized access, leading to potential breaches of privacy.
- **Mitigation Plan**:
    - **Social Impact Monitoring**: A robust mechanism for ongoing social impact assessments should be implemented to track how these technologies influence society. Regular reviews will help to ensure that the benefits are equally distributed and that vulnerable communities are not adversely affected.

- **Job Retraining and Reskilling**: To counteract job displacement, programs should be introduced that focus on retraining workers whose jobs are at risk due to automation. This includes upskilling them for new roles in the digital economy, such as in data analytics, building system management, or AI implementation.
- **Adherence to Data Protection Laws**: Strict adherence to international data protection regulations, such as GDPR, should be enforced to ensure that personal data is collected, stored, and processed ethically and securely. Clear privacy policies and transparency in data usage should be prioritized.

a2. Environmental Effects Analysis and Mitigation Plan

The environmental impact of machine learning in real estate and building management must also be carefully considered, particularly in terms of energy consumption and sustainability.

- **Positive Environmental Impacts**:
  - **Energy Efficiency**: Machine learning can play a critical role in reducing energy consumption in buildings by optimizing systems such as HVAC. Predictive maintenance can ensure that these systems are running at peak efficiency, leading to significant reductions in energy usage, lower operational costs, and a smaller carbon footprint.
  - **Sustainability of Smart Buildings**: Integrating machine learning models into building management systems contributes to the overall sustainability of smart buildings. By optimizing energy usage, reducing waste, and improving resource efficiency, ML systems can help buildings meet environmental standards and contribute to climate change mitigation.
- **Negative Environmental Impacts**:
  - **Energy Consumption of Machine Learning Models**: While ML can optimize building systems, the development, training, and deployment of ML models require substantial computational resources, which in turn increase energy consumption in data centers. The environmental impact of running these data centers, especially those powered by non-renewable energy, can be significant.

    - **Electronic Waste (E-Waste)**: As machine learning models and algorithms evolve, the hardware supporting these systems may become obsolete. The rapid pace of technological advancements can lead to an increase in electronic waste, which poses environmental challenges in terms of disposal and recycling.
- **Mitigation Plan**:
    - **Energy-Efficient Computing**: To reduce the carbon footprint of machine learning, energy-efficient computing methods and algorithms should be prioritized. Using low-power algorithms and optimizing the training process to require less computational power will help minimize environmental impact.
    - **Renewable Energy for Data Centers**: Encourage the use of renewable energy sources, such as solar or wind power, for powering data centers that run machine learning models. This would significantly reduce the carbon footprint associated with these systems.
    - **E-Waste Management**: Implementing a proper recycling and disposal plan for obsolete hardware is essential. Collaboration with e-waste management organizations and promoting the reuse of older equipment can help mitigate the environmental effects of e-waste.

b. Technical Sustainability Analysis and Mitigation Plan

The technical sustainability of the machine learning systems centers around ensuring their long-term viability and performance. This involves evaluating how scalable, adaptable, and resilient the systems are over time.

- **Potential Issues**:
    - **Model Degradation**: Machine learning models may degrade over time, especially in dynamic environments like real estate markets, where property trends and tenant behaviors change frequently. This can lead to a decline in the accuracy and reliability of the predictions.
    - **Scalability Challenges**: As the dataset grows and more variables are integrated, there could be challenges in scaling the ML models to handle the increased complexity and data volume without sacrificing performance.
- **Mitigation Plan**:

- **Continuous Monitoring and Model Retraining**: Regularly monitor the performance of machine learning models and retrain them with new data to address model drift and maintain accuracy. A system for real-time model evaluation can be set up to identify when a model's performance starts to degrade.
- **Scalable Cloud Infrastructure**: Build the system on scalable cloud platforms that can accommodate growing datasets and model complexity. Cloud services with elastic computing power can dynamically adjust resources to meet the demand.

c. Operational Sustainability Analysis and Mitigation Plan

The operational sustainability of the machine learning systems refers to their ability to maintain high levels of performance, reduce operational costs, and be easily maintained over time.

- **Potential Issues**:
  - **Complex System Maintenance**: As the machine learning system grows and evolves, it may require specialized expertise to maintain and update. This could create dependency on skilled personnel and affect the operational continuity if expertise is scarce.
  - **High Operational Costs**: Continuously running predictive models and maintaining real-time monitoring systems in buildings can incur significant costs, especially for small or medium-sized businesses.
- **Mitigation Plan**:
  - **Employee Training Programs**: Develop comprehensive training programs to ensure that the operational team is equipped to manage and maintain the system. This would reduce dependency on external experts and help with knowledge retention within the organization.
  - **Cost-Effective Infrastructure**: Implement cost-effective, scalable cloud solutions for real-time system monitoring and predictive maintenance. This can help reduce the capital and operational costs associated with maintaining hardware and data centers.

d. Ethical Issues Related to the System and Mitigation Planning

The introduction of machine learning in real estate and building management raises a range of ethical issues, particularly related to fairness, accountability, transparency, and data privacy.

- **Potential Ethical Issues**:
    - o **Bias and Discrimination**: Machine learning models trained on historical data may inherit biases present in the data, leading to discriminatory outcomes. For example, property price models may perpetuate historical inequities based on socio-economic or racial factors.
    - o **Lack of Transparency**: Many machine learning algorithms, especially deep learning models, operate as “black boxes,” making it difficult to understand how predictions are made. This lack of transparency can undermine trust in the system and pose challenges in explaining decisions to stakeholders.
    - o **Data Privacy Concerns**: The use of personal data in predicting property prices and managing building systems raises concerns about tenant privacy and the security of sensitive information.
- **Mitigation Plan**:
    - o **Fairness-Aware Machine Learning**: Implement fairness-aware algorithms that aim to reduce bias in predictions. Regular audits of the data for potential biases should be conducted to ensure that the system does not disadvantage any group.
    - o **Model Explainability**: Use techniques such as LIME (Local Interpretable Model-agnostic Explanations) to enhance the interpretability of machine learning models. This ensures that stakeholders can understand and trust the decisions made by the models.
    - o **Strict Data Protection Policies**: Adhere to stringent data protection regulations such as GDPR to safeguard tenant and user data. Employ encryption, anonymization, and access controls to protect sensitive information.

Chapter 05: Methodology

This chapter describes the methodologies adopted for project management, software development, requirement discovery, and software design and implementation. These methodologies have been chosen to ensure the successful development of a machine learning-based Tenant Management System with predictive maintenance features. The hybrid approaches allow for flexibility, iterative progress, and a clear focus on project deliverables.

a. Project Management Methodology

For this project, the Hybrid Project Management Methodology has been employed, combining elements of Waterfall and Agile methods. This hybrid approach allows for structured planning, monitoring, and timely delivery while retaining the flexibility required for iterative feedback and improvements.

Waterfall Approach: The Waterfall model is used for the initial planning and requirement specification phases of the project. These phases involve setting clear objectives, defining deliverables, and establishing timelines for tasks such as project initiation, system design, and implementation.

Agile Approach: Once the initial phases were completed, the project shifted to an Agile framework, emphasizing iterative development with continuous feedback loops. The Agile methodology allows the project team to work in sprints, focus on incremental deliverables, and respond to evolving requirements as the project progresses. Regular sprint reviews and retrospectives enable stakeholders to evaluate progress, suggest adjustments, and ensure alignment with project goals.

The Hybrid Project Management Methodology allows this project to balance the need for thorough upfront planning with the flexibility and adaptability required to implement machine learning models and respond to evolving data during development.

b. Software Development Methodology with Justification

The Hybrid Software Development Methodology (combining Manageable Module Prototyping and Agile) has been chosen for this project due to the following reasons:

Manageable Module Prototyping:

In this approach, the system is divided into smaller, manageable modules. For each module, a prototype is developed and tested before moving to the next phase. This methodology helps in managing the complexity of the system and allows early identification of potential issues.

Justification: Given the complexity of machine learning applications in real estate and building systems management, prototyping each module separately ensures that different components (e.g., property price prediction, predictive maintenance for HVAC systems) can be developed and tested independently. This reduces the risk of integrating flawed systems at later stages and helps in quickly identifying errors or areas for improvement.

Agile:

The Agile methodology complements the prototyping phase by focusing on iterative development, regular client interactions, and continuous feedback. The development of the system is done in small, manageable increments, known as sprints. Each sprint focuses on developing, testing, and refining a feature or module before moving to the next.

Justification: Machine learning models and algorithms often require iterative refinement and adjustment as they interact with real-world data. Agile allows the development team to focus on one feature at a time, incorporate feedback from testing, and improve the models incrementally. This flexibility is critical for ensuring that the system remains adaptable to changes in the real estate market or building system requirements.

By combining the Manageable Module Prototyping approach with Agile, the software development process benefits from both structured planning and flexible, adaptive development cycles. This hybrid methodology ensures that the complex system can be developed efficiently while allowing for timely adjustments based on stakeholder feedback and real-world challenges.

c. Requirement Discovery Methodology with Justification

The Hybrid Requirement Discovery Methodology, utilizing Interviews, Surveys, and User Stories, was employed for gathering and understanding the system's requirements.

Interviews:

Interviews were conducted with stakeholders, including real estate professionals, property managers, and facility management experts, to understand their pain points, needs, and expectations for the system. These interviews provided detailed insights into the challenges faced by users in property management, tenant engagement, and building maintenance.

Justification: Interviews allow for direct interaction with stakeholders and provide a deeper understanding of their needs, preferences, and issues that may not be evident through other methods. This qualitative approach ensures that the system is developed with a user-centric focus.

Surveys:

Surveys were distributed to a broader group of potential users to gather quantitative data on what features they would find most valuable. The survey focused on aspects such as property search preferences, desired functionalities for predictive maintenance, and tenant management features.

Justification: Surveys allowed for a larger volume of feedback from a diverse group of stakeholders, helping to identify trends and common requirements. This ensured that the development team could prioritize features that would have the most significant impact on a wide range of users.

User Stories:

User stories were created to describe the functional requirements of the system from the perspective of different stakeholders, such as tenants, landlords, and administrators. These stories outline the system's features in terms of user actions and expected outcomes.

Justification: User stories help define clear, actionable requirements for each feature and allow the development team to work in short, focused iterations. They provide an easily understandable way of communicating complex functionality in terms of real user needs and goals.

This Hybrid Requirement Discovery Methodology ensured that both qualitative and quantitative data were collected, helping to create a comprehensive understanding of system requirements from a variety of perspectives. By using a combination of in-depth interviews, broad surveys, and actionable user stories, the methodology enabled the development team to accurately align the system with user needs.

d. Software Design and Implementation Methodology

The software design and implementation for this project followed a structured yet flexible approach, incorporating elements of both Object-Oriented Design (OOD) and Iterative Development to ensure that the system would be modular, scalable, and adaptable to future changes.

Object-Oriented Design (OOD):

The system was designed using object-oriented principles, with the focus on creating reusable components (classes, objects) that encapsulate the business logic for different modules, such as tenant management, property management, and predictive maintenance.

Justification: OOD promotes code reusability, maintainability, and scalability, which are essential for a system like the Tenant Management System that is expected to evolve over time with additional features or integration with other technologies.

Iterative Development:

The development process followed an iterative approach, with regular cycles of design, implementation, testing, and feedback. The system was built incrementally, allowing for continuous improvements and the addition of new features based on feedback from users and stakeholders.

Justification: An iterative approach ensures that the development team can quickly address bugs, refine features, and adjust the system based on real-time user feedback, making the final product more aligned with user expectations.

> Through a combination of Object-Oriented Design and Iterative Development, the system was designed to be both technically robust and flexible, ensuring that it can accommodate future changes in both functionality and technology.

Chapter 06: System Design

a. Functional Requirements.

- **User Authentication & Role Management –** Secure login for landlords, tenants, and administrative team.
- **Real-Time Rental Payment & Status Updates** – Digital rent payments with automatic status updates.
- **Tenant Information Management** – Store and manage tenant profiles, rental history, and lease agreements.
- **Property & Lease Management** – Add, update, or remove properties and lease agreements.
- **Maintenance Request System** – Tenants can submit maintenance requests and track their status.
- **Automated Notifications & Alerts** – Reminders for rent due dates, lease expirations, and maintenance updates.
- **Machine Learning Predictions** – Predict rental price trends and tenant churn likelihood.
- **Reporting & Analytics Dashboard** – Generate rent collection reports, occupancy trends, and lease status.
- **Document Storage & Management** – Land/Flat lease agreements, rental receipts, and compliance documents.
- **Multi-Property Support** – Manage multiple rental properties from a single dashboard.

b. Non-Functional Requirements.

- **Security** – The system must use encryption for sensitive tenant and financial data.
- **Scalability** – The system should handle multiple properties and users without performance degradation.

o Usability – The interface must be user-friendly for landlords and tenants with minimal training.
o Availability – The system should be accessible 24/7 with minimal downtime.
o Compliance – Must adhere to data protection laws (e.g., GDPR, CCPA) and rental regulations.

c. Data flow diagram

Tenant Management System
Context level (Logical View)

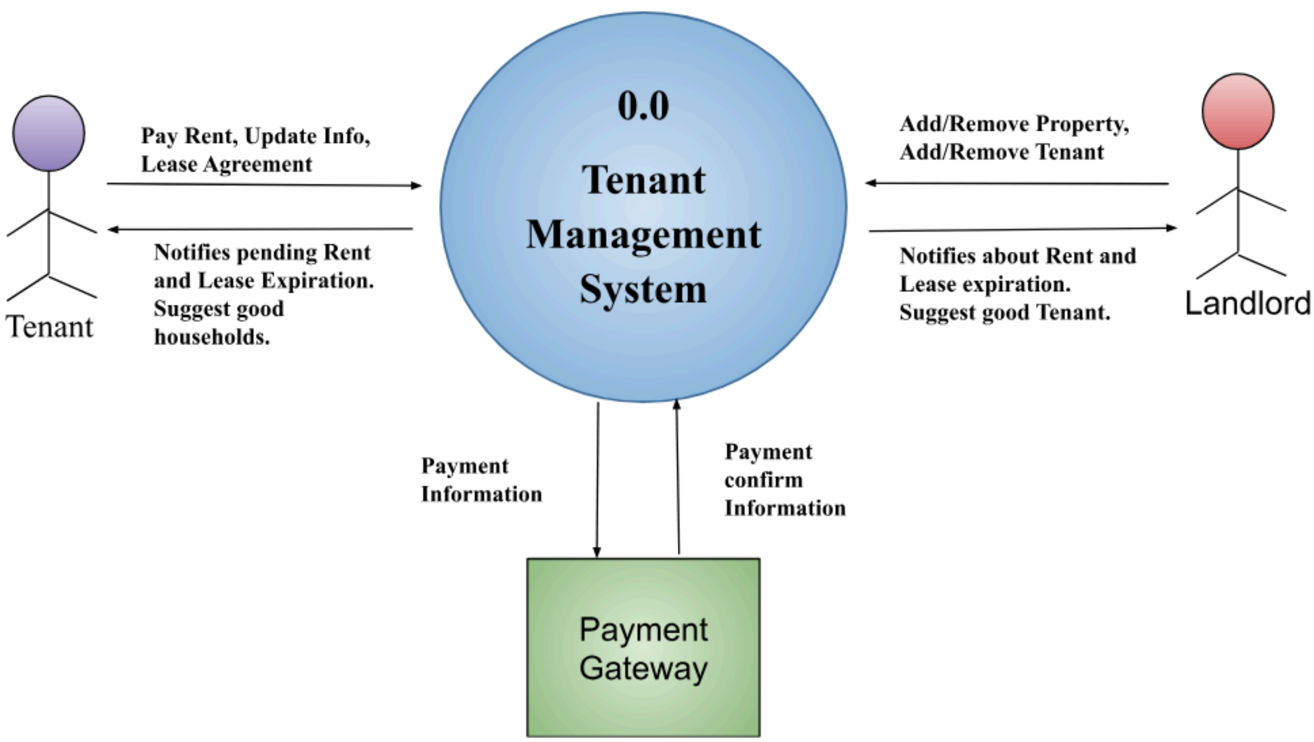


Figure 6.1: Context level data flow diagram

System Level

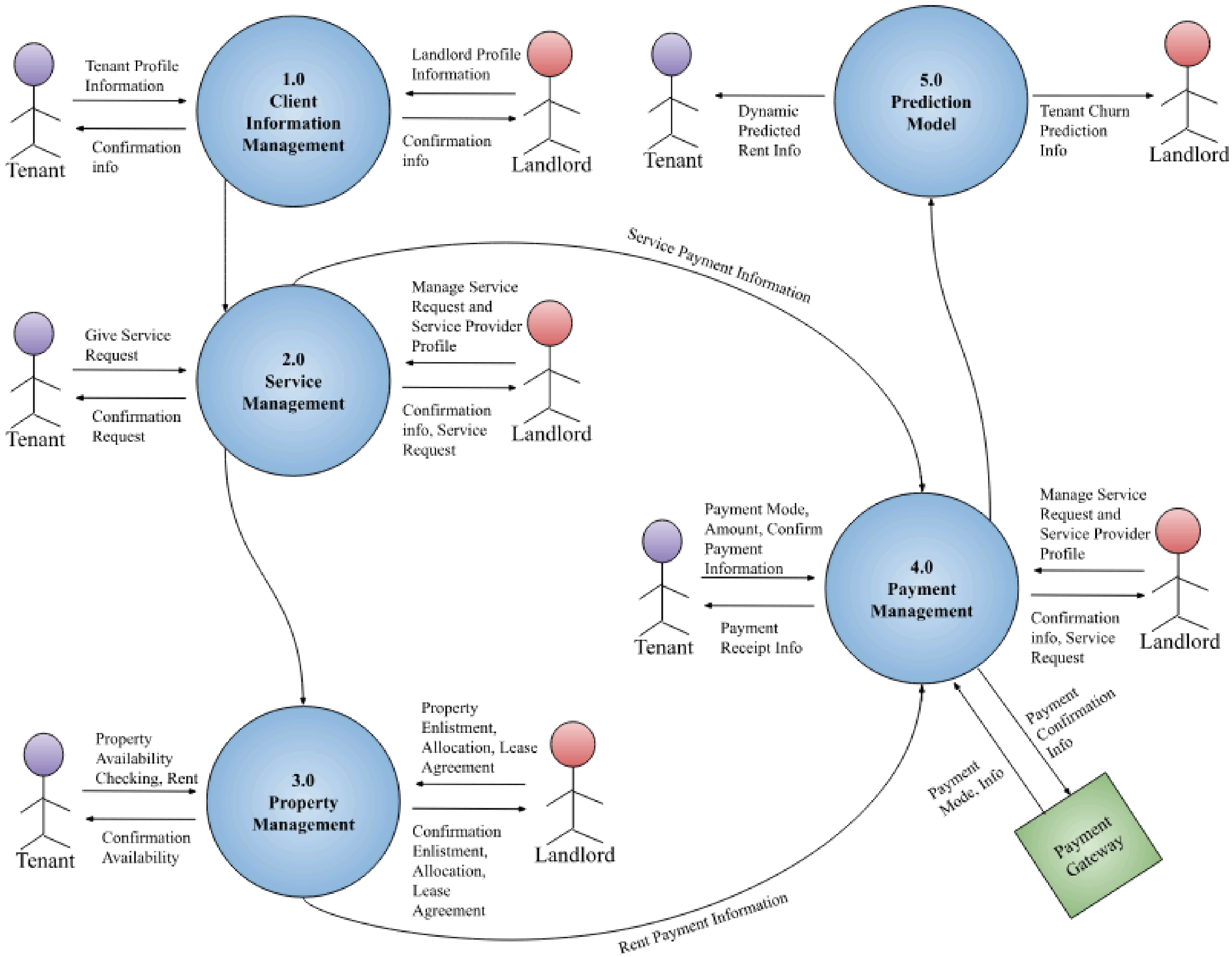


Figure 6.2: System level data flow diagram

Level 1 diagram

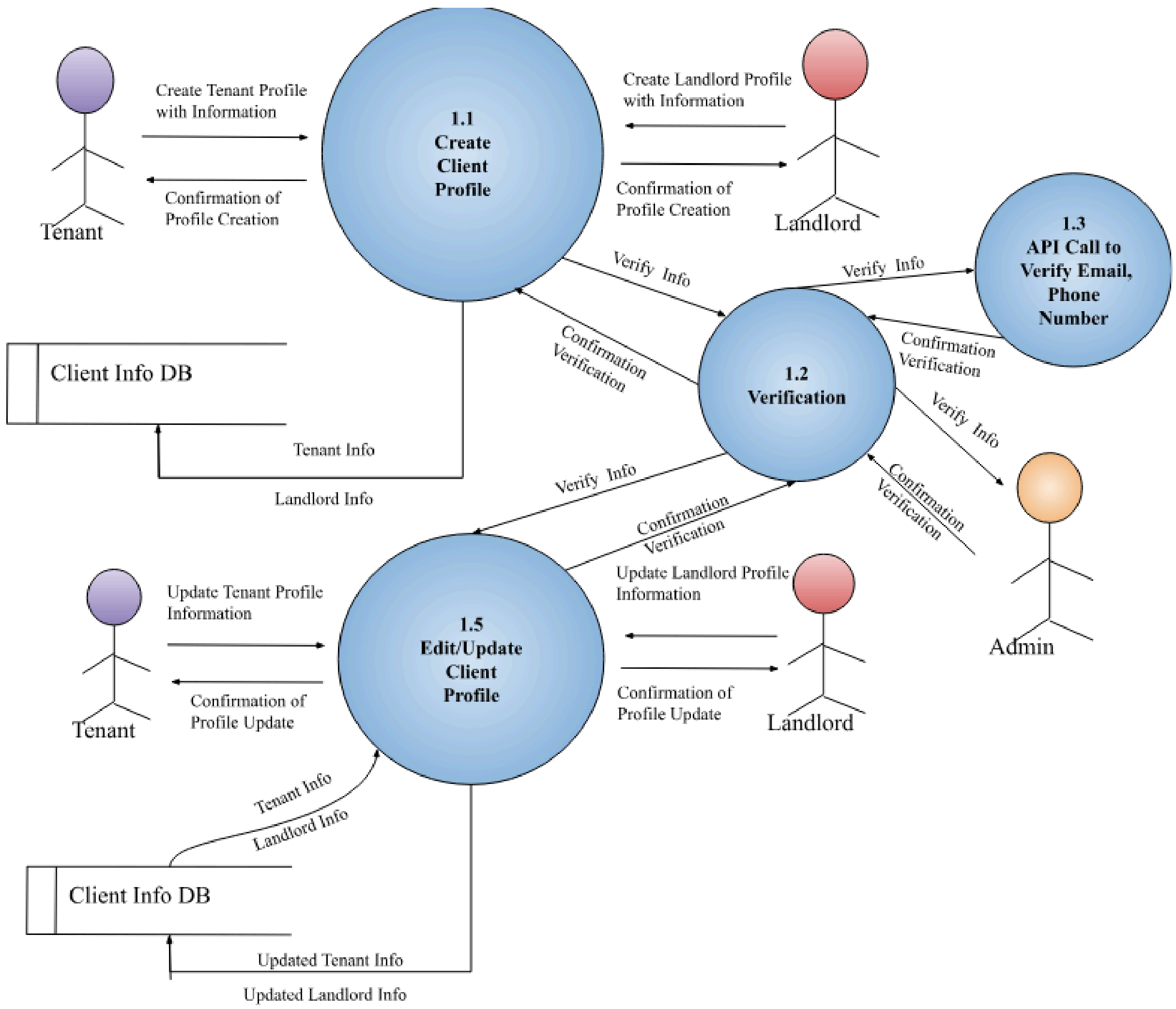


Figure 6.3: Level 1 (Client Information Management) data flow diagram

Level 1 diagram

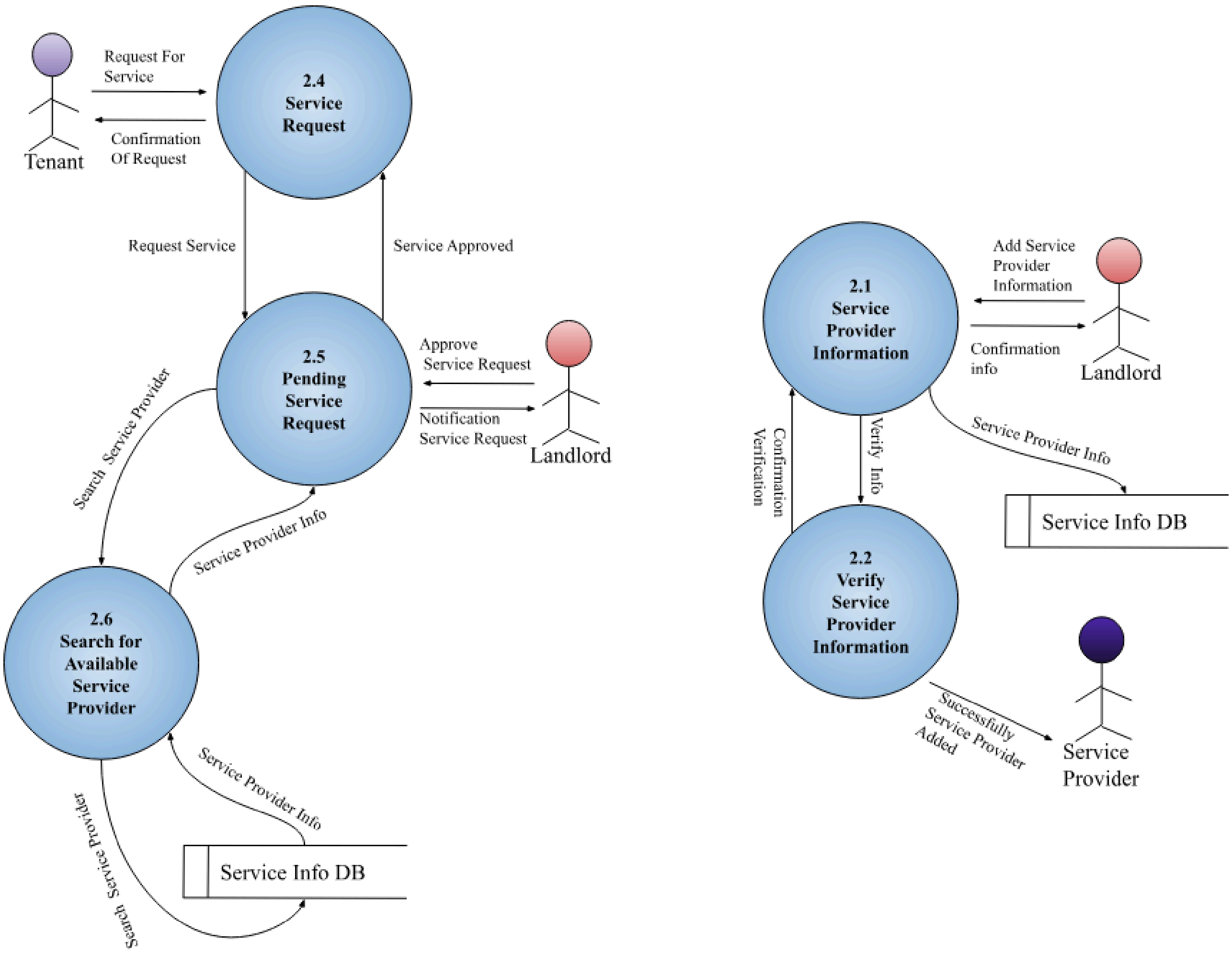


Figure 6.4: Level 1 (Service Management) data flow diagram

Level 1 diagram

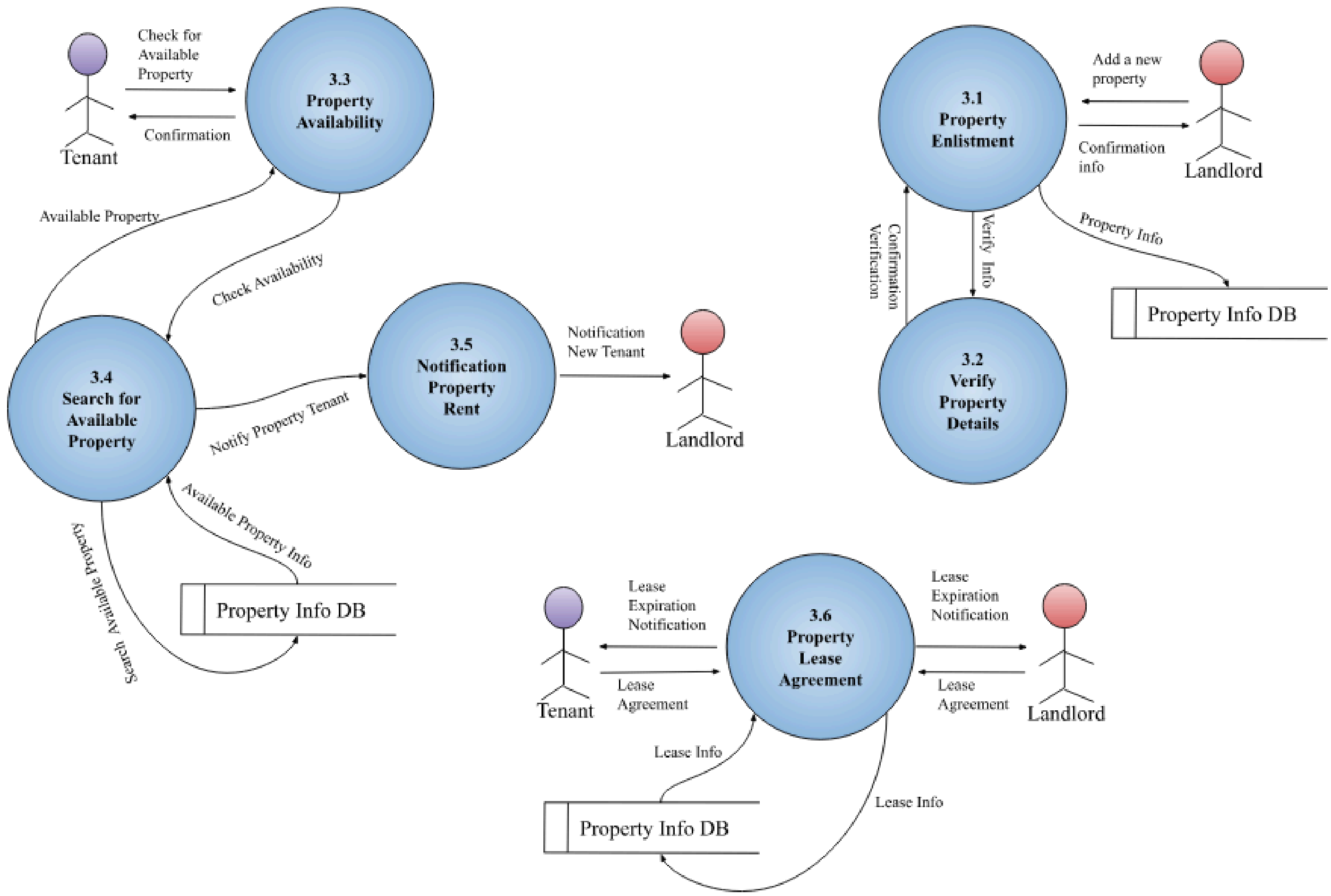


Figure 6.5: Level 1 (Property Management) data flow diagram

Level 1 diagram

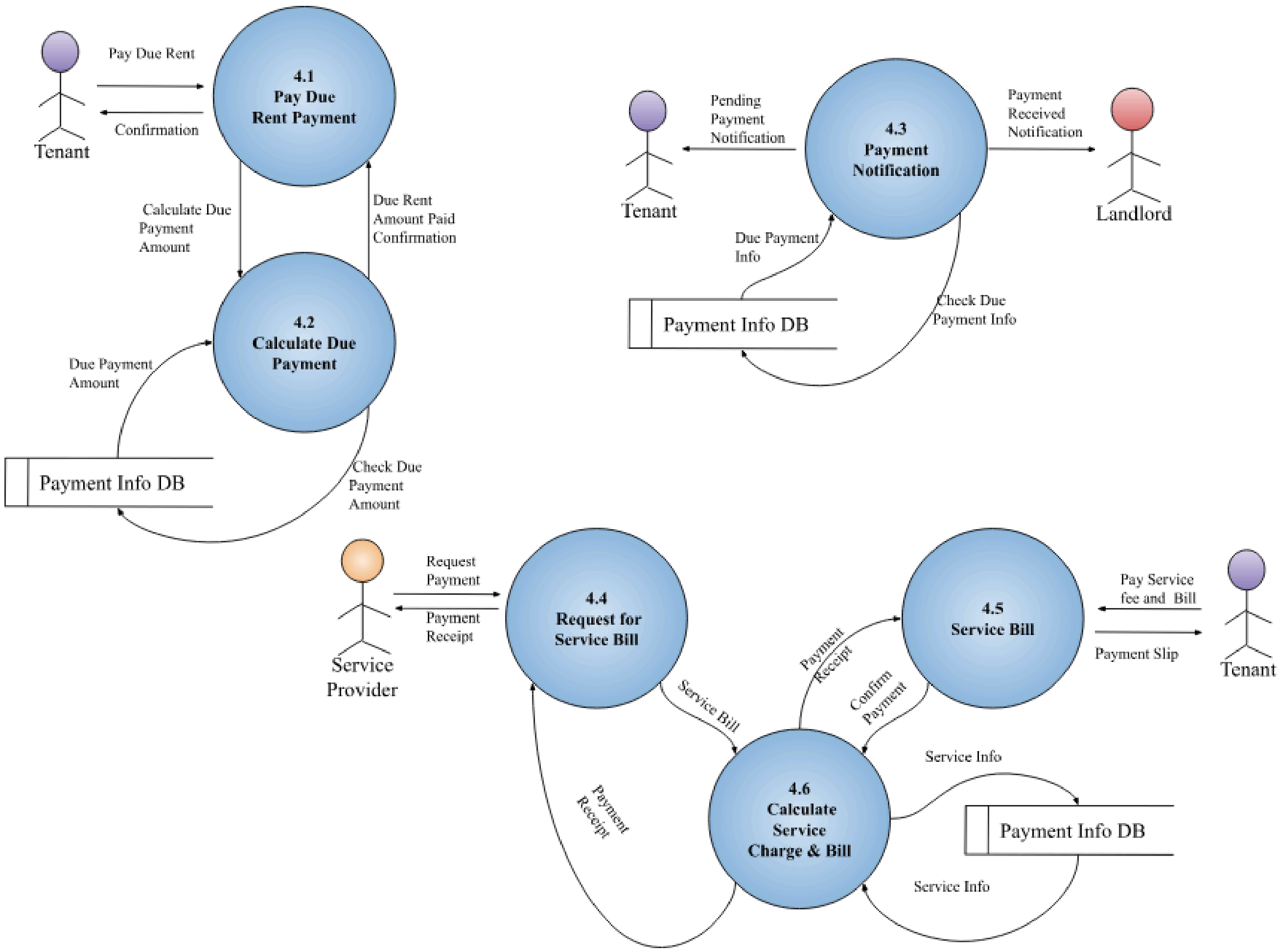


Figure 6.6: Level 1 (Payment Management) data flow diagram

Level 1 diagram

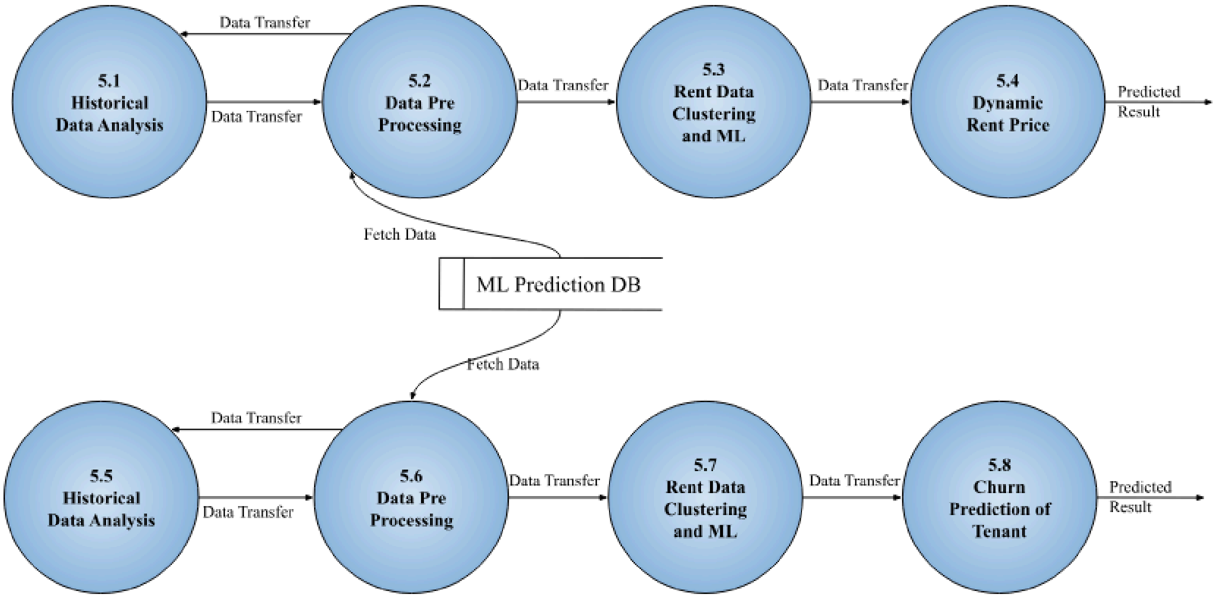
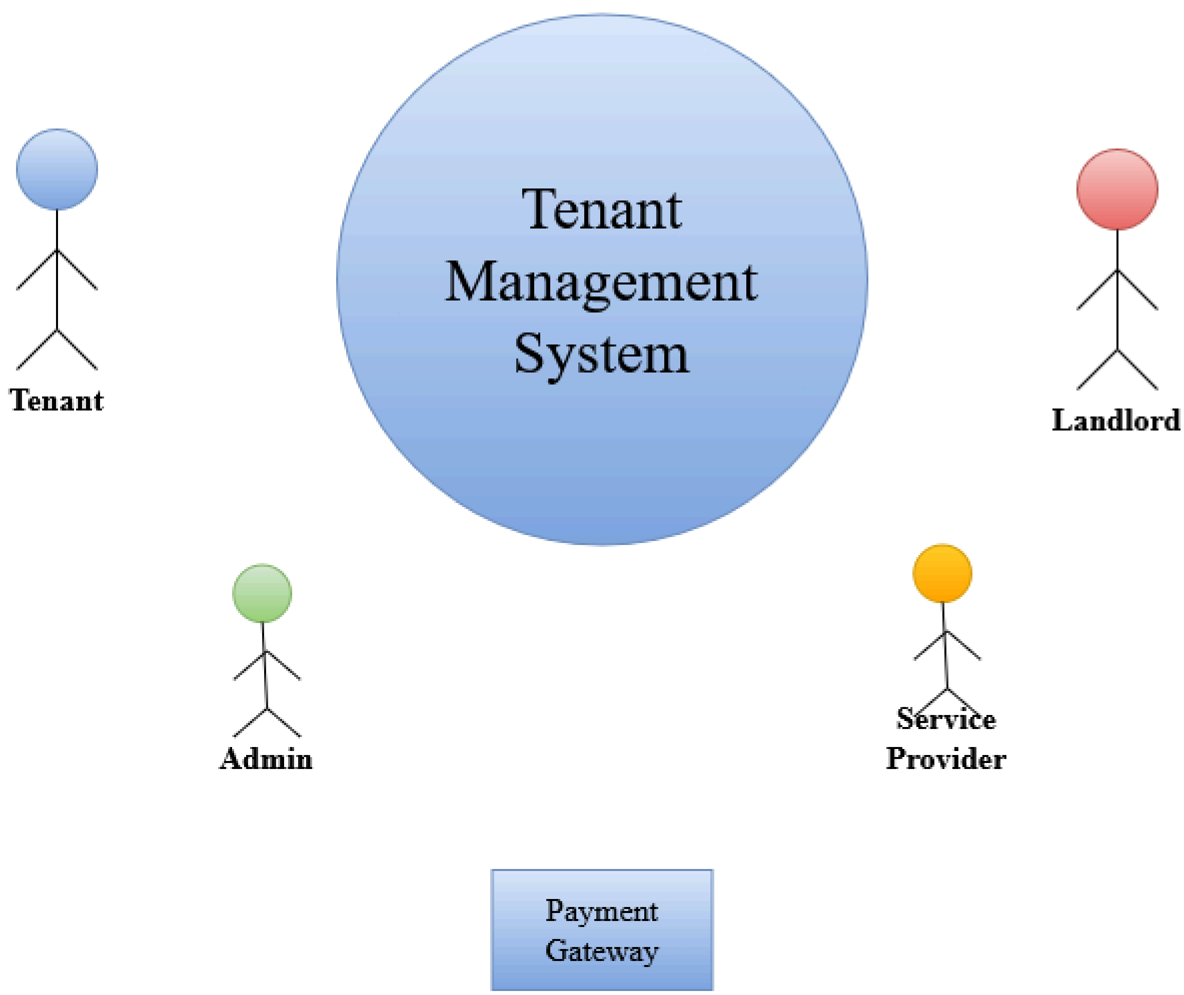


Figure 6.7: Level 1 (Prediction Model) data flow diagram

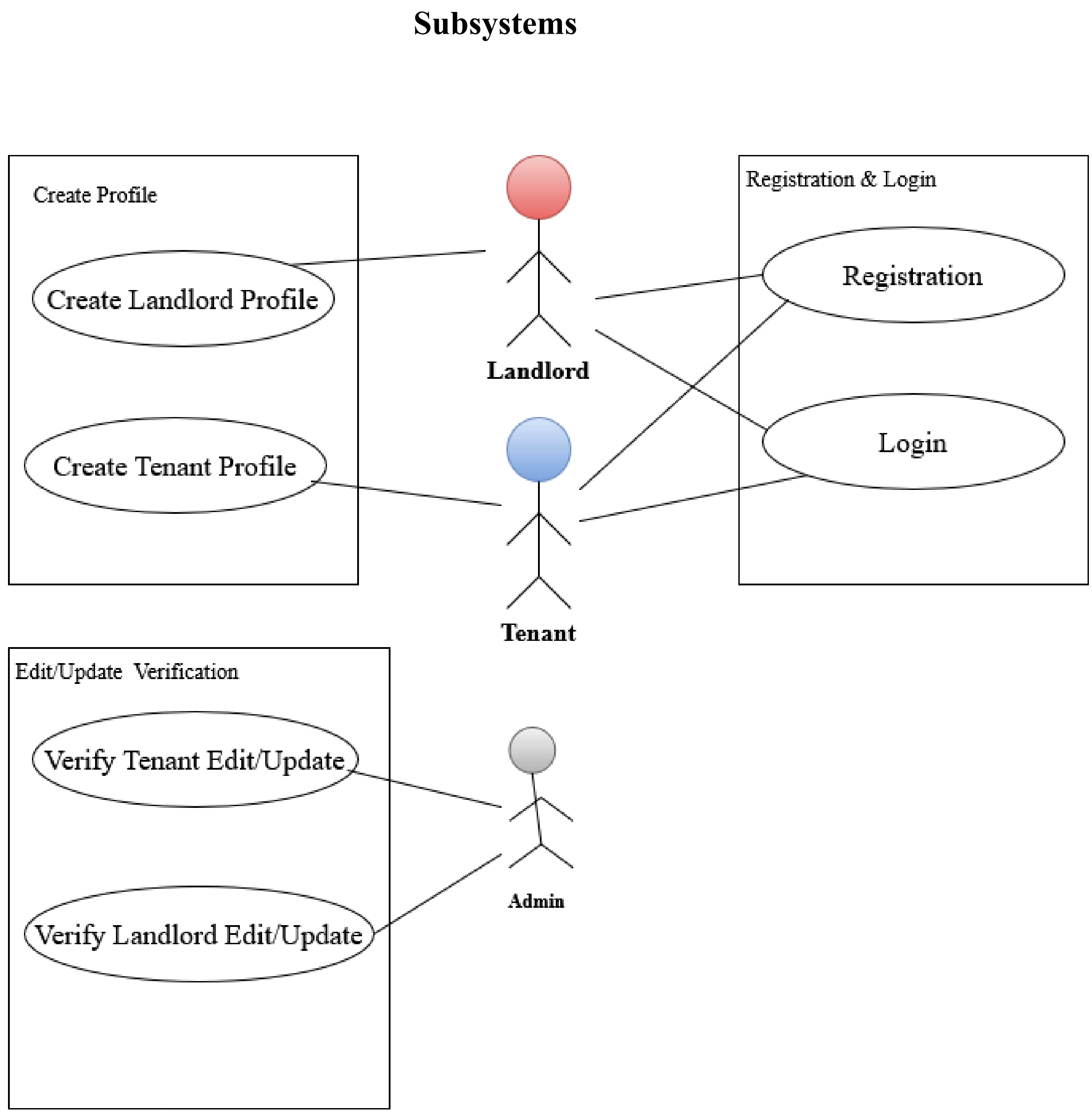
d. Object-oriented design of the system.

d1. Use case diagram.

Context Level

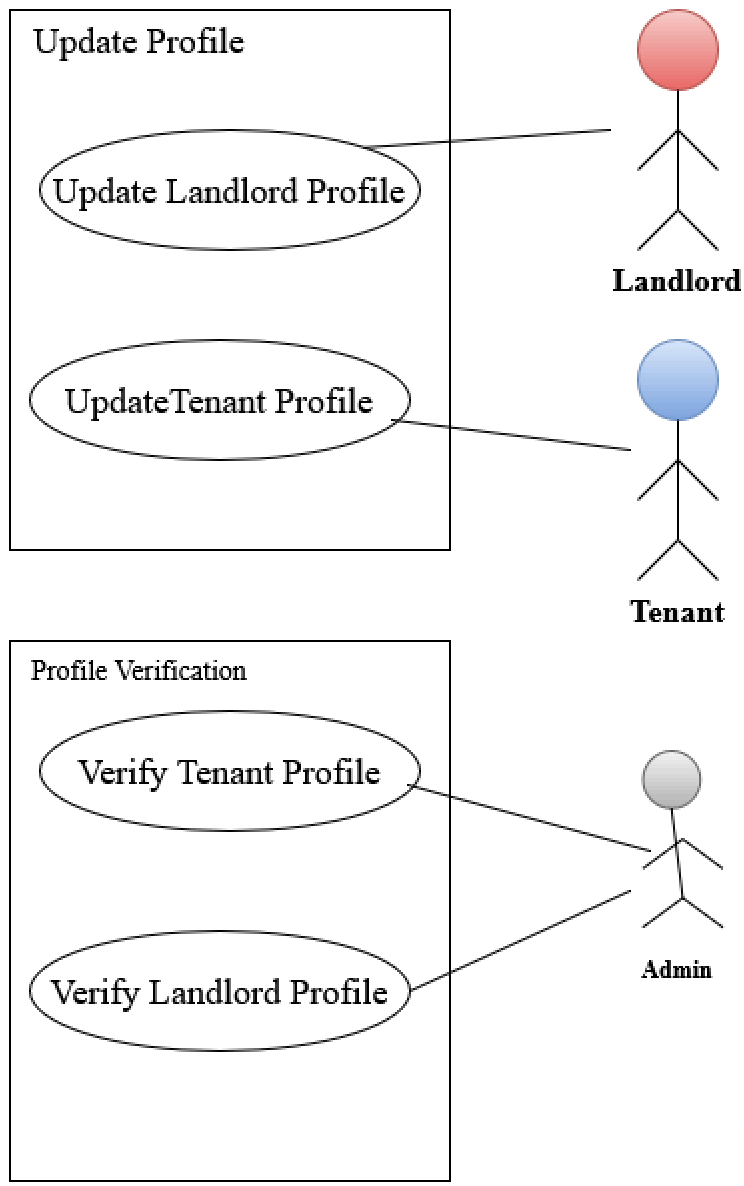


Use case diagram:



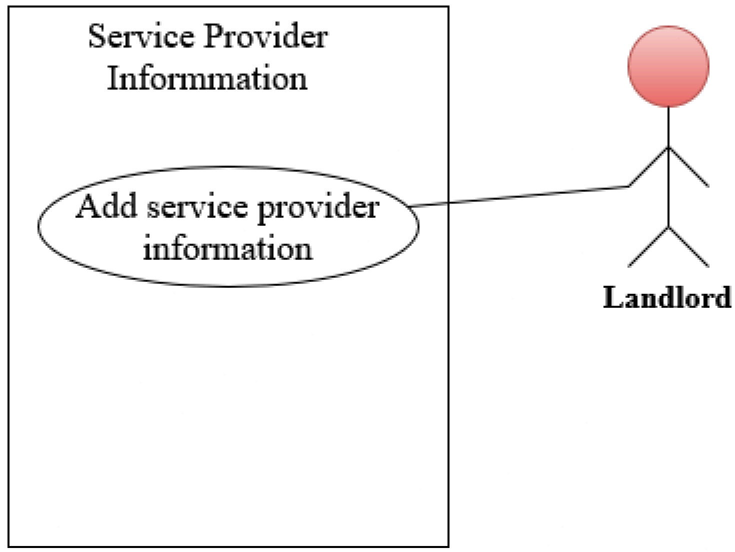
Use case diagram:

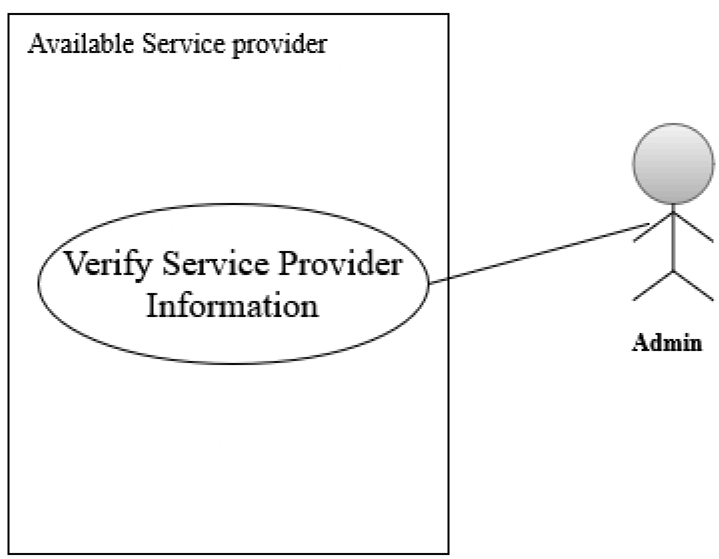
Subsystems



Use case diagram:

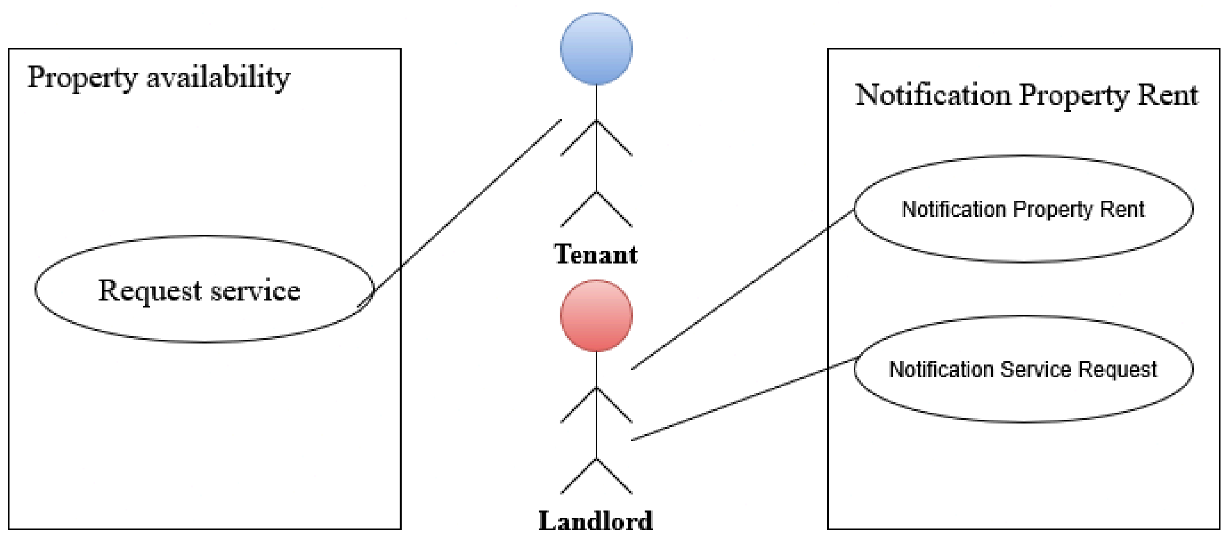
Subsystems



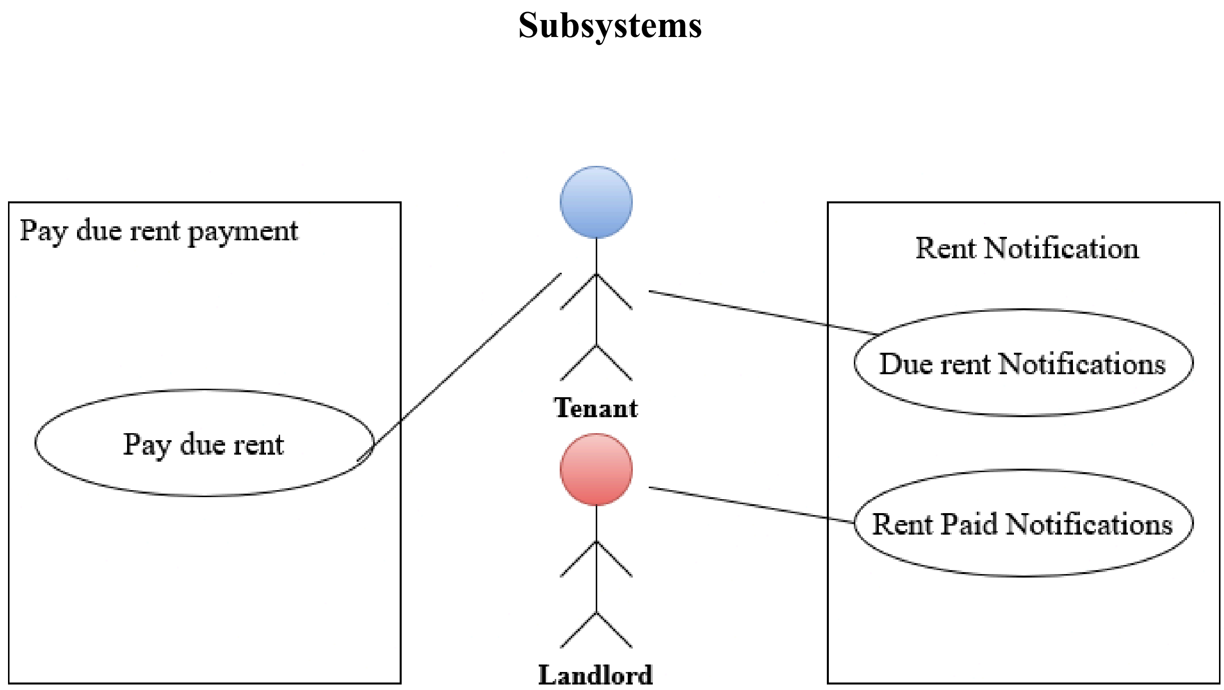


Use case diagram:

Subsystems

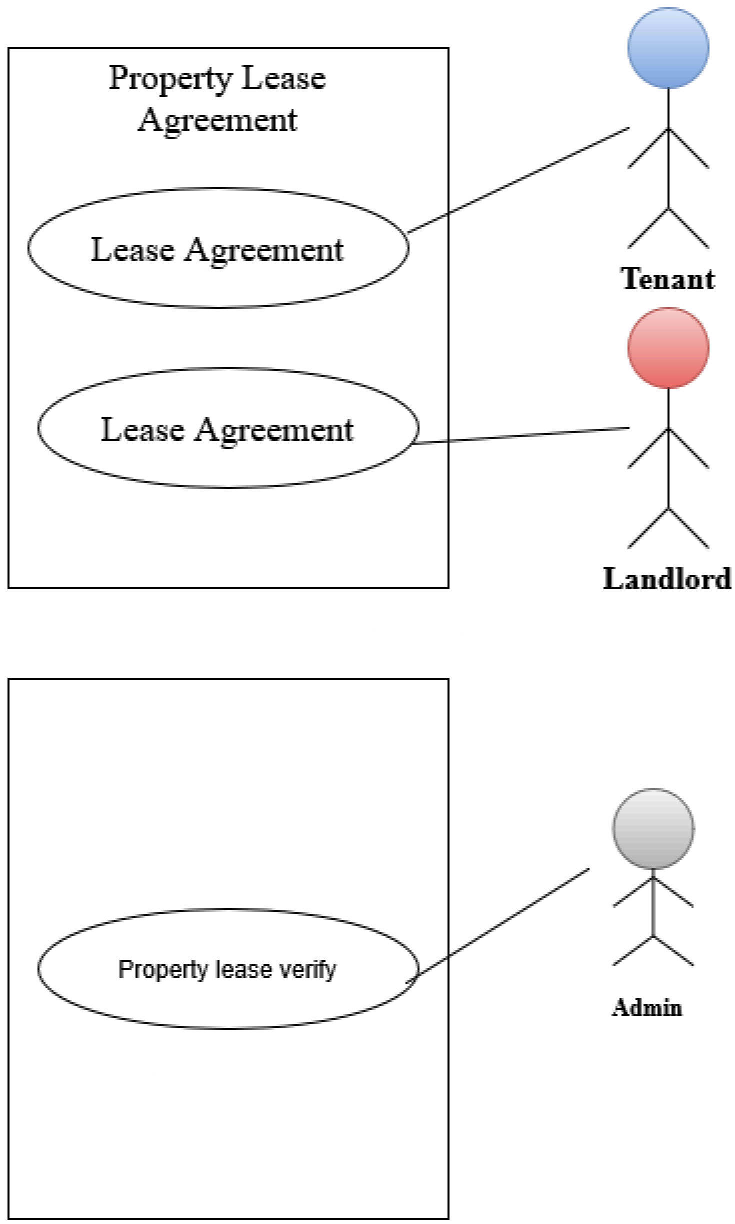


Use case diagram:



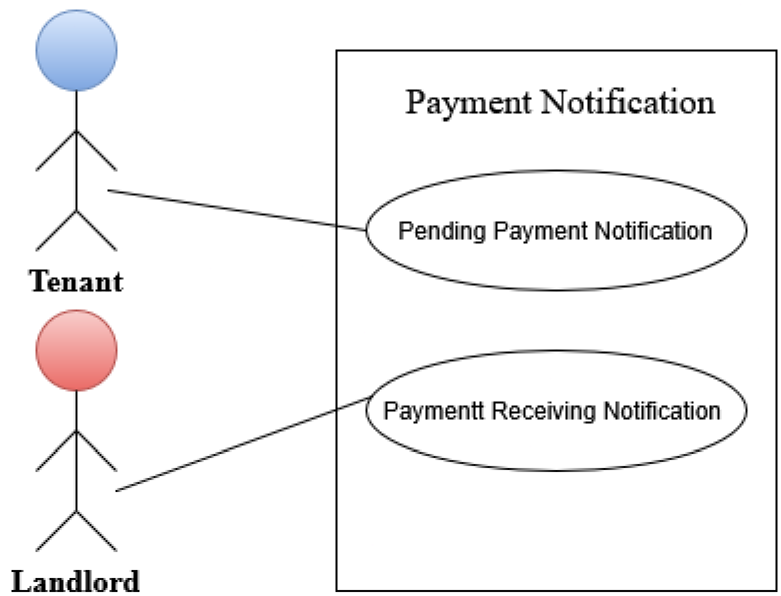
Use case diagram:

Subsystems



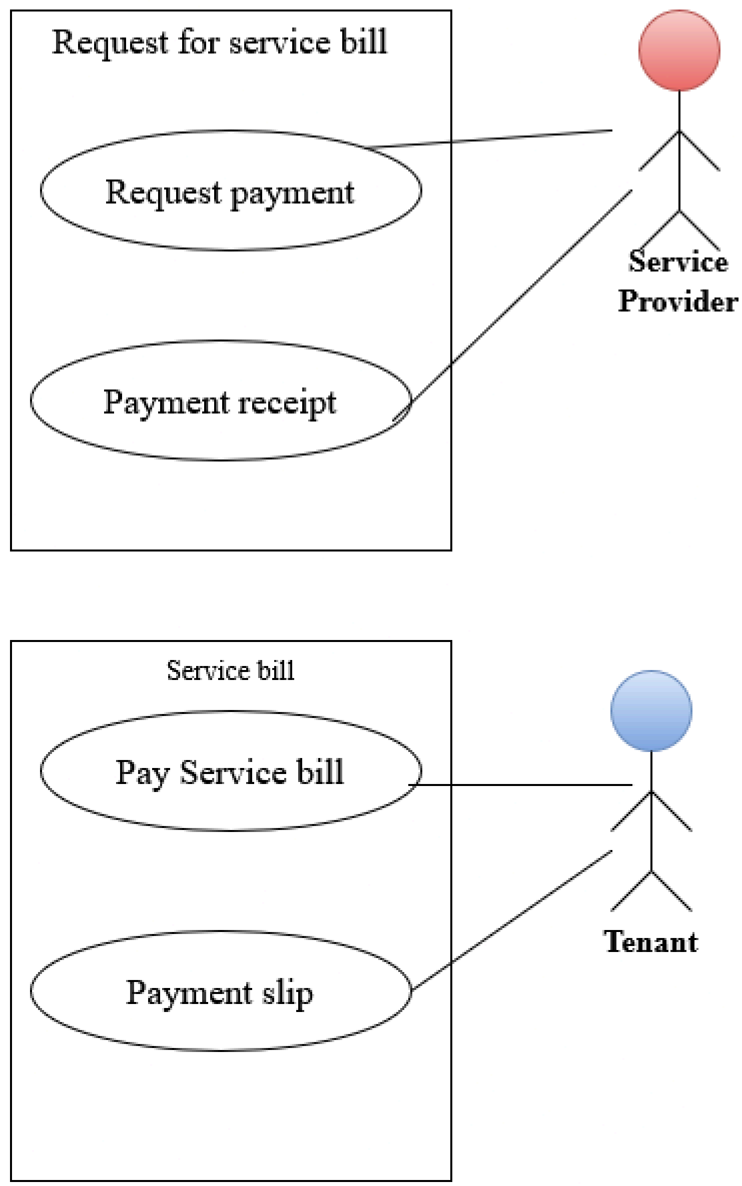
Use case diagram:

Subsystems



Use case diagram:

Subsystems



Use case Narration

Use Case Name	Client Information Management	
Actors	Landlord, Tenant, Admin	
Description	This use case describes how information is managed by a Landlord and Tenant In the system and verified by the Admin.	
Precondition	Only a valid registered Tenant and Landlord with Subscription (optional) will be able to manage the information.	
Typical Course of Event	Actors Action	System Response
	Step 01: **Landlord** and **Tenant** create their profile and request **Admin** for Information Verification. Step 04: **Tenant** and **Landlord** Edit their profile. Step 06: **Tenant** and **Landlord** login to their	Step 02: **Admin** checks the Tenant and Landlord's information. Verify their NID, Address and Identity verification and approve for their profile. Step 03: System stores the information in the database and profile verification is successful.

	profile and subscribe to the subscription. Step 08: **Tenant** and **Landlord** pay for their Subscription.	Step 05: System responses to Edit profile that this feature needs to login and a subscription (optional). Step 07: System takes to Subscription payment gateway. Step 09: Successful payment of Subscription.
Alternative Courses	Alt Step 03: **Landlord** and **Tenant** will be notified regarding his/her invalid status through the system. Alt Step 08: **Tenant** and **Landlord** skip pay for their Subscription and use free version. Alt Step 09: **Tenant** and **Landlord** will be notified regarding his/her invalid mode of payment through the system.	
Conclusion	This use case ensures that Tenant and Landlord profiles are created, verified, and managed efficiently, with optional subscription features for enhanced functionality.	

Use case Narration

Use Case Name	Property Management	
Actors	Landlord, Tenant, Admin	
Description	This use case describes how information is managed by a Landlord and Tenant In the system and verified by the Admin.	
Precondition	Only a valid registered Landlord with Subscription (optional) will be able to manage their property. Lease Agreement needs both Subscription and login.	
Typical Course of Event	Actors Action	System Response
	Step 01: **Landlord** Enlist a new property. Step 03: **Tenants** search for available property. Step 05: **Landlord** allocates available property.	Step 02: System stores the information in the database and also responds to login first. Step 04: System response with available property list and needs to login first.

	Step 07: **Tenant** and **Landlord** applies for a lease agreement. Step 09: **Tenant** and **Landlord** applies for a lease agreement verification. Step 10: **Tenant** and **Landlord** login to their profile and subscribe to the subscription Step 12: **Tenant** and **Landlord** pay for their Subscription.	Step 06: System response with allocation is successful and needs to login first. and needs to login first and subscription (optional). Step 08: System responses to lease agreement that this feature needs to lease verification, login and a subscription. Step 11: System takes to Subscription payment gateway. Step 13: **Admin** checks the Tenant and Landlord's lease agreement. Verify their NID, Address and Identity verification and approve for their agreement. Step 14: System stores the information in the database

		and lease agreement verification is successful.
Alternative Courses	Alt Step 03: **Tenant** will be notified regarding no property is available through the system. Alt Step 11: **Tenant** and **Landlord** will be notified regarding his/her invalid mode of payment through the system. Alt Step 12: **Tenant** and **Landlord** skip pay for their Subscription and use free version. Alt Step 13: **Landlord** and **Tenant** will be notified regarding his/her invalid status through the system.	
Conclusion	This use case facilitates the management, leasing, and verification of properties by Landlords and Tenants, with optional subscription features for enhanced service.	

Use case Narration

Use Case Name	Service Management
Actors	Landlord, Tenant

Description	This use case describes how service is managed between a Landlord and Tenant In the system.	
Precondition	Only a valid registered Tenant and Landlord with Subscription (optional) will be able to manage the payment.	
Typical Course of Event	Actors Action	System Response
	Step 01: **Landlord** adds a service provider information. Step 03: **Tenant** request for a Service. Step 05: **Tenant** login to their profile and subscribe to the subscription. Step 07: **Tenant** pays for their Subscription.	Step 02: System stores the information in the database and also responds to login first. Step 04: System response with request is successful and waiting for the **Landlord** Approval**.** System needs to login first and subscribe. Step 06: System takes to Subscription payment gateway. Step 08: Successful payment of Subscription Step 10: System sends notification to **Landlord** and

	Step 09: **Landlord** approves service request. Step 11: **Tenant** gives feedback to the service	**Tenant** about the successful approval. Step 12: System responds "Your Feedback will help us to improve"..
Alternative Courses	Alt Step 05: **Tenant** will be notified regarding his/her invalid status through the system if he/she skips subscription. Alt Step 07: **Tenant** skip pay for their Subscription and use free version. Alt Step 08: **Tenant** will be notified regarding his/her invalid mode of payment through the system. Alt Step 09: **Landlord** rejects the service request and system notified the **Tenant**. Alt Step 11: **Tenant** skipped feedback for provided service.	
Conclusion	This use case streamlines payment management and service requests between Landlords and Tenants, with optional subscription features for enhanced functionality.	

Use case Narration

Use Case Name	Payment Management	
Actors	Landlord, Tenant	
Description	This use case describes how payment is managed by a Landlord and Tenant In the system.	
Precondition	Only a valid registered Tenant and Landlord with Subscription (optional) will be able to manage the payment.	
Typical Course of Event	Actors Action	System Response
	Step 01: **Landlord** increases the rent. Step 03: **Tenant** pays the rent. Step 06:**Tenant** and **Landlord** click to see yearly rent audit. Step 08: **Tenant** and **Landlord** login to their profile and subscribe to the subscription	Step 02: System updates the rent information and stores it to the database. Step 02: System sends notification to the **Tenant.** Step 04: System takes to rent payment gateway. Step 05: Successful payment of rent notification sent to the **Tenant** and **Landlord.**

	Step 10: **Tenant** and **Landlord** pays for their Subscription. Step 12: **Tenant** and **Landlord** gives feedback.	Step 07: System response with request is successful and System needs to login first and subscribe. Step 09: System takes to Subscription payment gateway. Step 11: Successful payment of Subscription and shows the yearly Audit. Step 13: System responds "Your Feedback will help us to improve" System needs to login first and subscribe.
Alternative Courses	Alt Step 02: **Landlord** will be notified regarding his/her invalid status through the system as per lease agreement he/she can't increase the rent. Alt Step 05: **Tenant** will be notified regarding his/her invalid mode of payment through the system. Alt Step 10: **Tenant** and **Landlord** skip pay for their Subscription and use free version.	

	Alt Step 12: **Tenant** and **Landlord** skipped feedback for provided service.
Conclusion	This use case ensures Payment Management ensures a seamless process for landlords and tenants to manage rent payments, subscriptions, and feedback.

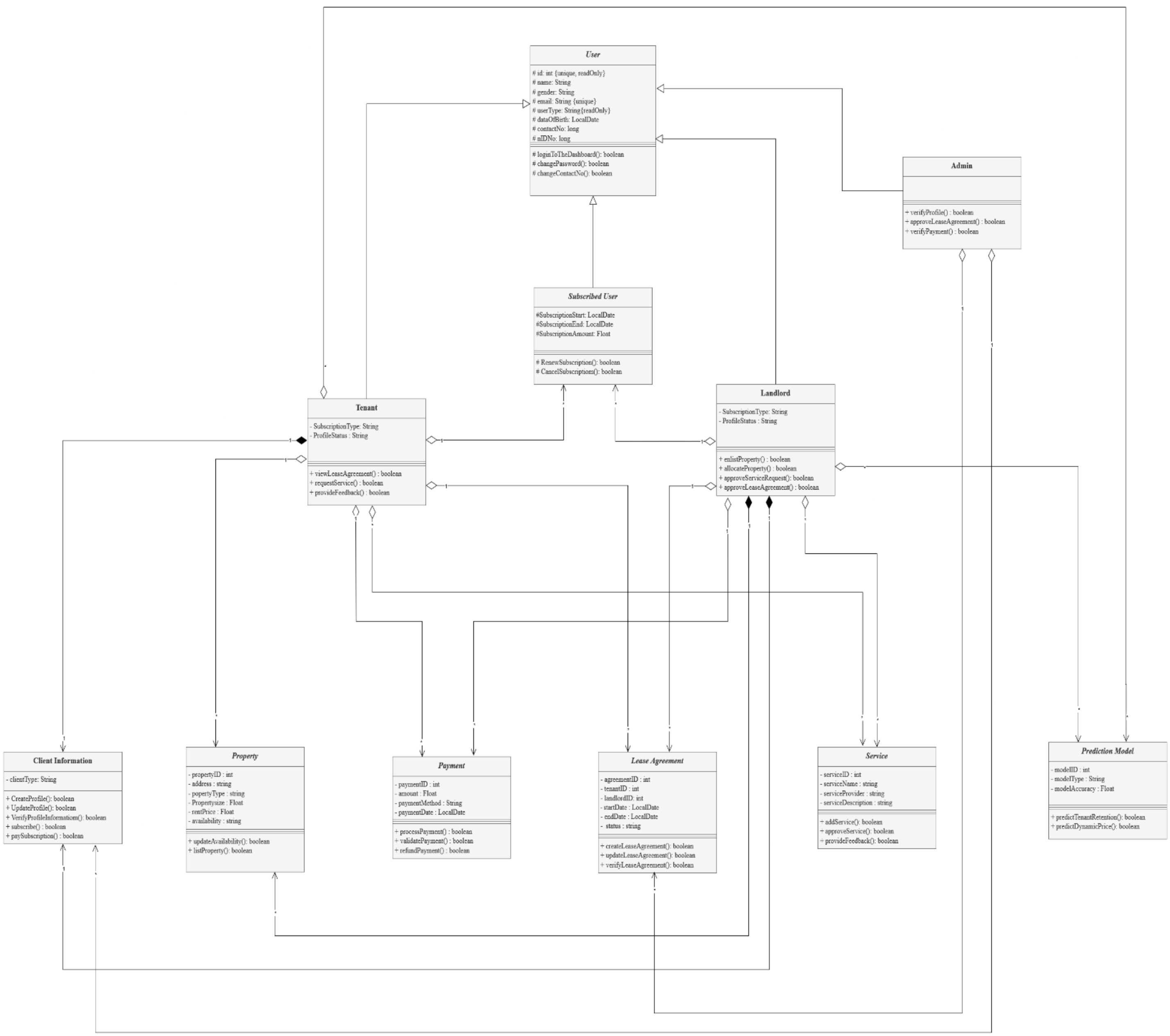
Use case Narration

Use Case Name	Prediction Model	
Actors	Landlord, Tenant	
Description	This use case describes how a prediction model based on machine learning is used by a Landlord and Tenant In the system.	
Precondition	Only a valid registered Tenant and Landlord with Subscription will be able to use the prediction models benefit.	
Typical Course of Event	Actors Action	System Response
	Step 01: **Landlord** click to see the Churn Prediction of Tenant (Whether a Tenant will stay or not).	Step 02: System responds by using a machine learning model on the previous data of that Tenant to show

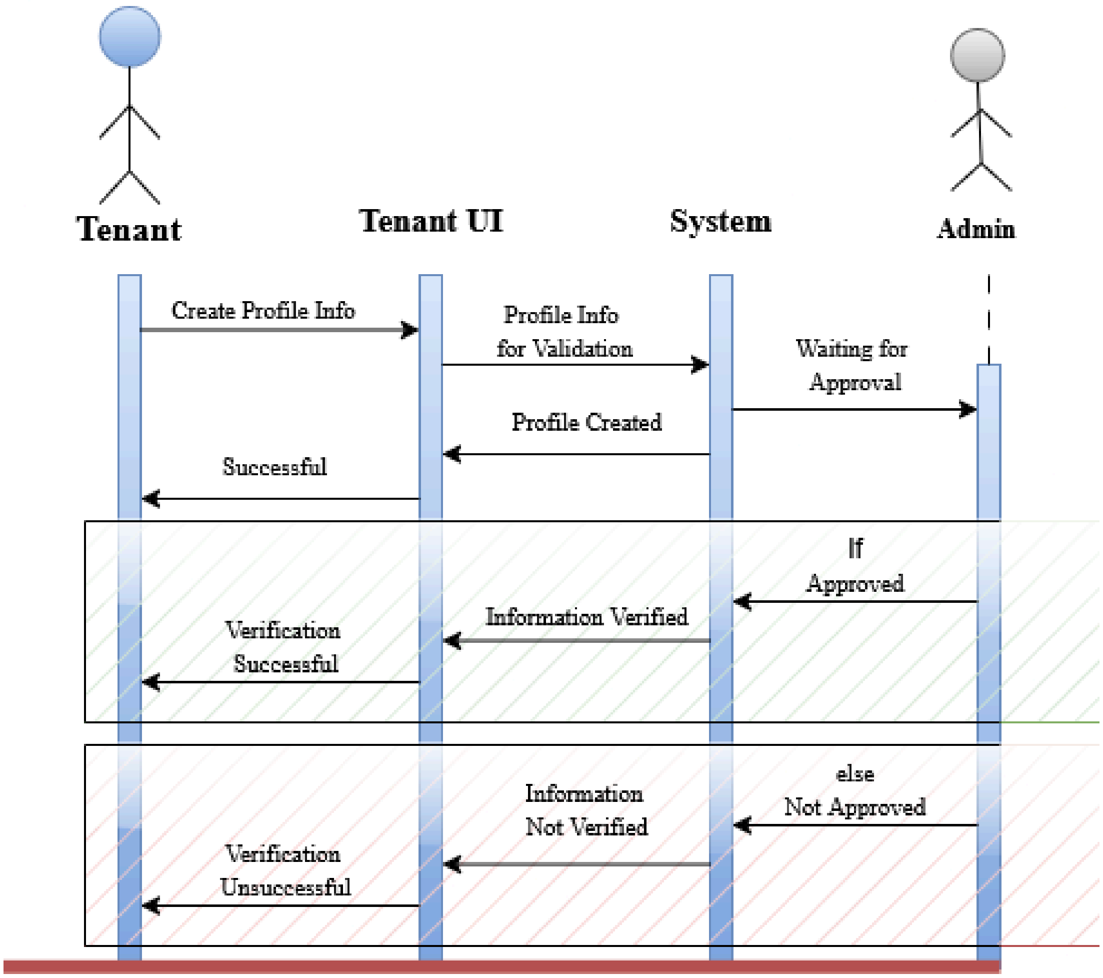
	Step 04: **Tenant** clicks to Dynamic Price comparison of the property. Step 06: **Tenant** and **Landlord** login to their profile and subscribe to the subscription. Step 08: **Tenant** and **Landlord** pay for their Subscription. Step 10: **Tenant** and **Landlord** give rating.	whether he/she will stay or not. Step 03: System needs to login first and subscribe. Step 05: System responds by using a machine learning model on the previous data of that property with comparison of others property. Step 07: System takes to Subscription payment gateway. Step 09: Successful payment of Subscription. Step 11: System responds "Your rating will help us to improve users" System needs to login first and subscribe.

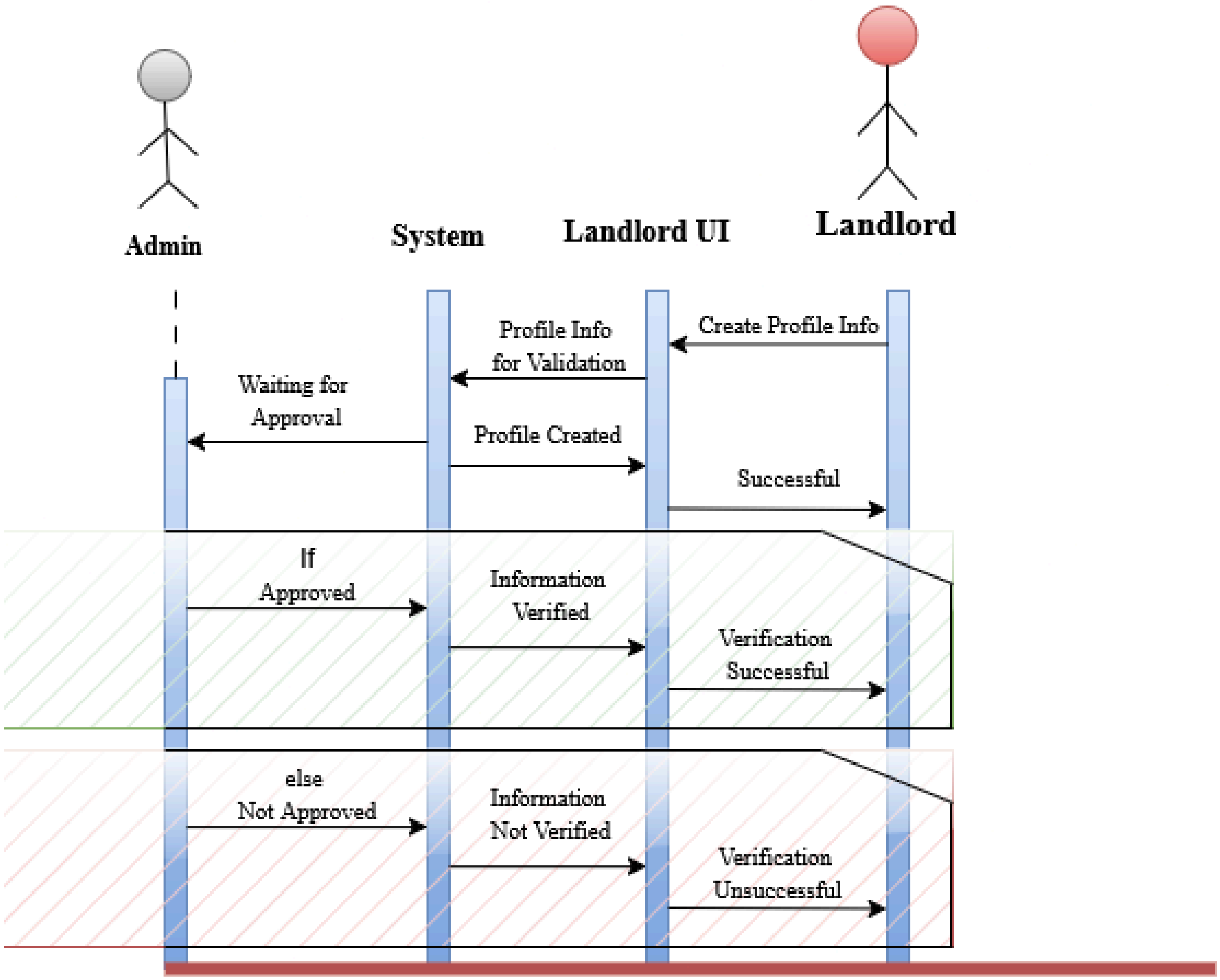
Alternative Courses	Alt Step 6: **Tenant** and **Landlord** skip pay for their Subscription and use free version. Alt Step 09: **Tenant** will be notified regarding his/her invalid mode of payment through the system. Alt Step 10: **Tenant** and **Landlord** skipped rating for provided service.
Conclusion	This use case Prediction Model leverages machine learning to provide valuable insights for landlords and tenants on tenant retention and property pricing, with access granted through subscription.

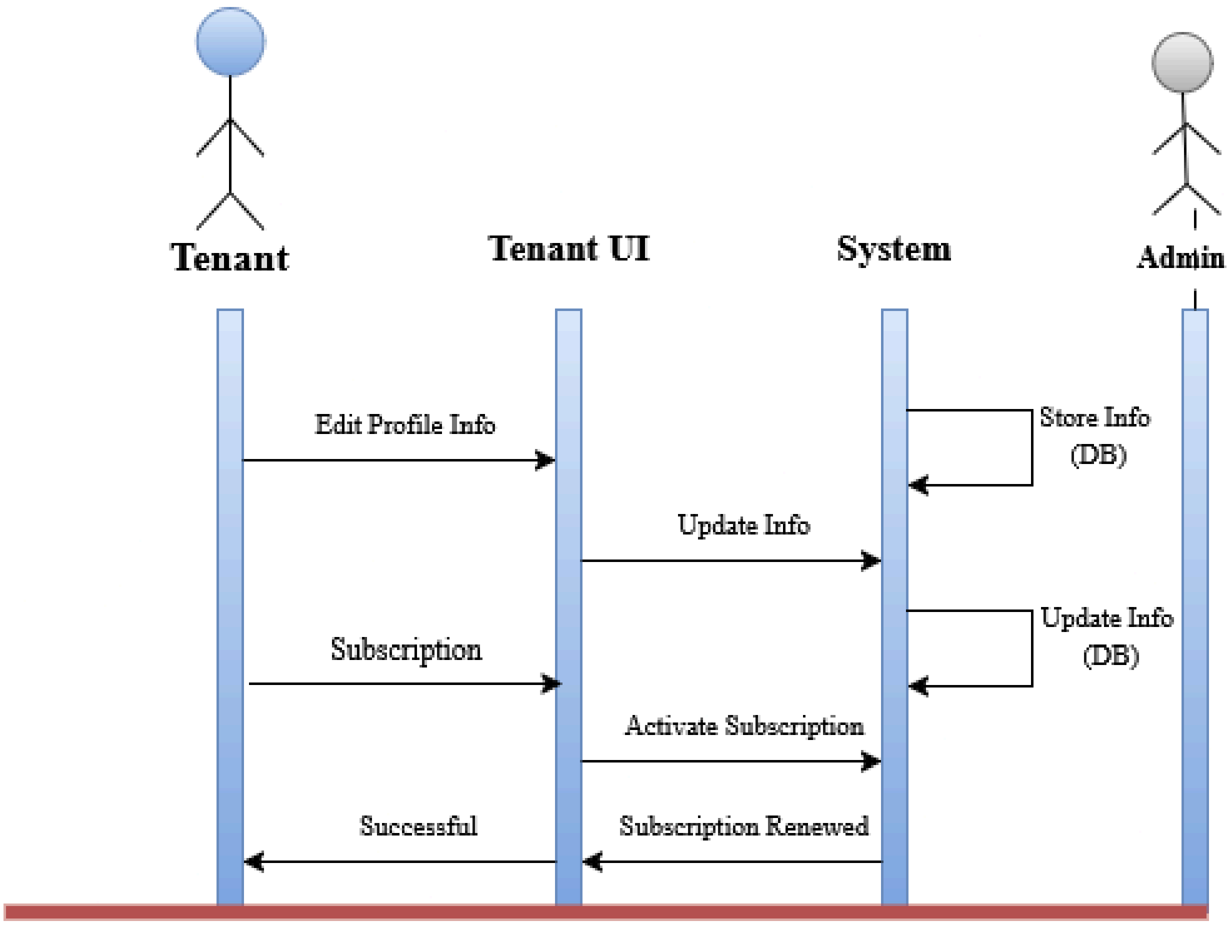
d2. Class diagram.

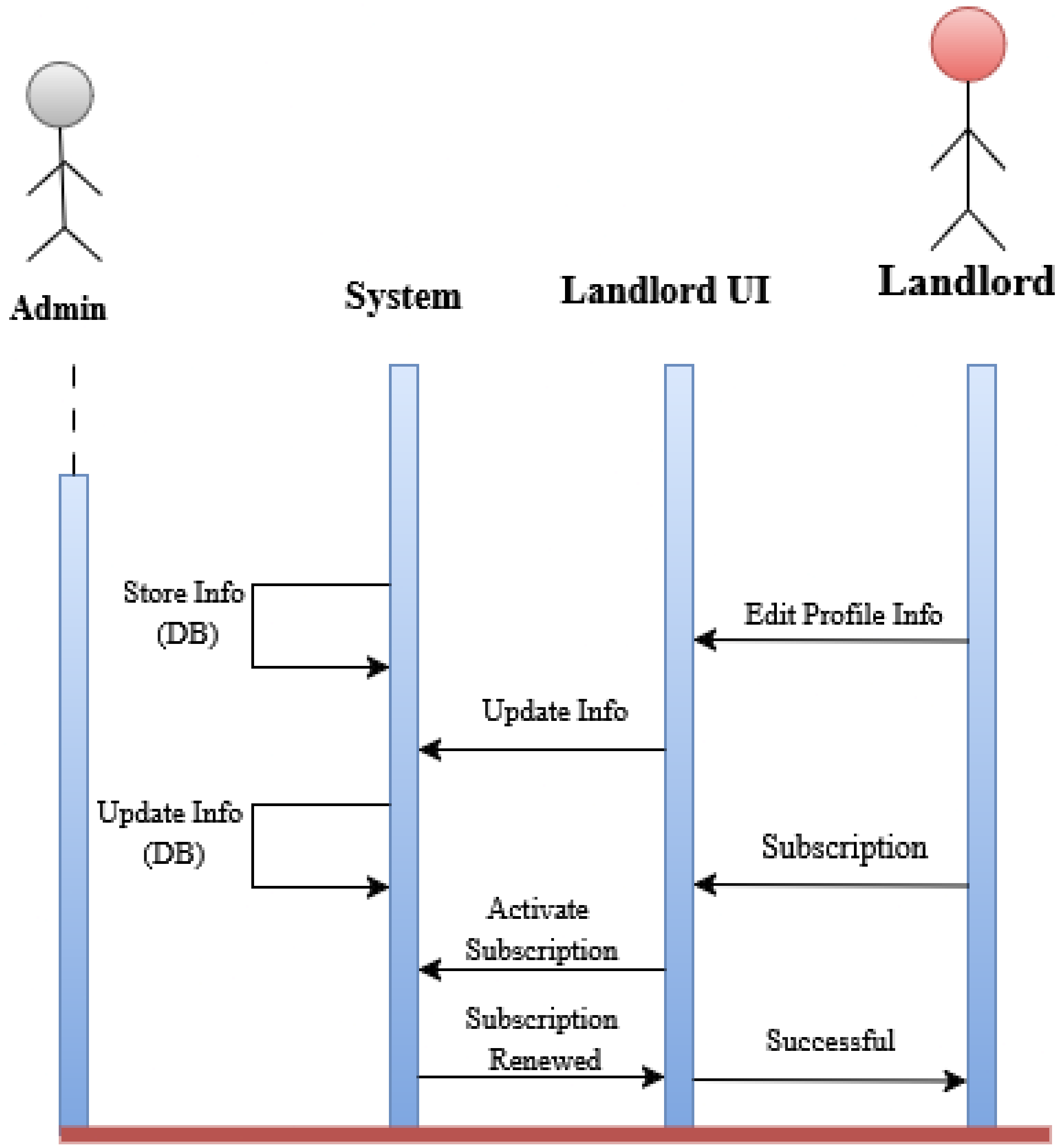


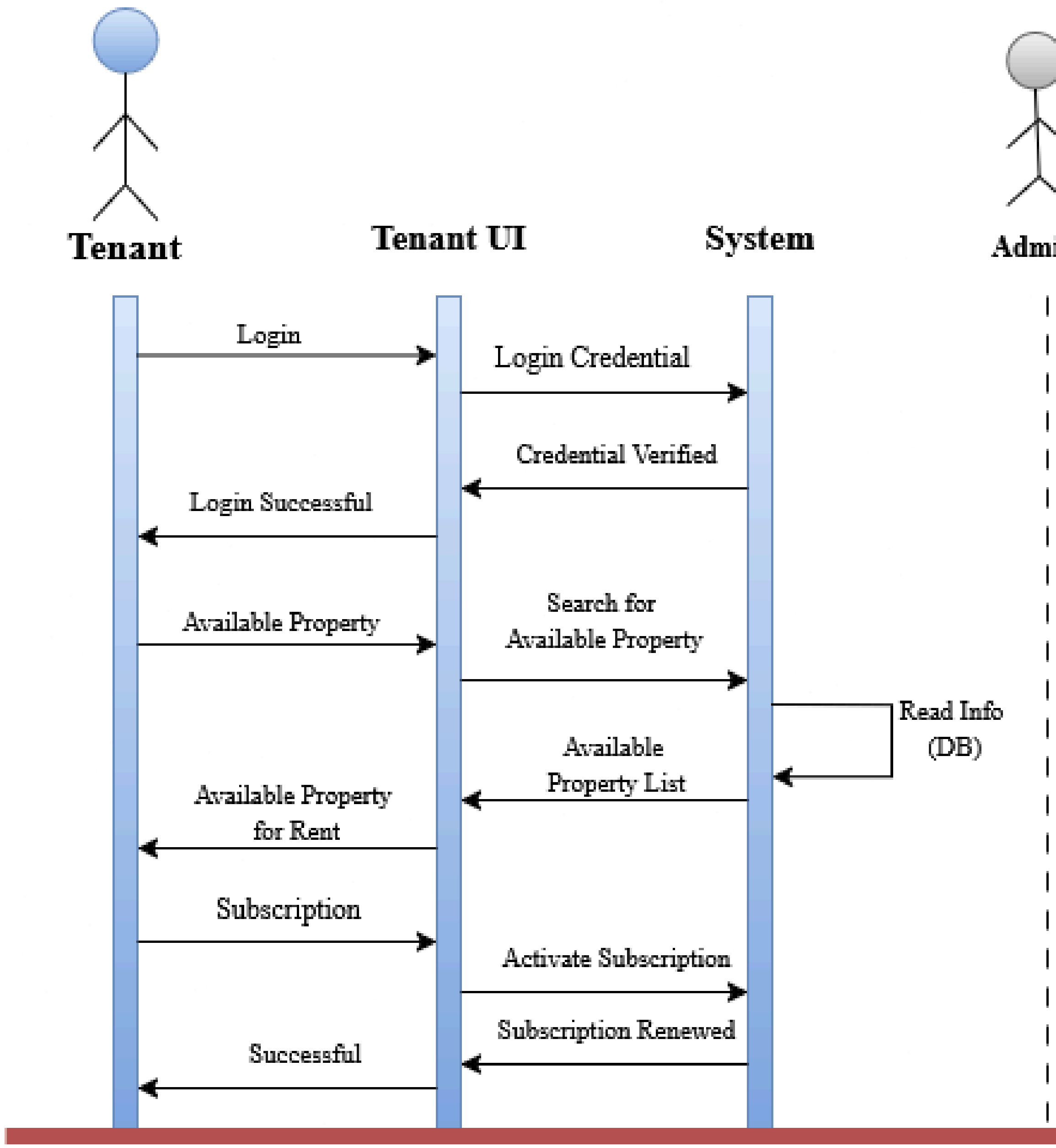
d3. Sequence diagram.



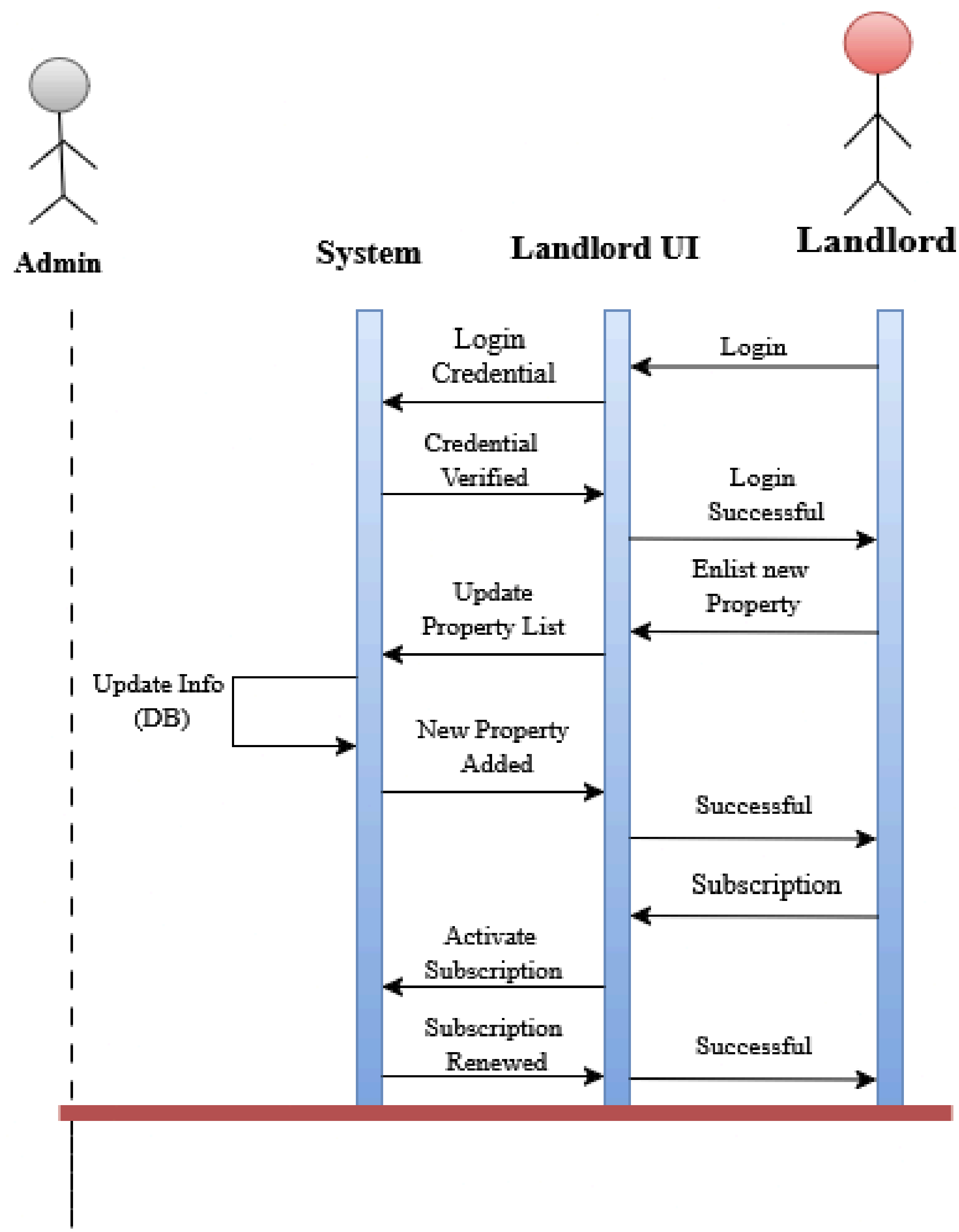

Admin
System
Landlord UI
Landlord
Create Profile Info
Profile Info
for Validation
Waiting for
Approval
Profile Created
Successful
If
Approved
Information
Verified
Verification
Successful
else
Not Approved
Information
Not Verified
Verification
Unsuccessful

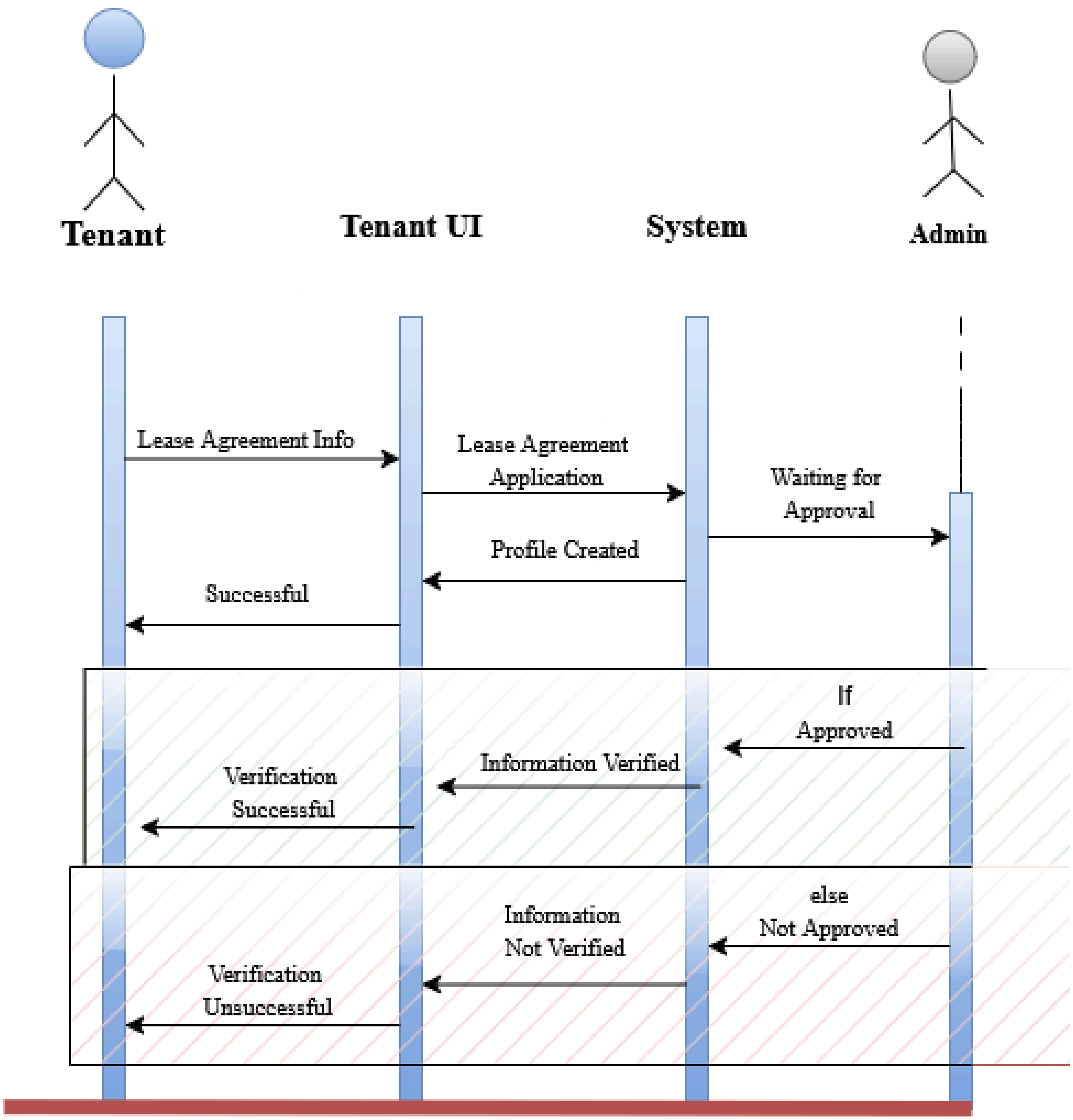

Tenant
Tenant UI
System
Admin
Edit Profile Info
Store Info (DB)
Update Info
Update Info (DB)
Subscription
Activate Subscription
Successful
Subscription Renewed

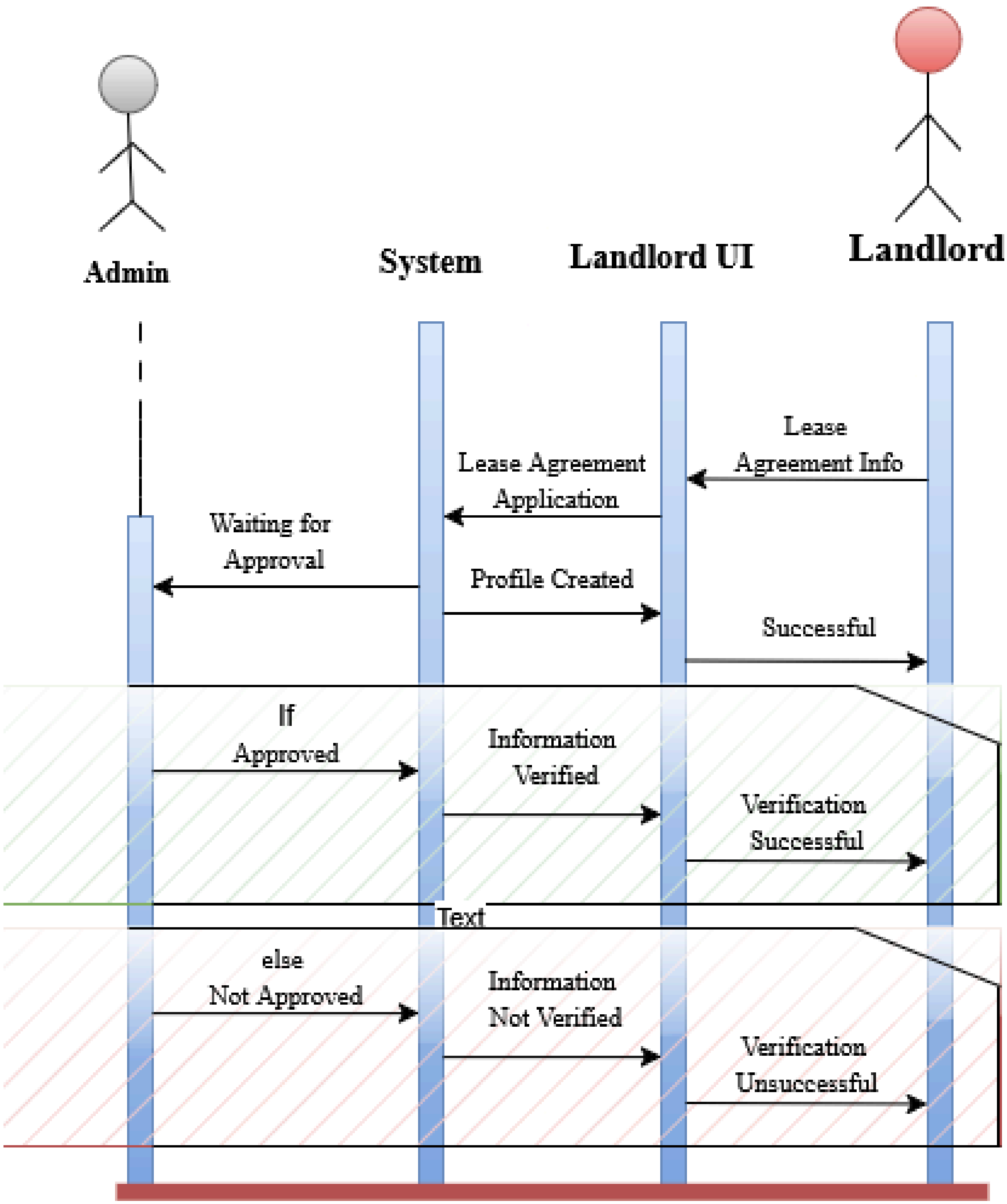

Admin
System
Landlord UI
Landlord
Store Info (DB)
Edit Profile Info
Update Info
Update Info (DB)
Subscription
Activate Subscription
Subscription Renewed
Successful

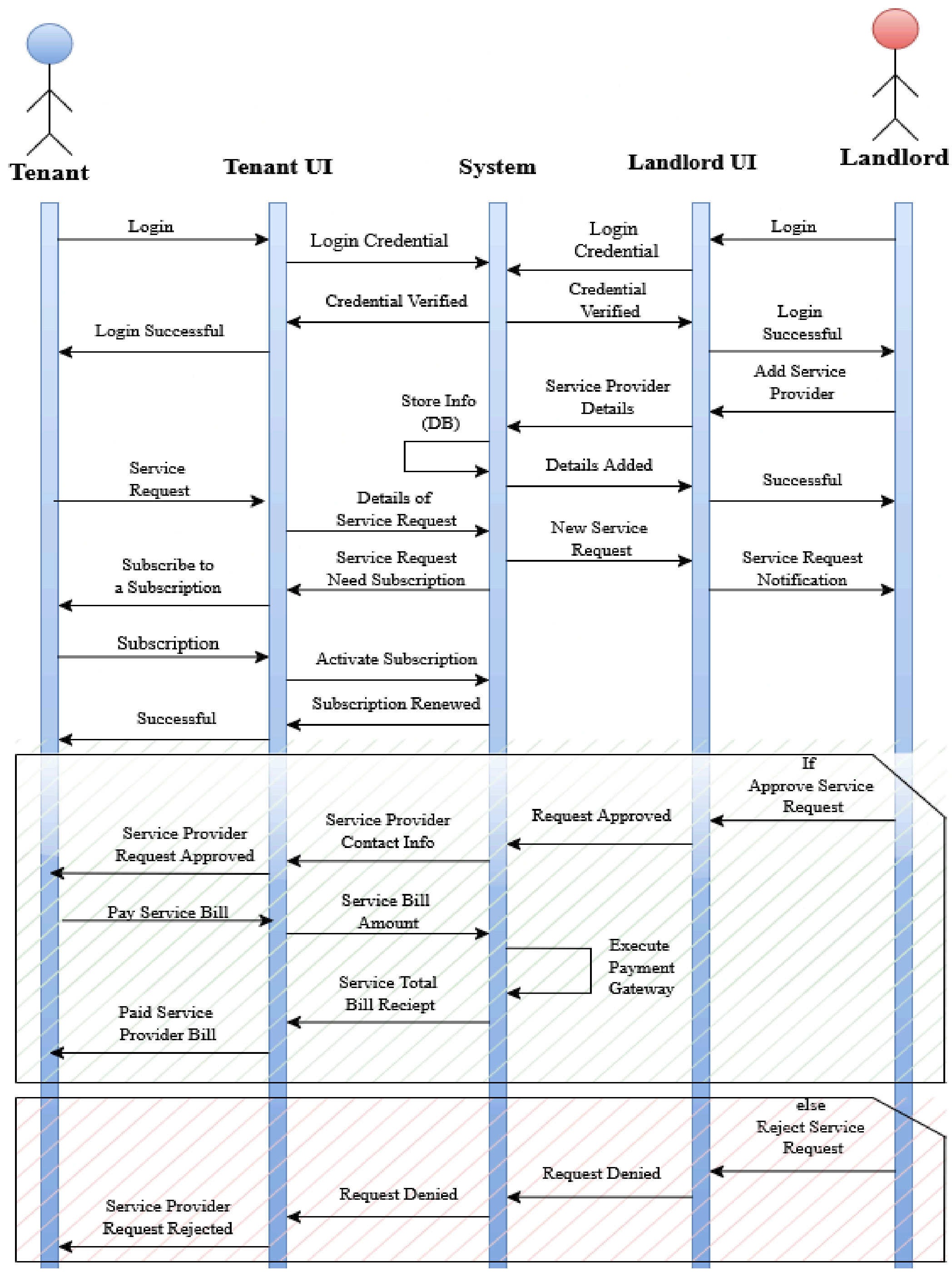


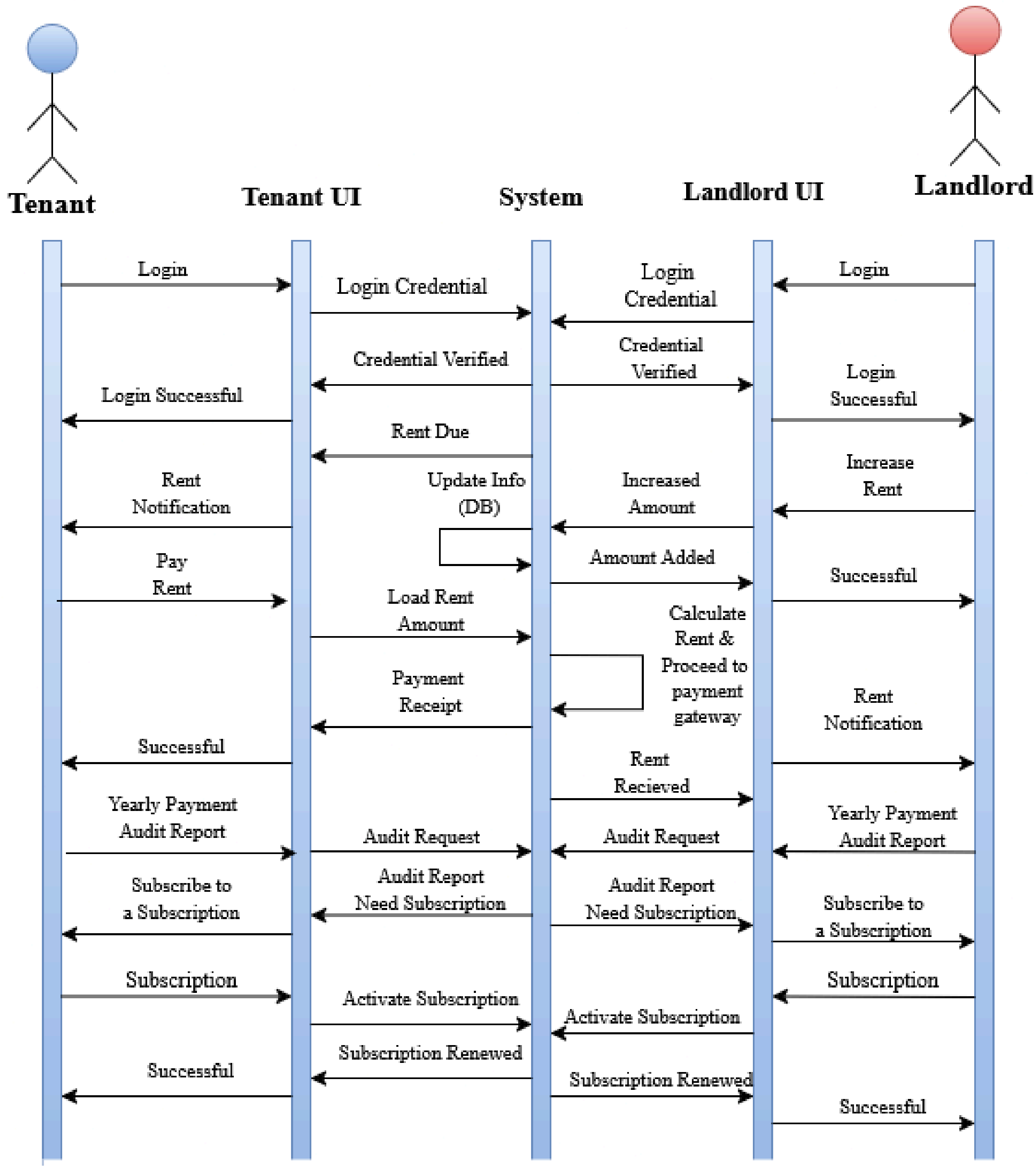
Tenant
Tenant UI
System
Admin
Login
Login Credential
Credential Verified
Login Successful
Available Property
Search for
Available Property
Read Info
(DB)
Available
Property List
Available Property
for Rent
Subscription
Activate Subscription
Subscription Renewed
Successful

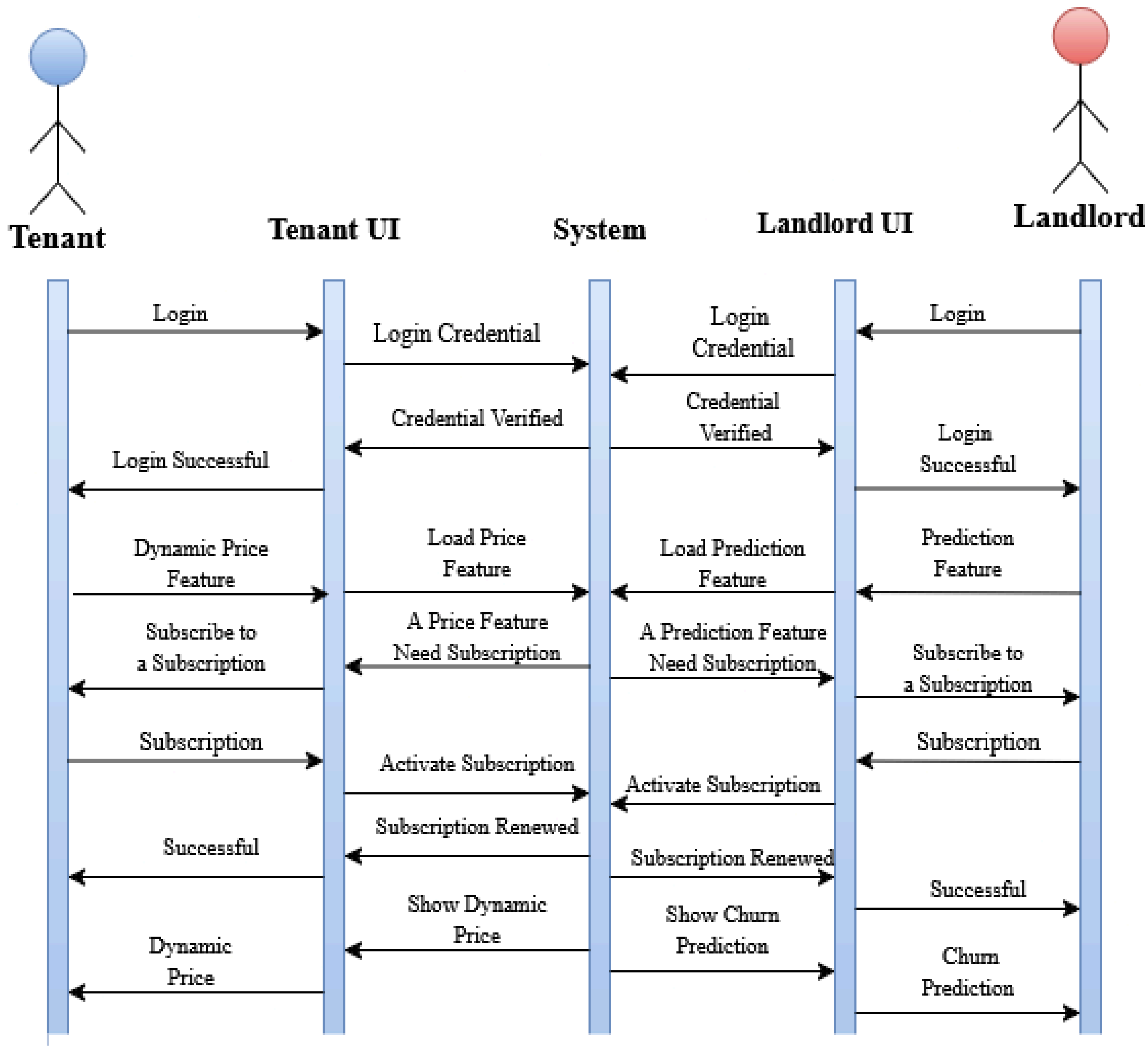

Admin
System
Landlord UI
Landlord
Login
Login Credential
Credential Verified
Login Successful
Enlist new Property
Update Property List
Update Info (DB)
New Property Added
Successful
Subscription
Activate Subscription
Subscription Renewed
Successful


Tenant
Tenant UI
System
Admin
Lease Agreement Info
Lease Agreement Application
Waiting for Approval
Profile Created
Successful
If Approved
Information Verified
Verification Successful
else Not Approved
Information Not Verified
Verification Unsuccessful


Admin
System
Landlord UI
Landlord
Lease
Agreement Info
Lease Agreement
Application
Waiting for
Approval
Profile Created
Successful
If
Approved
Information
Verified
Verification
Successful
Text
else
Not Approved
Information
Not Verified
Verification
Unsuccessful


Tenant
Tenant UI
System
Landlord UI
Landlord
Login
Login Credential
Login Credential
Login
Credential Verified
Credential Verified
Login Successful
Login Successful
Add Service Provider
Service Provider Details
Store Info (DB)
Details Added
Successful
Service Request
Details of Service Request
New Service Request
Service Request Notification
Subscribe to a Subscription
Service Request Need Subscription
Subscription
Activate Subscription
Subscription Renewed
Successful
If Approve Service Request
Request Approved
Service Provider Contact Info
Service Provider Request Approved
Pay Service Bill
Service Bill Amount
Execute Payment Gateway
Service Total Bill Reciept
Paid Service Provider Bill
else Reject Service Request
Request Denied
Request Denied
Service Provider Request Rejected


Tenant
Tenant UI
System
Landlord UI
Landlord
Login
Login Credential
Login Credential
Login
Credential Verified
Credential Verified
Login Successful
Login Successful
Rent Due
Rent Notification
Update Info (DB)
Increased Amount
Increase Rent
Pay Rent
Amount Added
Successful
Load Rent Amount
Calculate Rent & Proceed to payment gateway
Payment Receipt
Rent Notification
Successful
Rent Recieved
Yearly Payment Audit Report
Audit Request
Audit Request
Yearly Payment Audit Report
Subscribe to a Subscription
Audit Report Need Subscription
Audit Report Need Subscription
Subscribe to a Subscription
Subscription
Activate Subscription
Activate Subscription
Subscription
Subscription Renewed
Successful
Subscription Renewed
Successful


Tenant
Tenant UI
System
Landlord UI
Landlord
Login
Login Credential
Login Credential
Login
Credential Verified
Credential Verified
Login Successful
Login Successful
Dynamic Price Feature
Load Price Feature
Load Prediction Feature
Prediction Feature
Subscribe to a Subscription
A Price Feature Need Subscription
A Prediction Feature Need Subscription
Subscribe to a Subscription
Subscription
Activate Subscription
Activate Subscription
Subscription
Successful
Subscription Renewed
Subscription Renewed
Successful
Dynamic Price
Show Dynamic Price
Show Churn Prediction
Churn Prediction

d4. Activity diagram.

Activity Diagram

Tenant Management System

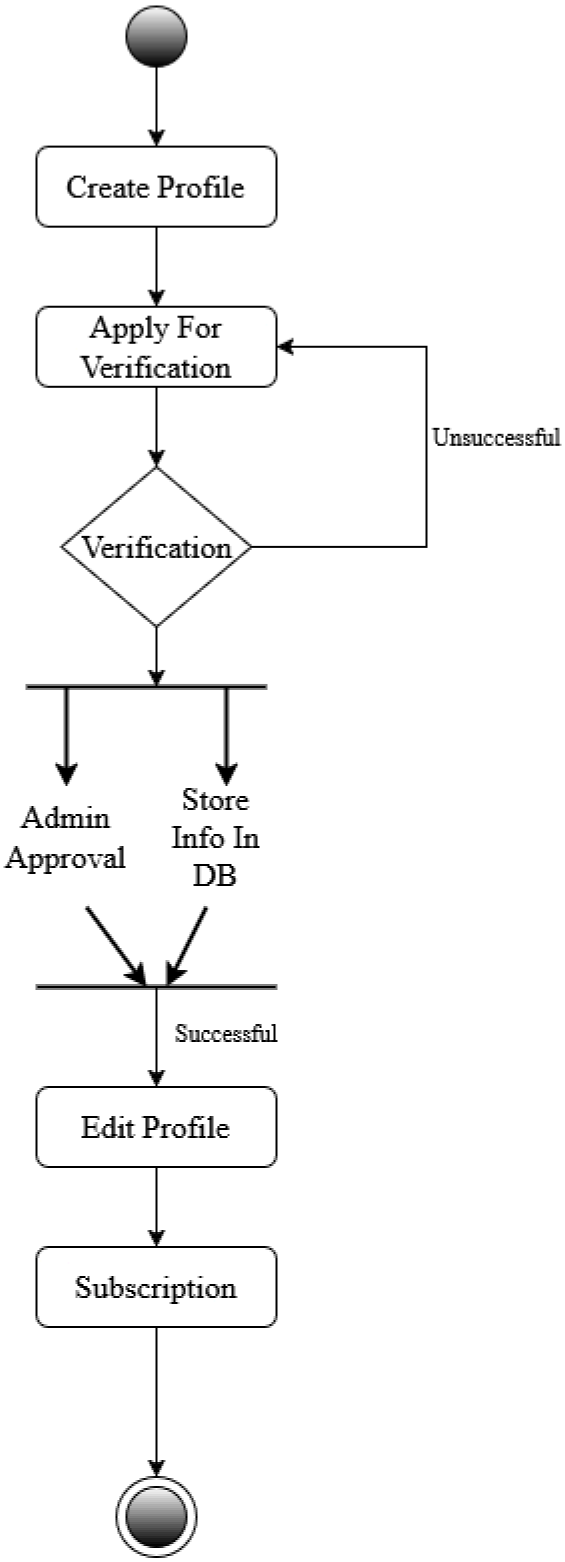


Figure 20: Client Information Management Activity Diagram

Activity Diagram

Tenant Management System

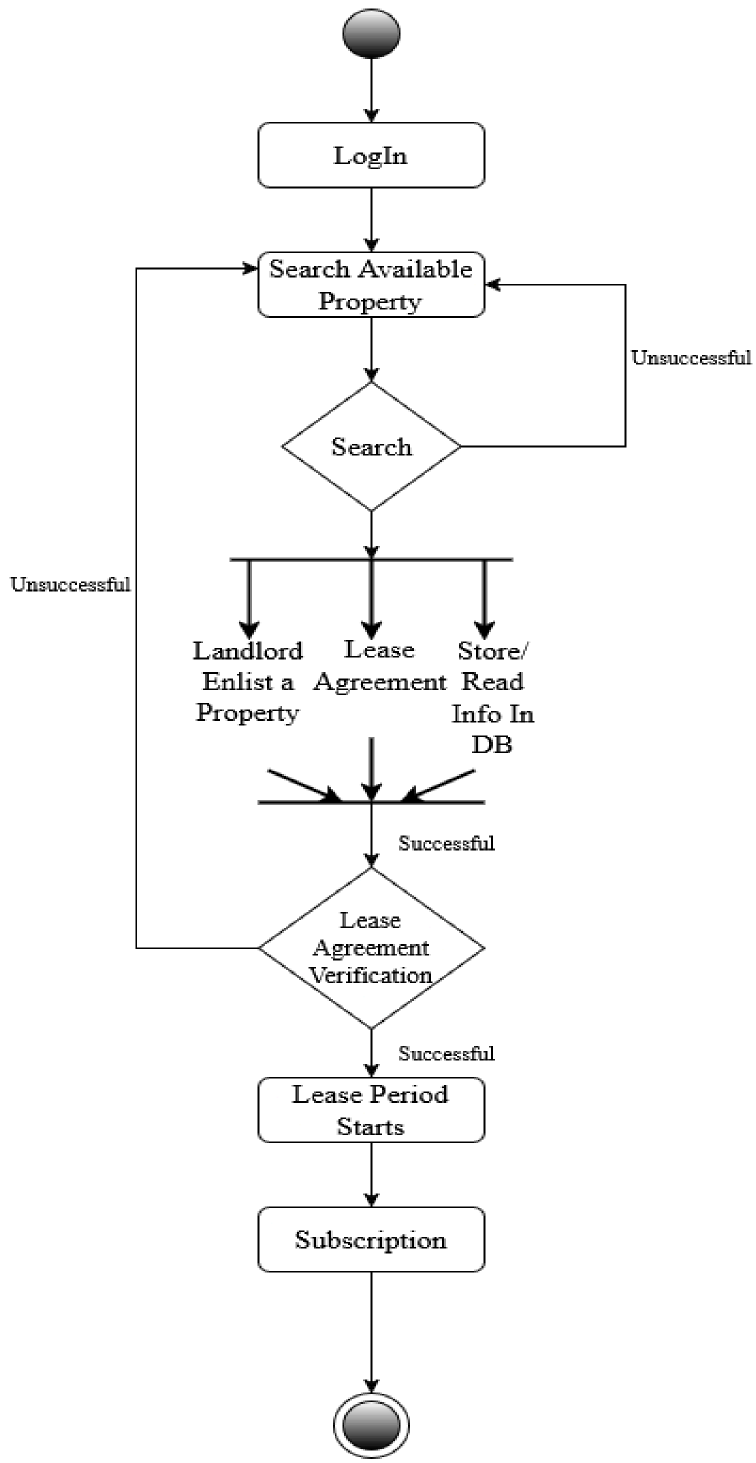


Figure 21: Property Management Activity Diagram

Activity Diagram

Tenant Management System

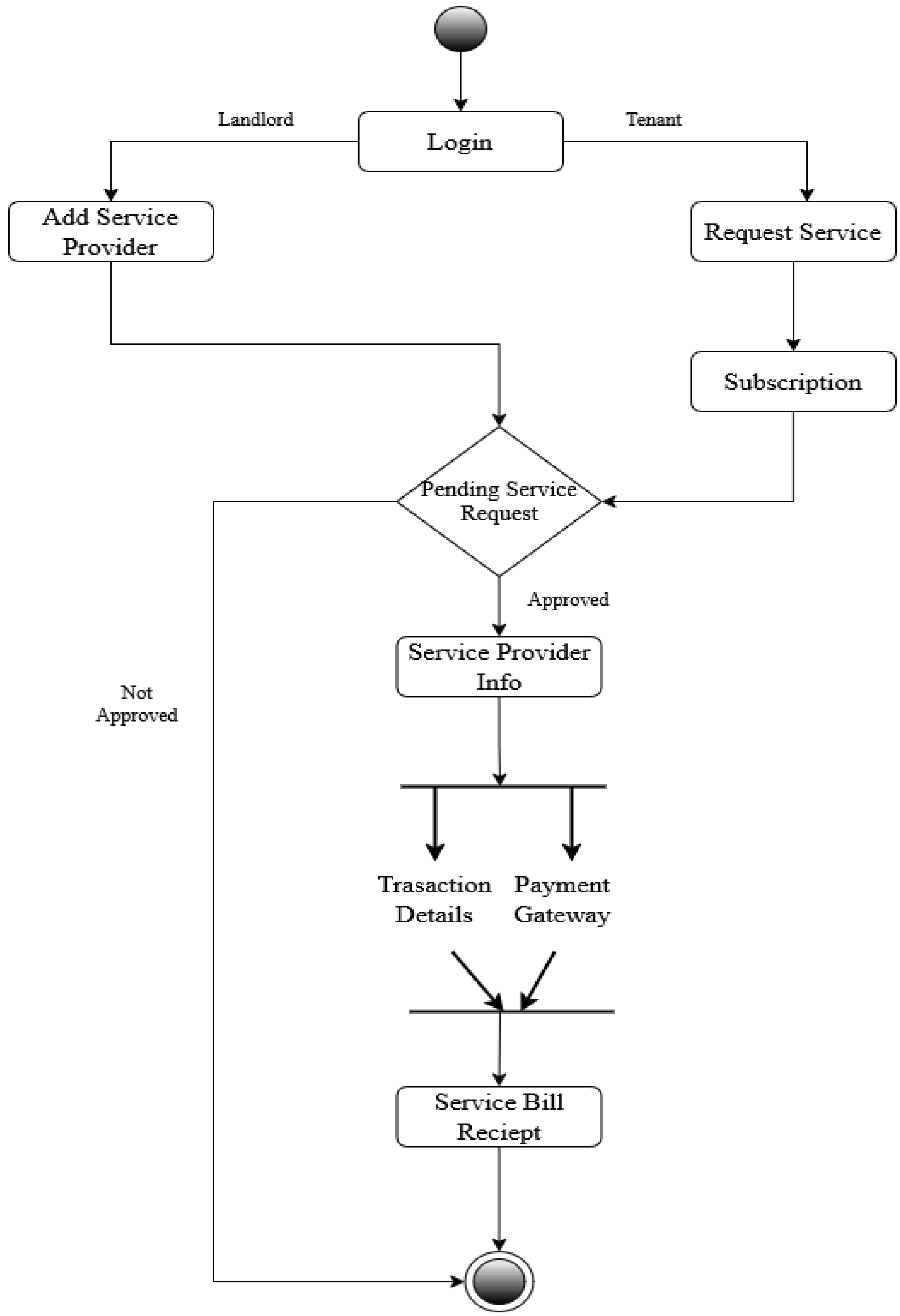


Figure 22: Service Management Activity Diagram

Activity Diagram

Tenant Management System

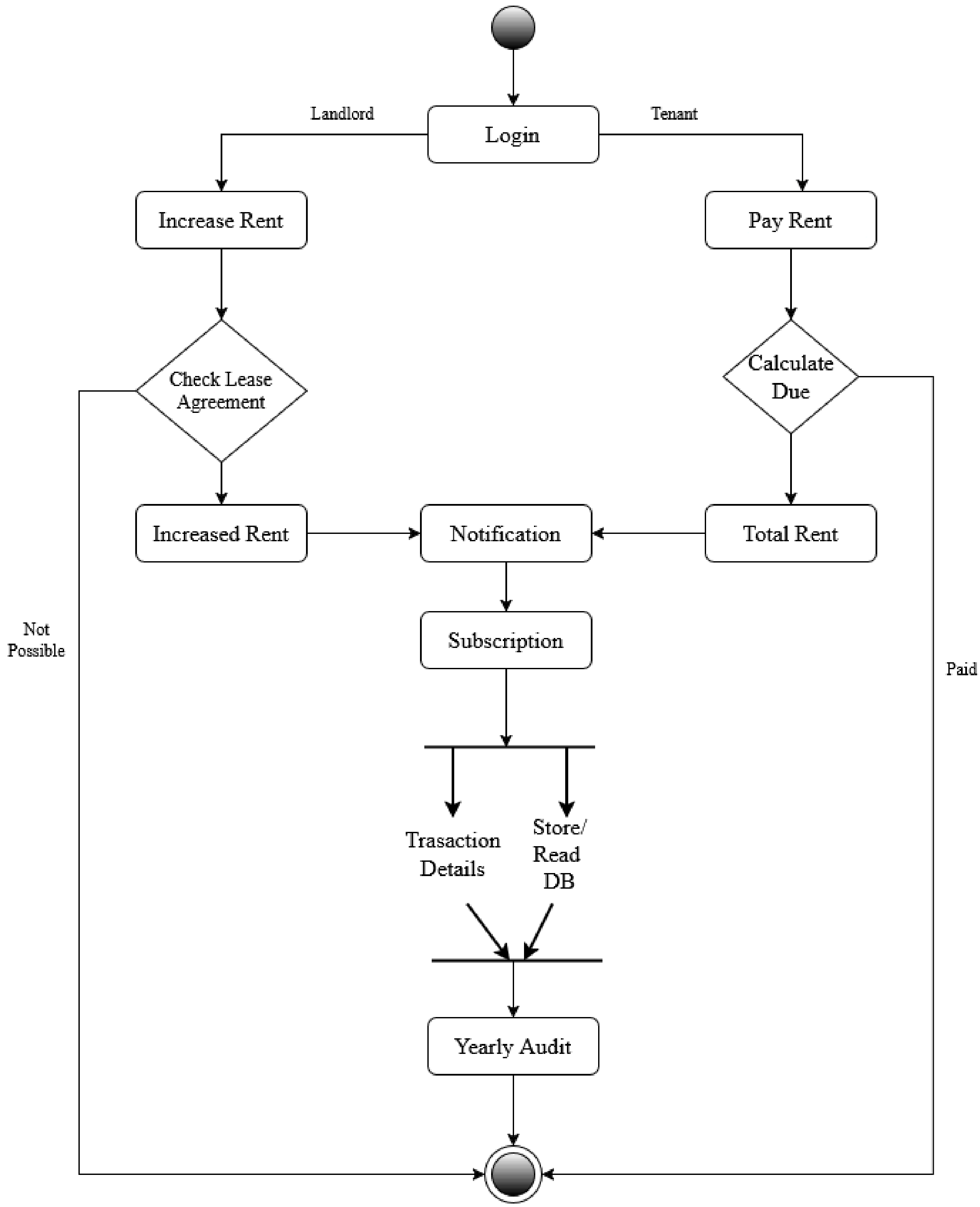


Figure 23: Payment Management Activity Diagram

Activity Diagram

Tenant Management System

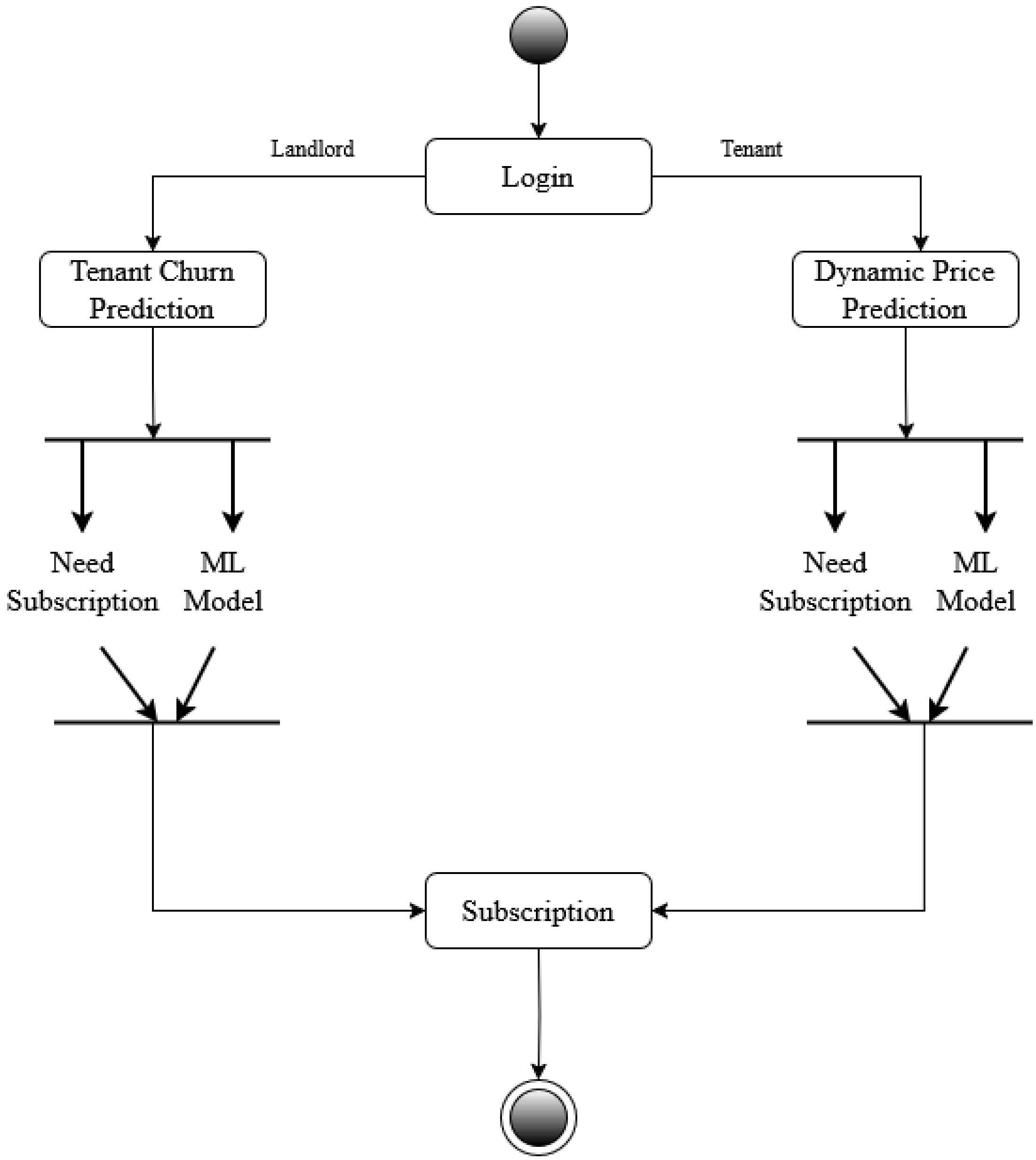


Figure 23: Prediction Model Activity Diagram

d5. Deployment diagram.

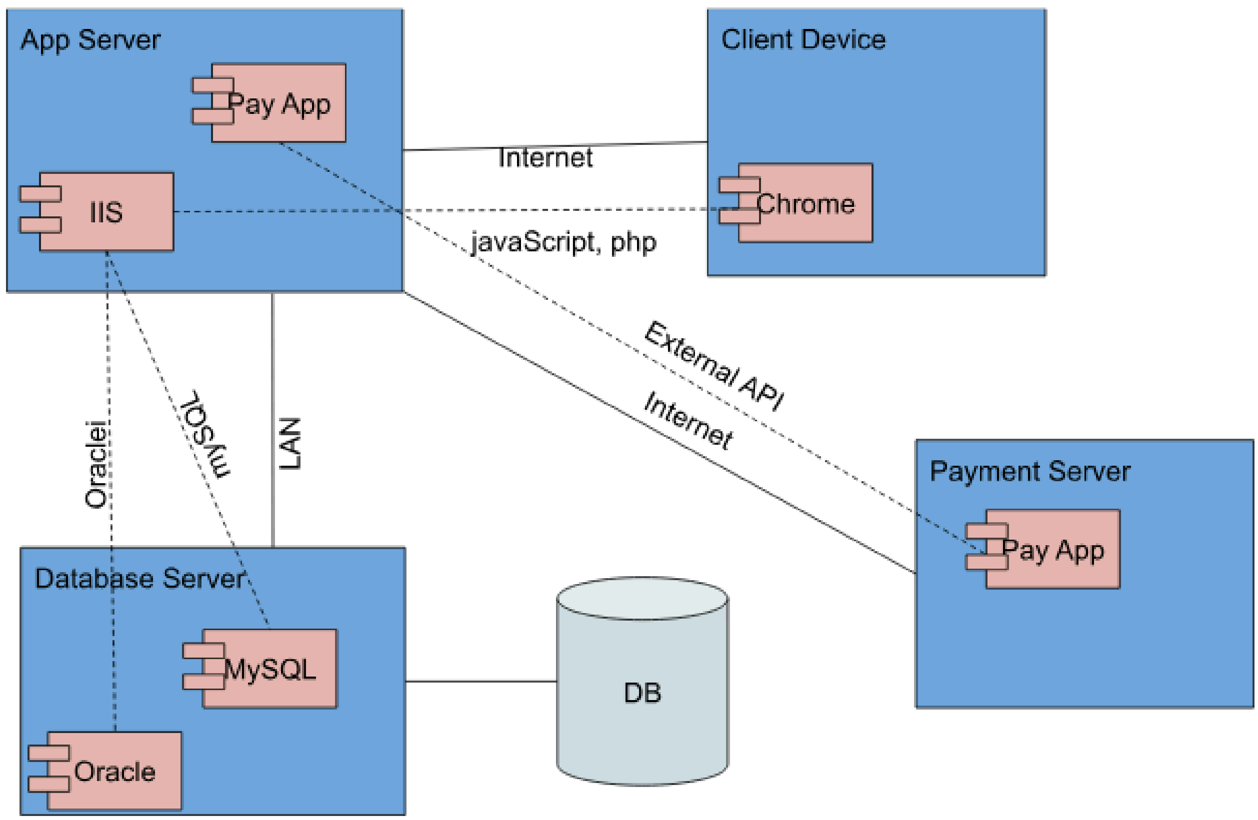


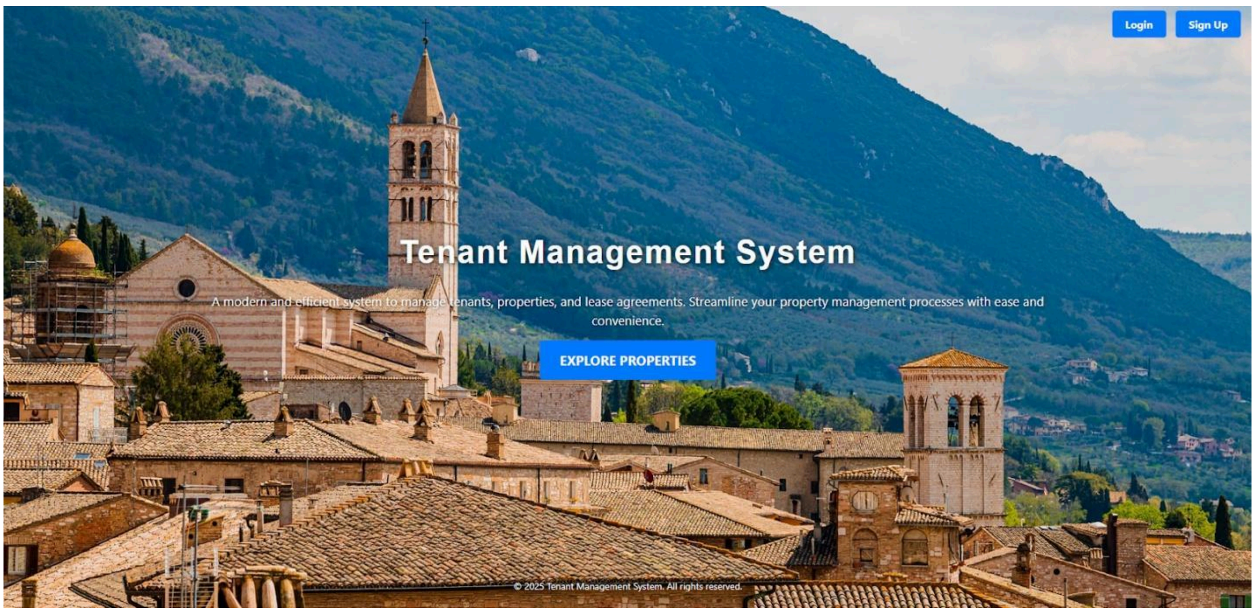
Figure 6.24: Deployment Diagram

Chapter 7: Input and Output Design and Result Analysis.

a. System Input Design System Output Design

a1. Property Exploration Module

Action 01: Browse Available Properties



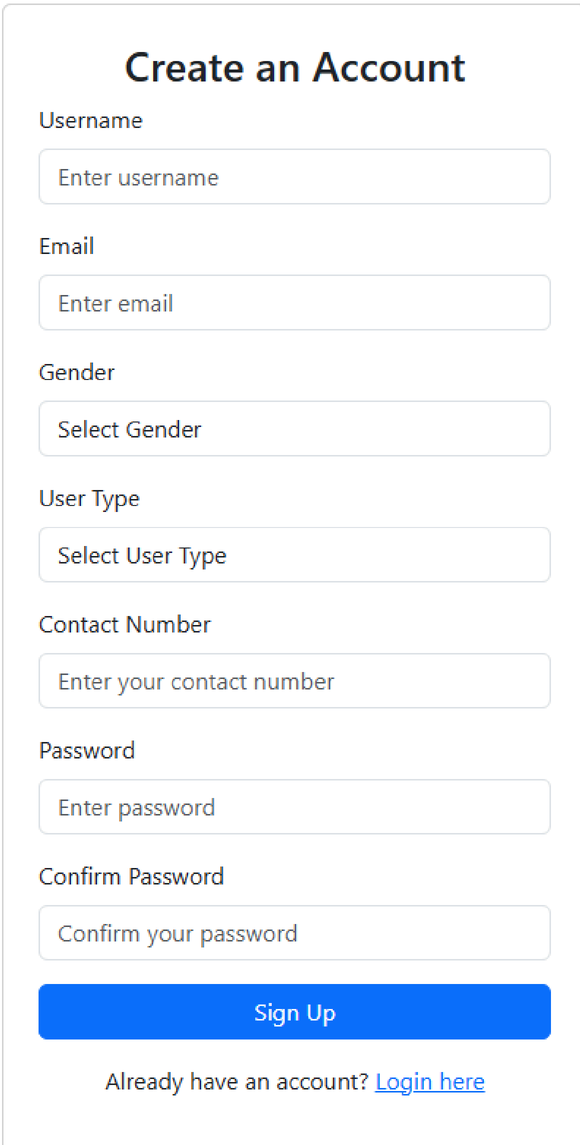
Purpose:
To allow users (tenants, landlords, or agents) to explore and view a list of available properties for lease or purchase. The module provides an overview of properties managed by the system, enabling users to make informed decisions.

Controls and Options:

- The property listings feature provides users with a scrollable or paginated list of available properties, each displaying essential details such as location, price, and property type to facilitate quick browsing. To enhance usability, search and filter options allow users to refine their searches based on specific criteria, including location, price range, or property type—whether residential, commercial, or other categories. Each property entry includes a "View Details" button, which redirects users to a comprehensive page with additional information, such as high-quality images, detailed descriptions, and lease terms. Additionally, a "Contact Agent" button is integrated into each listing, enabling users to directly communicate with the property manager or landlord for inquiries or further assistance, streamlining the rental or purchase process. This combination of features ensures a seamless and efficient user experience.

a2. User Registration Module

Action 02: Account Creation



Purpose:
To allow new users (tenants, landlords, or agents) to create an account in the Tenant Management System. This ensures secure access to property listings, lease agreements, and other system features.

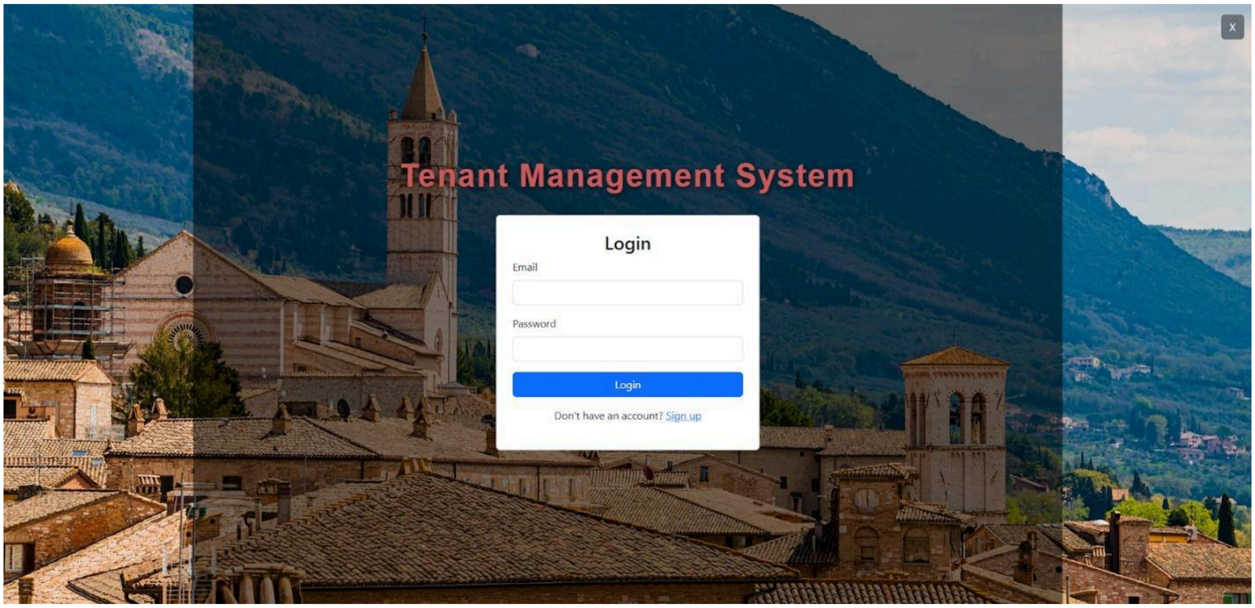
Controls and Options:

The registration form includes several input fields to collect user information securely and efficiently. The Username field is a free-text input that allows users to create a unique identifier. The Email field validates the entered email format and checks against existing registrations to prevent duplicates. For Gender, a dropdown menu offers standard options (e.g., Male, Female, Other), while the User Type dropdown lets users specify their role (e.g., Tenant, Landlord, Agent). The Contact Number field includes format validation to ensure correct phone number entry. For security, the Password and Confirm Password fields mask input with dots and verify that both entries match. Below the form, a "Login Here" hyperlink redirects existing users to the login page. Finally, the "Sign Up" button validates all inputs and creates the account if all criteria are satisfied, completing the registration process. This structured approach ensures data accuracy and a smooth user experience.

a3. User Authentication Module

Action 03: User Login

Purpose:
To provide secure access to the Tenant Management System for registered users (tenants, landlords, or agents). This ensures only authorized individuals can manage properties, leases, or tenant interactions.

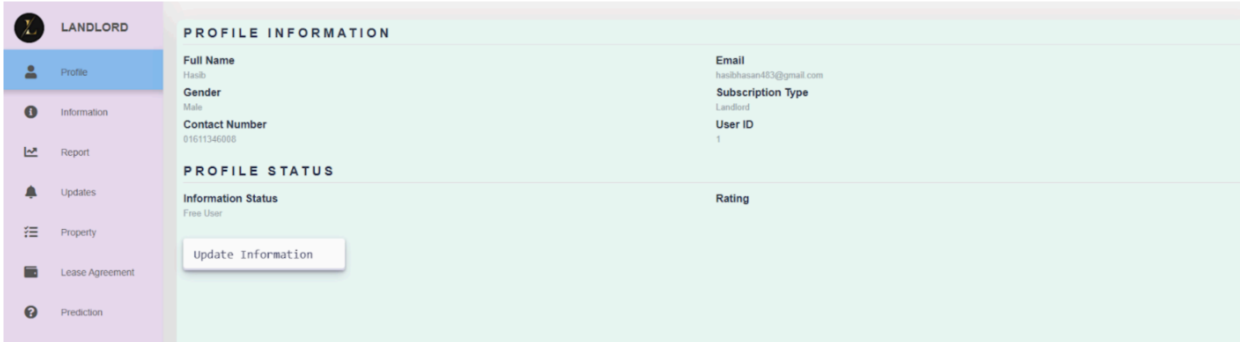


Controls and Options:

- The login interface features an Email field that validates the entered format and verifies if the account exists in the system, along with a Password field that securely masks input with dots (••••) to protect sensitive credentials. The Login button authenticates the user, granting dashboard access upon successful verification or displaying an error like *"Invalid email/password"* if credentials are incorrect, while the Sign Up button redirects new users to the registration page for account creation. Additional enhancements may include a "Forgot Password?" option for secure credential recovery and an optional "Remember Me" checkbox for convenient session persistence on trusted devices, ensuring both security and user convenience.

a4. User Profile Management Module

Action 04: View and Update Profile Information



Purpose:

To allow users to review and modify their personal and account details, ensuring accurate and up-to-date information is stored in the Tenant Management System.

- The profile interface displays read-only fields showing the user's essential information, including their registered Full Name (e.g., "Hello"), selected Gender (e.g., "Male"), saved Contact Number (e.g., "0101134008"), and registered Email (e.g., "haibhanahf@gmail.com"). Additionally, it indicates the account's Subscription Type (e.g., "Free User") and unique User ID (e.g., "1") for reference. For profile management, an Update Information button redirects users to an editable form where they can modify certain details like their name or contact number, while the Rating Section remains available for potential user ratings, though it appears empty in the current view. Notably, the "Profile Status" section may update dynamically to reflect account upgrades (e.g., switching to "Premium User"), while sensitive fields like Email and User ID remain non-editable to ensure security and prevent unauthorized changes. This setup balances transparency with user control over their personal data.

a5. Landlord Analytics & Reporting Module

Action 05: Monthly Usage Report Overview

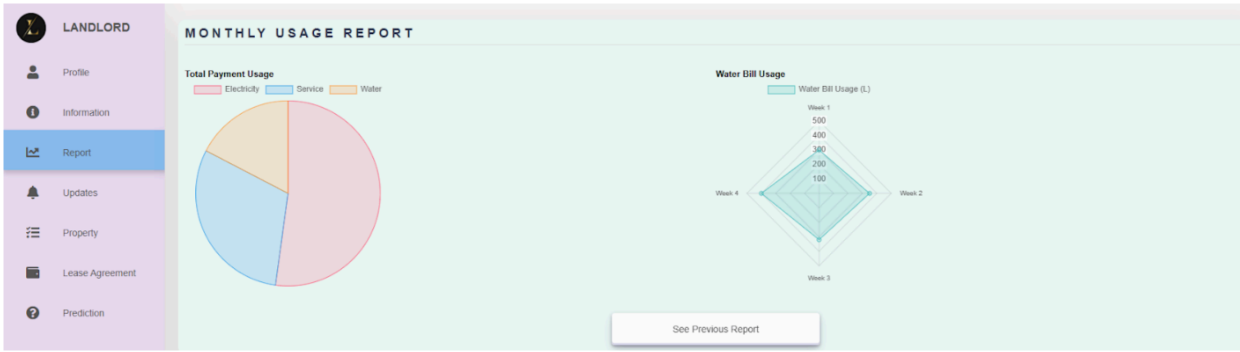
Purpose:
To provide landlords with a consolidated view of utility and service bill usage across their properties, enabling better financial tracking and decision-making.

Controls and Options:

- The Monthly Usage Report Overview provides an interface that organizes billing information displays Different charts such as Bar chart for service bill usage and line chart for electricity bill usage each segmented to weeks. The Landlord can study and change the bill type along with visuals to understand the amount, changes and trend over time. This tab-based filtering system enables efficient financial tracking by separating different expense categories while maintaining an intuitive user experience.

a6. Landlord Billing & Analytics Module

Action 06: Monthly Resource Usage Tracking



Purpose:
To provide landlords with a detailed breakdown of utility payments (water, services, etc.) across their properties, enabling cost analysis and operational planning.

Sub-Action 1: Total Payment Overview

Controls and Options:

- The interface organizes billing information through three category tabs for streamlined navigation. The Event/Exit tab likely handles one-time transactions or move-out related charges, while the Service tab consolidates recurring fees such as maintenance or security payments. The Water tab specifically tracks water usage metrics and associated costs. Functionally, users can click any of these tabs to dynamically filter the report, displaying only the relevant payment type - allowing for quick access to specific financial data without overwhelming the view with unrelated information. This tab-based filtering system enables efficient financial tracking by separating different expense categories while maintaining an intuitive user experience.

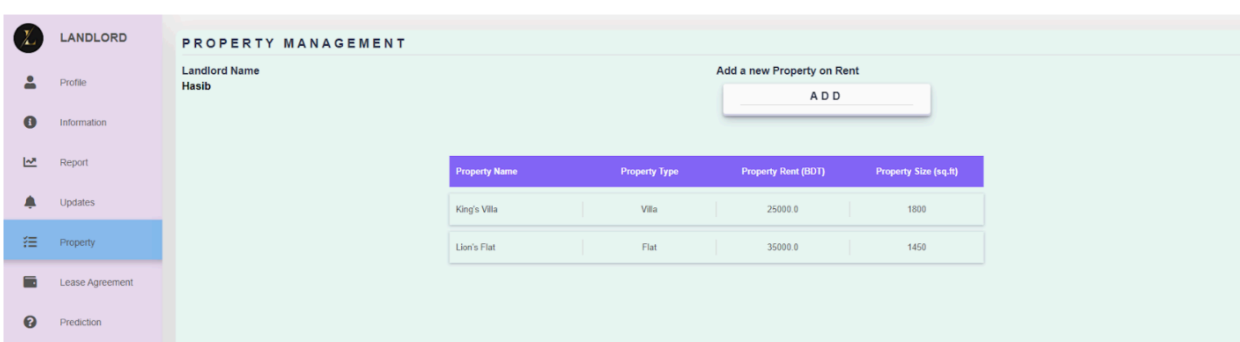
Sub-Action 2: Water Usage Breakdown

Controls and Options:

- The water usage dashboard features a primary "Water Bill Usage (L)" metric that clearly displays total consumption (e.g., 5000L), providing users with an instant overview of their water expenditure, while seven detailed line items (Water 1-7) beneath it offer granular insights into sub-categories such as individual property usage, tenant-specific allocations, or tiered pricing structures, with interactive hover/click functionality that reveals trends, historical data, and billing parameter adjustments. The top navigation bar includes essential financial management tools: Profile/Information for account settings, Report for data export, Updates for usage pattern alerts and payment deadlines, direct links to Property details and Lease Agreements, and Prediction tools for forecasting future consumption, creating a comprehensive system that enables detailed monitoring and analysis of water usage while facilitating informed decision-making and efficient utility management.

a7. Landlord Property Management Module

Action 07: Property Portfolio Management



Purpose:
To enable landlords to view, add, and manage properties available for rent, including tracking key details like type, rent, and size.

Sub-Action 1: Landlord Profile & Tools

Controls and Options:

- The landlord dashboard prominently displays the landlord's name (e.g., "Hasib") for quick identification, accompanied by a set of interactive buttons that provide comprehensive management tools: the Information button allows viewing detailed landlord profiles, Report generates performance analytics for properties, Updates checks system notifications including new lease requests, Property offers direct access to listings, Lease Agreement manages active tenant contracts, and Prediction forecasts key metrics like rental income and occupancy rates, creating a centralized control panel for efficient property management.

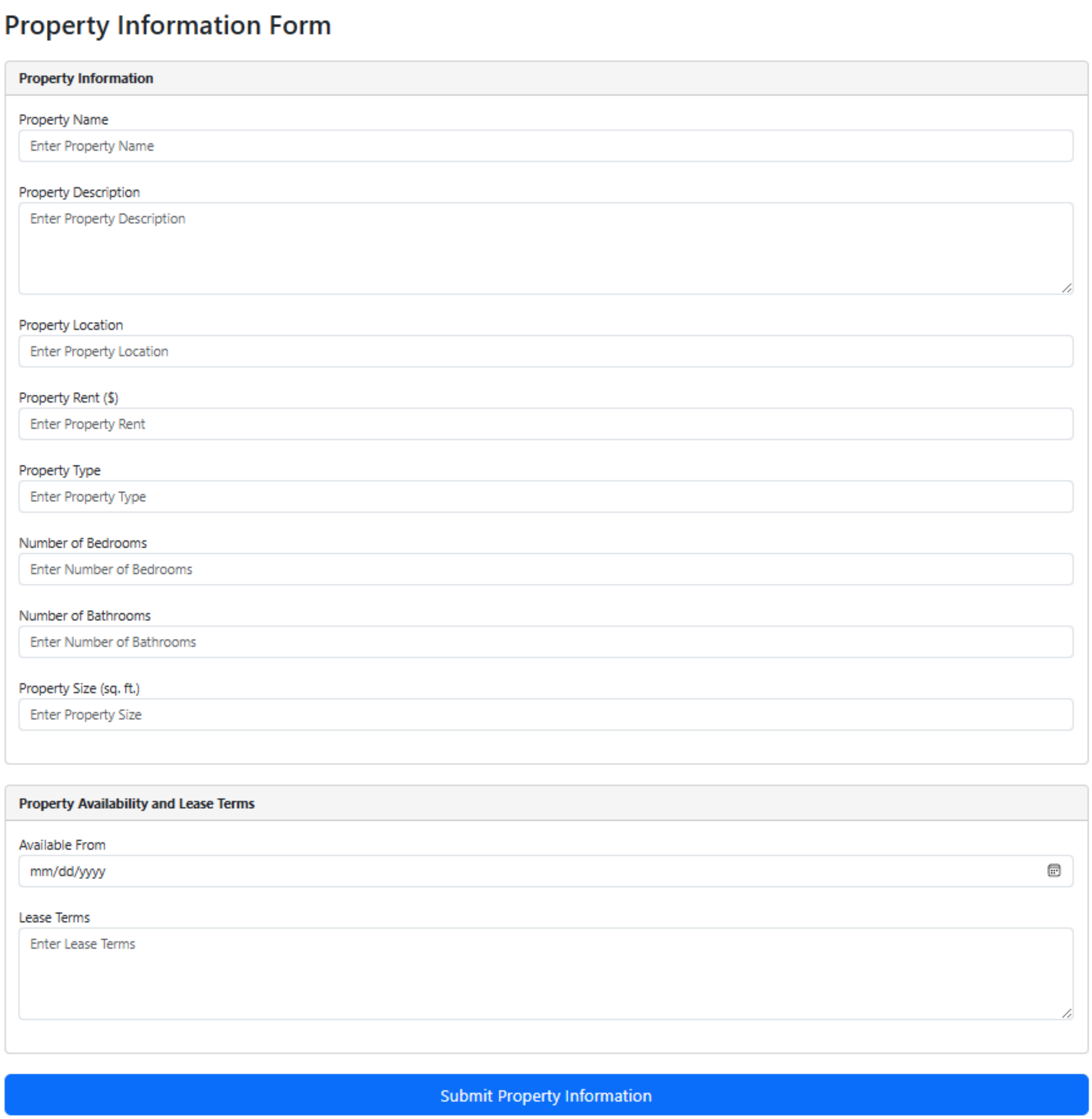
Sub-Action 2: Add/Manage Properties

Controls and Options:

- The "Add a New Property on Rent" section features an "ADD" button that opens a form for entering property details such as name, type, rent, and size. Below this, a Property Table organizes listings with columns for Property Name (e.g., "King’s Vita"), Property Type (e.g., "Vita," "Flat"), Property Rent (EQT) (e.g., "25000.0" BDT), and Property Size (m^2) (e.g., "1800"). Users can click rows to edit details or sort/filter columns (e.g., by highest rent). The system also supports bulk actions, like deactivating multiple properties simultaneously, streamlining large-scale management. This layout combines intuitive data entry with flexible table operations for efficient property listing maintenance.

a8. Property Listing Management Module

Action 08: Add/Edit Property Information



Purpose:
To allow landlords or property managers to input or update detailed property information, ensuring accurate listings for potential tenants.

Sub-Action 1: Core Property Details

Controls and Options:

- The property input form includes several fields to capture essential details: a Property Name free-text field (e.g., "Sunrise Apartments") for identification, followed by a Property Description multiline field where users can list features and amenities. The Property Location field offers address input with autocomplete functionality for accuracy, while the Property Rent ($) field ensures valid currency entry through numeric validation. A Property Type dropdown provides standardized options like "Apartment" or "House," and numeric inputs for Bedrooms and Bathrooms (e.g., "3") quantify the layout. Finally, the Property Size (sq. ft.) field captures the unit's dimensions numerically. Together, these fields streamline property listing creation while maintaining data consistency.

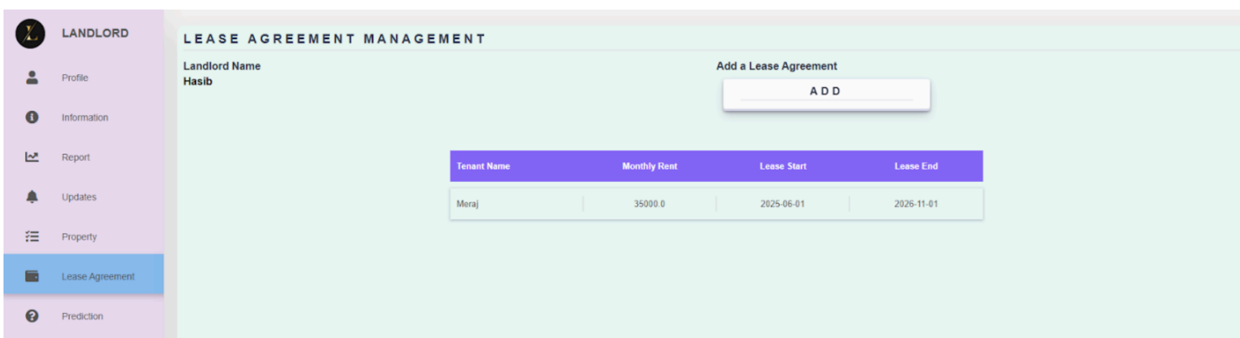
Sub-Action 2: Availability & Lease Terms

Controls and Options:

- The form includes a Date Picker with an "Available From" calendar widget that allows users to select the property's move-in date, ensuring clarity on occupancy timing. For lease specifications, the Lease Terms field offers flexibility through either free-text entry or a dropdown menu with predefined options like "12-month lease" or *"Flexible"*, accommodating various rental agreements. Finally, the Submit Button validates all entered information—checking for completeness and correctness—before saving the data to the database and automatically redirecting users to the updated property listings, creating a seamless transition from data entry to viewing results. This combination of intuitive date selection, adaptable lease terms, and automated validation streamlines the property listing process.

a9. Lease Agreement Management Module

Action 09: Create/Manage Lease Agreements



Purpose:
To enable landlords to generate, track, and modify lease agreements for tenants, ensuring legal compliance and clear rental terms.

Sub-Action 1: Landlord & Agreement Overview

Controls and Options:

- The interface prominently displays the landlord's name (e.g., "Hasib") to establish accountability and personalization within the lease management system. Directly accessible is an "ADD" button, which serves as the primary action for initiating new lease agreements - when clicked, it launches a comprehensive form that allows landlords to either create contracts from scratch or select from pre-existing templates, streamlining the documentation process while maintaining flexibility for custom terms. This design ensures landlords can efficiently generate legally-binding agreements while keeping all records clearly attributed under their name in the system.

Sub-Action 2: Lease Agreement Fields

Controls and Options:

- The lease agreement form includes core fields to capture essential rental terms: an Account Name field identifies the tenant or property (e.g., "Label"), while a Monthly Rent input ensures accurate currency entry (e.g., "36000.0"). Lease Start/End date pickers define the tenancy period (e.g., June 1, 2025, to November 1, 2026), with a clear visual timeline. Dynamic elements like the "[Min:]" placeholder indicate customizable clauses (e.g., adjustable minimum lease durations), allowing landlords to tailor agreements while maintaining standardized data structure for easy processing and compliance. This balance of fixed fields and flexible terms accommodates diverse rental scenarios.

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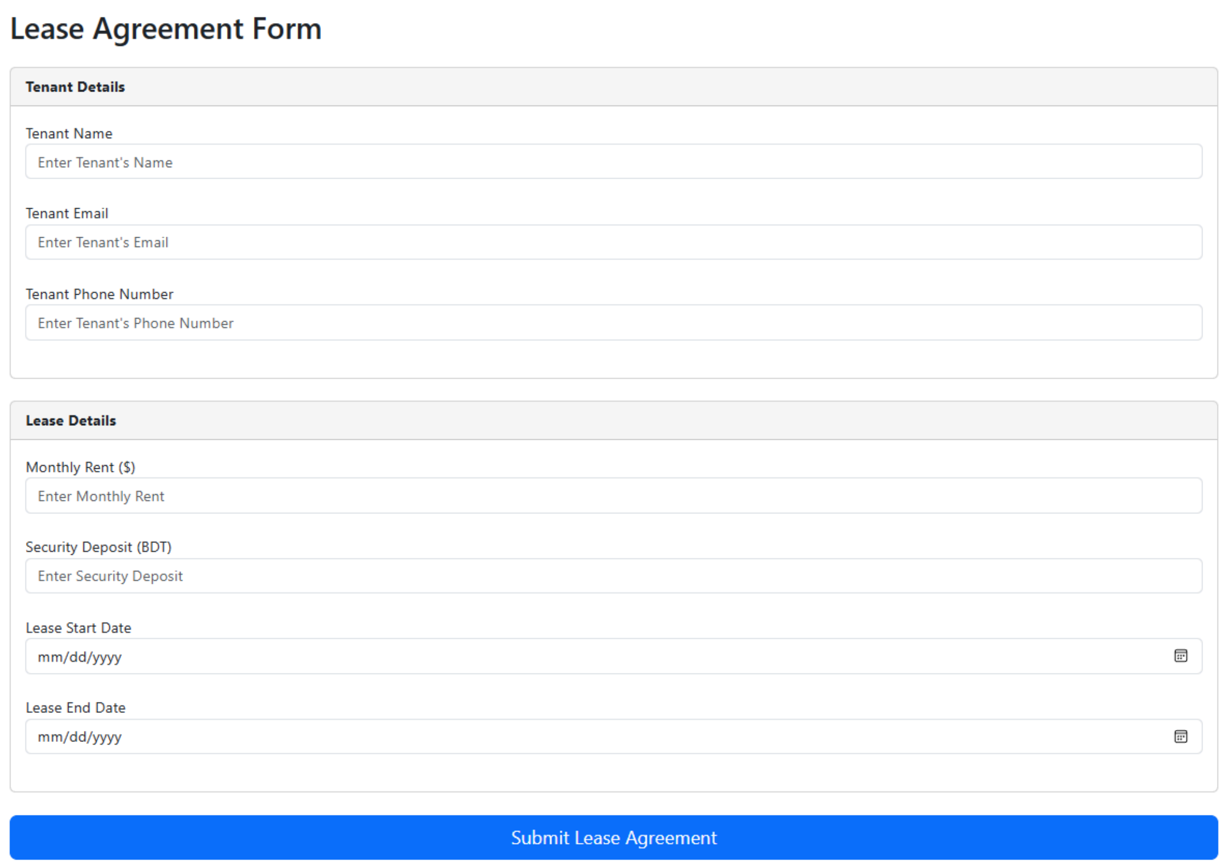
a10. Lease Agreement Creation Module

Action 10: Generate New Lease Agreement



Lease Agreement Form

Tenant Details

Tenant Name

Enter Tenant's Name

Tenant Email

Enter Tenant's Email

Tenant Phone Number

Enter Tenant's Phone Number

Lease Details

Monthly Rent ($)

Enter Monthly Rent

Security Deposit (BDT)

Enter Security Deposit

Lease Start Date

mm/dd/yyyy

Lease End Date

mm/dd/yyyy

Submit Lease Agreement

Purpose:

To facilitate the creation of legally binding lease agreements between landlords and tenants by capturing essential tenant and lease details in a standardized format.

---

a11. Tenant Information Collection

Controls and Options:

- The lease agreement form includes essential input fields to capture tenant details: a Tenant Name free-text field collects the occupant's full legal name for contractual purposes, while a Tenant Email field validates the format (e.g., user@domain.com) to ensure reliable communication. The Tenant Phone Number field enforces proper formatting (e.g., +880XXXXXXXXXX) through real-time validation, preventing entry errors. These fields collectively establish the tenant's identity and contact framework, forming the foundation for all lease-related correspondence and documentation while maintaining data accuracy through systematic validation protocols. The clean, organized layout minimizes entry errors while meeting legal requirements for tenant identification.

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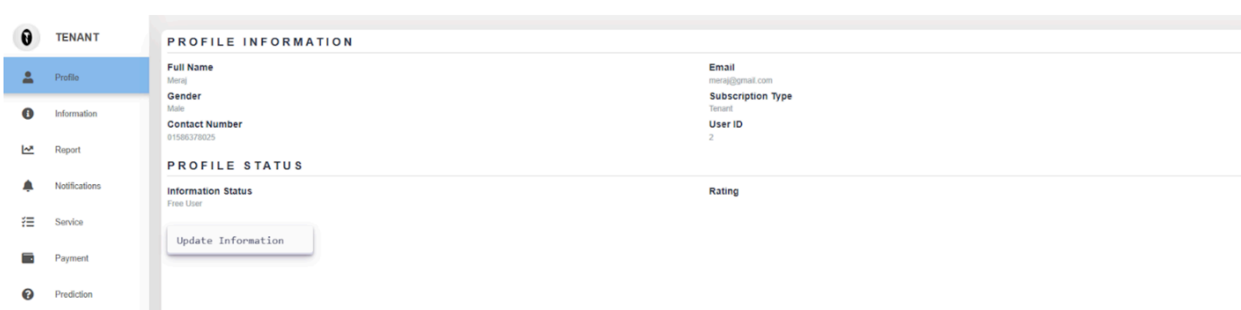
a12. Tenant Profile Module

Action 11: Tenant Profile Management

Purpose:

To allow tenants to view and manage their personal information, account status, and subscription details within the Tenant Management System.



Sub-Action 1: Personal Information

Controls and Options:

- The tenant profile section presents key user information through clearly labeled display fields: the Full Name field shows the tenant's registered name (e.g., "New"), while the Gender field indicates their selected demographic information (e.g., "Male"). Contact details include a validated Contact Number (e.g., "0106871005") and the account's primary Email address (e.g., "mcm@gmail.com"), both displayed for quick reference. A non-editable User ID (e.g., "2") serves as the unique system identifier for the tenant record. These read-only fields provide an at-a-glance overview of the tenant's core profile information while maintaining data security by preventing unauthorized modifications to sensitive details like the email and ID. The clean, organized presentation ensures easy verification of tenant information during lease management or communications.

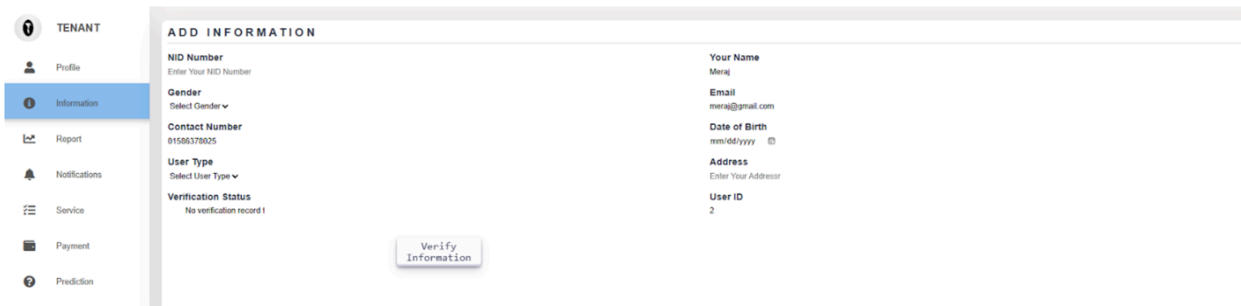
Sub-Action 2: Account Status & Services

Controls and Options:

- The tenant dashboard features a Profile Status section that clearly indicates the user's account tier (e.g., "Free User"), helping tenants understand their current access level and potential limitations. Interactive elements include an Update Information button that redirects to a secure form for editing personal details, and a Prediction feature (located under Payment) that analyzes historical data to forecast upcoming rent or payment trends, enabling better financial planning. The interface effectively balances account transparency with data protection, while the prediction tools and subscription details empower tenants to manage their housing commitments proactively.

a13. Tenant Information Verification Module

Action 12: Verify & Update Tenant Information



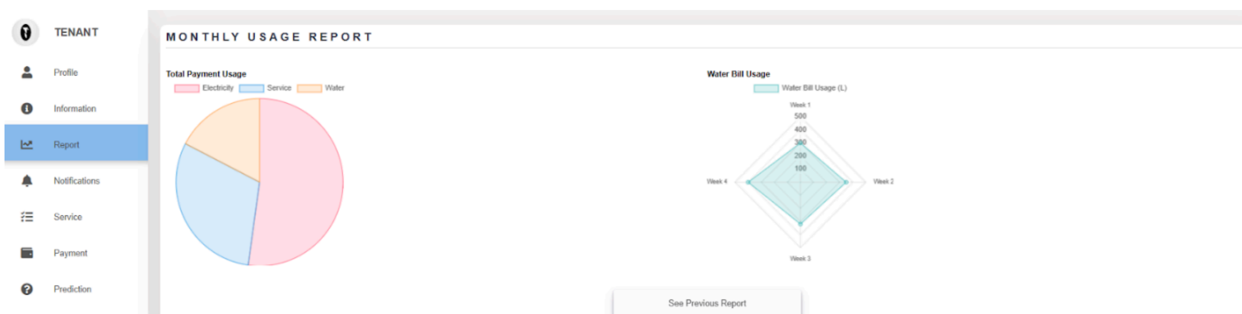
Purpose:
To allow tenants to complete and verify their profile information, ensuring accurate records for lease agreements and system communications.

Controls and Options:

- The "Verify Information" button initiates a secure identity verification process, potentially involving email/SMS confirmations or document uploads to authenticate user details. The form displays confirmed information including the user's full Name, verified Email , and a formatted Date of Birth field with input masking for consistency, along with a free-text Addressand a non-editable User ID (e.g., "2") for system reference. Profile/Information returns to the main dashboard, Report/Notifications accesses account alerts or statements, Service/Payment handles rental payments or service requests, and Prediction offers expense forecasting tools, creating a streamlined user experience that combines identity verification with comprehensive account management features.

a14. Tenant Utility Usage Module

Action 13: Track Monthly Utility Consumption



Purpose:

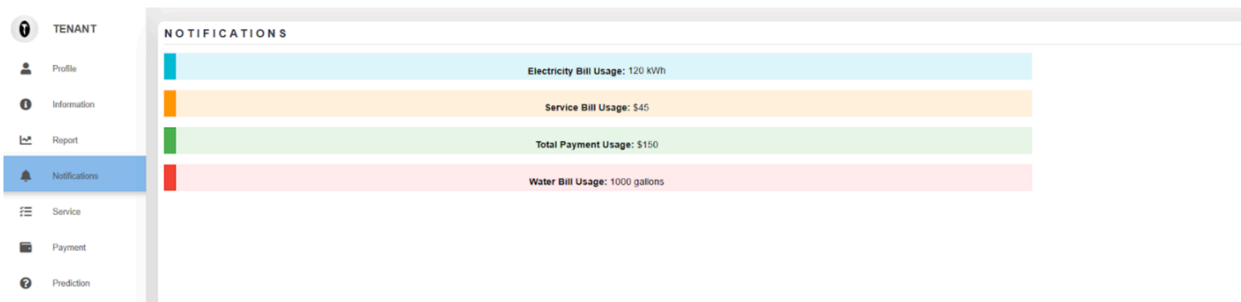
To provide tenants with a transparent breakdown of their monthly electricity and service bill usage, enabling better budget management and awareness of consumption patterns.

Controls and Options:

- This interface provides tenants with a transparent breakdown of their monthly electricity and service bill usage.The electricity usage , service bill, water usage and total payment usage is brought into one dashboard.. A "See More Report" option provides deeper insights, while the top menu offers quick navigation to profiles, alerts, and payments, ensuring efficient cost monitoring and management. Both dashboards balance precise metrics with user-friendly visuals for actionable insights.

a15. Tenant Notifications Module

Action 14: View Utility and Payment Alerts



Purpose:

To centralize critical notifications about utility usage and payments, helping tenants stay informed about upcoming bills, consumption thresholds, and account activity.

Controls and Options:

- The dashboard prominently displays real-time metrics to keep users informed of their current resource consumption and expenses. The Electricity reading shows "120 kWh," representing usage for the current billing cycle, while the Water metric indicates "1000 gallons" of total consumption, with potential alerts for unusual spikes that may suggest leaks. The Service Bill is listed as "$45," likely covering maintenance or shared amenities fees. These metrics are presented with a clear visual hierarchy—bold formatting (e.g., "Service Bill Usage") draws attention to urgent or high-priority items, ensuring users quickly spot critical information. This layout provides an efficient, at-a-glance overview of utility usage and costs while emphasizing areas requiring immediate attention.

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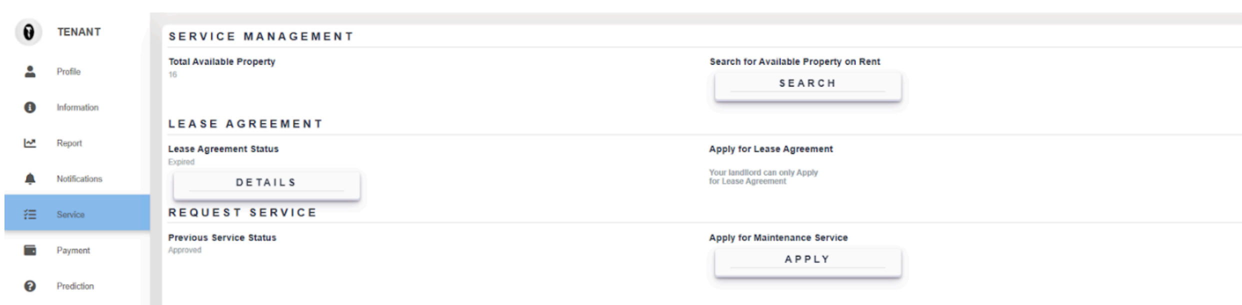
a16. Tenant Service Management Module

Action 15: Property and Lease Service Requests



Purpose:
To enable tenants to search for rental properties, manage lease agreements, and request maintenance services through a centralized platform.

Controls and Options:

- The dashboard features summary widgets that provide quick insights: Total Available Property displays the count of rentable units. Lease Agreement Status shows the number of active contracts and Previous Service Status tracks resolved or pending maintenance requests . Interactive buttons enhance functionality—the SEARCH button filters properties by criteria like location or price, while the APPLY for Lease Agreement button redirects tenants to a landlord-initiated process, clarifying that direct tenant applications are not permitted, ensuring a structured and transparent leasing workflow.

The "APPLY for Maintenance Service" button serves as the gateway for tenants to submit repair or upkeep requests, opening a comprehensive form that likely includes a dropdown menu to categorize the issue type (e.g., plumbing, electrical), a priority selector to distinguish between urgent and normal requests, and an option to upload photos as supporting evidence for the reported problem. This streamlined process ensures accurate documentation and efficient resolution of maintenance needs. The top menu bar reinforces workflow efficiency, with the Service Management tab remaining active during these actions, while adjacent tabs like Payment and Prediction provide quick access to financial tools or usage forecasts, creating a cohesive interface that balances immediate repair requests with broader property management functions.

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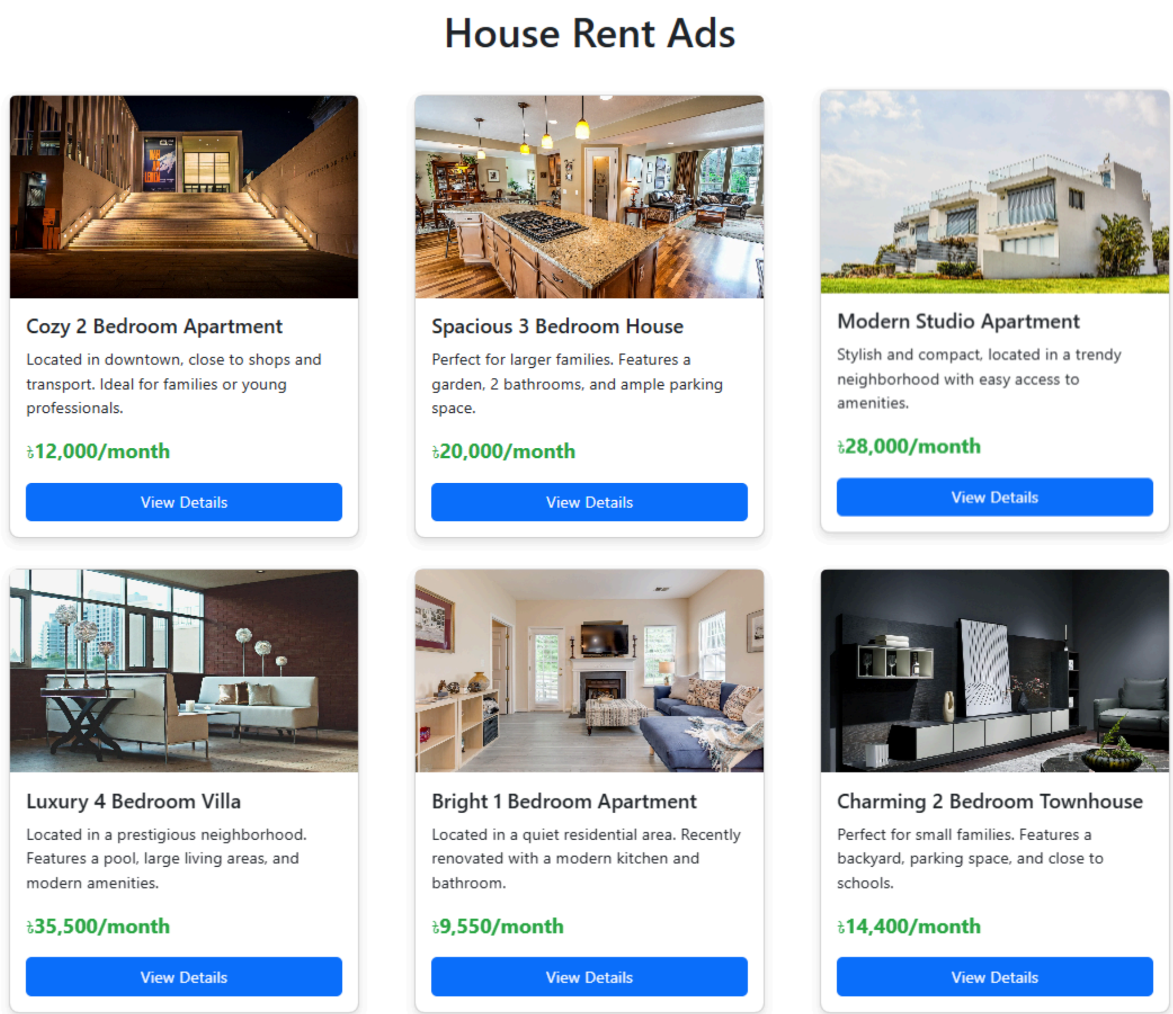
a17. Property Listing Module

Action 16: Browse Available Rental Properties



Purpose:
To provide tenants with a comprehensive view of available rental properties, including key details like location, price, and features, facilitating informed decision-making.

Sub-Action 1: Property Listings Overview

Controls and Options:

- The property listings are presented as visually organized cards, each containing key rental information for quick tenant review. The title prominently states the property type (e.g., "Cozy 2

Bedroom Apartment"), followed by a concise description that highlights attractive features like prime locations ("downtown") or amenities ("garden"). Monthly pricing stands out with currency formatting and an eye-catching emoji (e.g., 12,000/month), while the "View Details" button allows deeper exploration of each listing. The design employs clear visual hierarchy—emojis emphasize cost, consistent card dimensions enable rapid scanning, and strategic information placement (features → price → CTA) guides the user's attention flow. This card-based layout optimizes both information density and browsing efficiency, enabling tenants to compare multiple properties at a glance before selecting candidates for further investigation through the detailed view option.When users click the "View Details" button, the system opens a dedicated property page featuring high-resolution images for visual assessment, expanded descriptions with technical specifications (e.g., square footage, lease term options), and direct contact methods (e.g., landlord phone/email or agent inquiry forms), creating a seamless transition from discovery to decision-making. These behind-the-scenes features and workflows ensure users efficiently navigate from broad searches to granular property evaluations.

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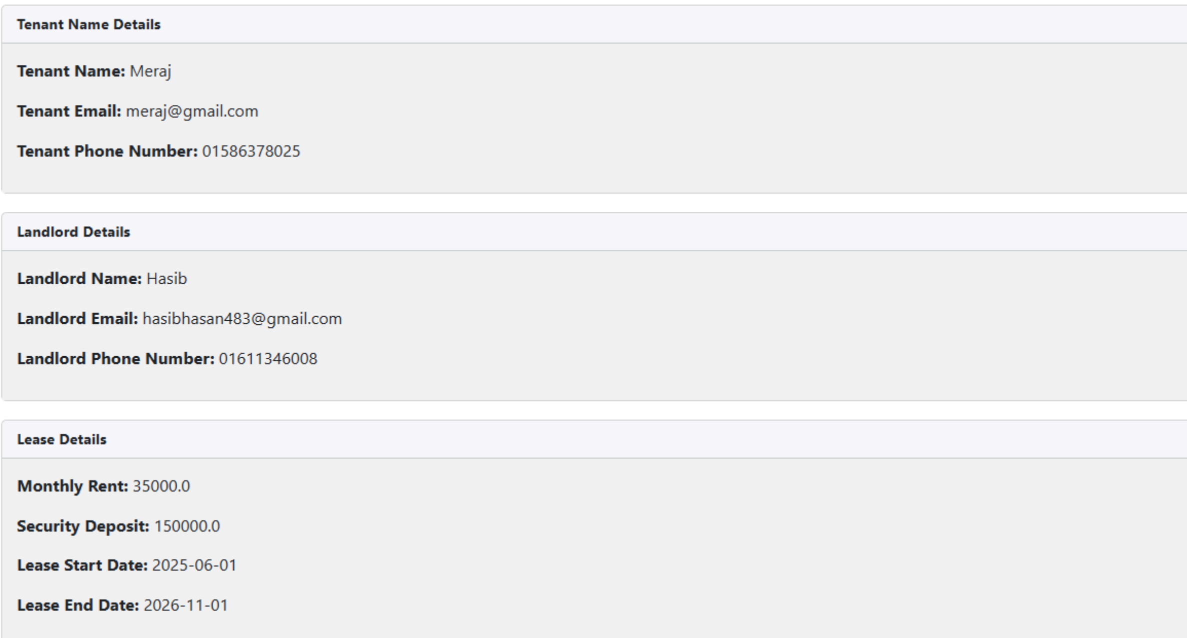
a18. Module Name: Lease Agreement Details Module

Action 17: View Lease Agreement Summary



Purpose:

To provide a consolidated view of lease agreement details for both tenants and landlords, ensuring transparency and easy access to critical rental information.

Sub-Action 1: Tenant & Landlord Information

Controls and Options:

- This bidirectional contact framework ensures both parties can reliably reach each other for operational (rent payments, maintenance) or legal (lease terms, notices) purposes, with all details presented in a standardized format to prevent miscommunication. The inclusion of multiple contact methods (email + phone) accommodates different communication preferences while meeting tenancy agreement requirements. The lease agreement's financial terms are presented with precision and transparency: the Monthly Rent is specified as "35000.0" while the Security Deposit of "150000.0" (refundable under standard conditions) is conspicuously displayed to ensure both parties acknowledge this upfront cost. For the tenure dates, the Lease Start ("2025-06-01") and Lease End ("2026-11-01") follow ISO date formatting to eliminate regional interpretation differences, clearly defining the 17-month fixed-term agreement. This structured presentation of monetary obligations and lease duration minimizes ambiguities, with the decimal-place consistency in financial fields implying system-generated accuracy for billing purposes, while the YYYY-MM-DD date format ensures universal clarity for contractual enforcement

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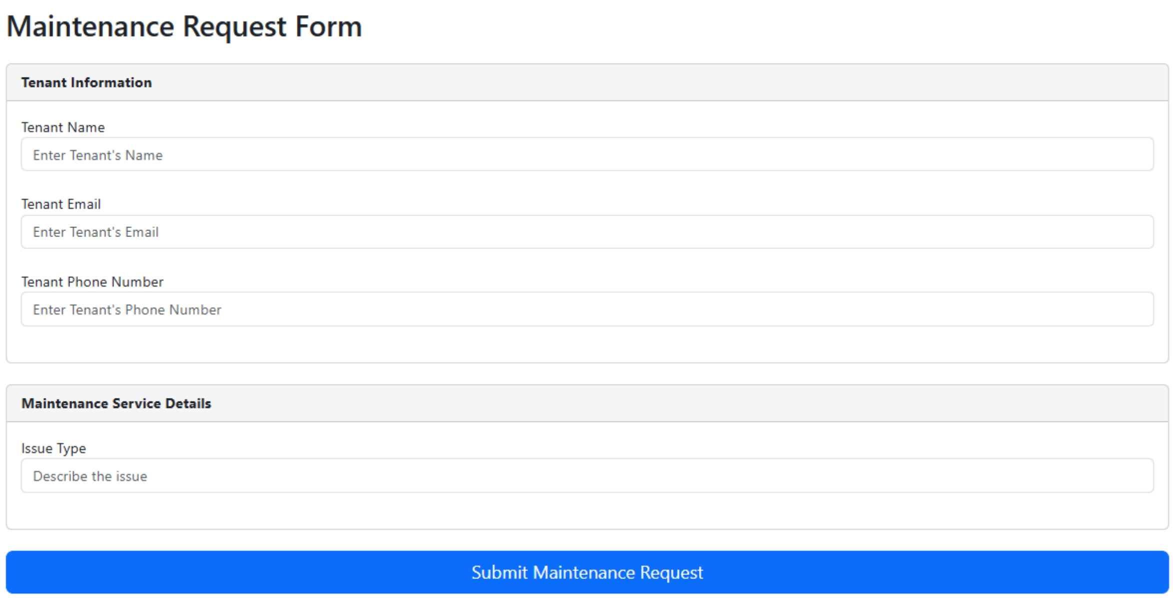
a19. Maintenance Request Module

Action 18: Submit Maintenance Request



Purpose:

To enable tenants to report property maintenance issues efficiently, ensuring timely repairs and clear communication with landlords or property managers.

Sub-Action 1: Tenant Information

Controls and Options:

- The maintenance request form features an Issue Type dropdown menu with categorized options (e.g., "Plumbing," "Electrical") to standardize service requests, accompanied by a Description Box for free-text details (e.g., "Kitchen sink leaking under the cabinet"), enabling tenants to provide specific problem context. The "Submit"

Button validates all entered information, transmits the request to the landlord/property manager, and automatically generates a unique tracking ticket for reference. Upon submission, the system triggers auto-notifications, sending the tenant a confirmation email/SMS while alerting the landlord to prioritize the issue, followed by ongoing status tracking visible in the tenant's "Service" tab (e.g., status updates like "Pending" or "Resolved"), creating a closed-loop communication system that ensures transparency and accountability throughout the maintenance process. This end-to-end workflow combines structured reporting with real-time updates to streamline property upkeep.

b. Results Analysis

This section presents the analysis of the results obtained from the application of machine learning models to real estate price prediction and building system optimization. The following subsections detail various mappings, comparisons, and feature-wise evaluations that were carried out to assess the effectiveness of the models, their predictive capabilities, and how they compare with existing systems.

b1. RQ vs Features Mapping Diagram (Analysis Tables and Figures with Narration)

This mapping shows how the research questions (RQs) align with the features used in the study. It identifies the key factors that were analyzed to address each research question and presents a visual representation of this alignment.

- **Research Question Mapping**:
  Each RQ is mapped to a set of features that were used to answer it. For example, RQ1 (How can ML improve the accuracy of property

price predictions?) is linked to features such as property location, size, age, economic factors, etc.

- **Analysis Table**:
  The table below shows the specific features used to answer each research question:

Feature Type	Features in Existing Systems	Features in Current Study
Property Features	Bedrooms, Square footage	Property size, Age, Location, Type of property
Building Features	Energy consumption data	Detailed HVAC performance data, Maintenance history
Economic and Social Features	Market trends, Historical price data	Real-time economic indicators, Demographic data, COVID-19 market impact

Figure

b4. Explanations (Feature-wise Results Comparison with the Existing System)

This subsection provides a detailed feature-wise comparison of the results obtained in this study with the performance of existing systems. It focuses on how the introduction of machine learning and additional features led to improvements in predictions and system optimization.

- **Table**:
  A comparison of key features and their results from the machine learning models versus existing models could look like this:

Feature	Existing System Accuracy	ML-Based Model Accuracy	Improvement (%)
Property size	80%	92%	+12%
Location	75%	88%	+13%
HVAC system performance	70%	85%	+15%
Energy consumption	68%	90%	+22%
Market trends	72%	89%	+17%

Narration:

- **Property Size**: The traditional systems relied on basic data such as square footage, but they did not account for more dynamic factors like property age and neighborhood dynamics. The machine learning model included a broader set of features, resulting in a 12% improvement in accuracy.
- **HVAC Performance**: Existing systems often only used basic energy consumption data, while our ML-based model integrated detailed sensor data and historical maintenance records. This resulted in a 15% improvement in predictive accuracy, allowing for better energy efficiency recommendations.

Figure

Chapter 8: Conclusion and Future Works

Conclusion

The integration of machine learning (ML) techniques into the real estate and building management sectors represents a significant shift in how property pricing and building system maintenance are approached. This study set out to explore the application of advanced ML algorithms, including Random Forest, XGBoost, and Neural Networks, to enhance the accuracy of property price prediction models and to optimize building management practices, particularly with predictive maintenance for Heating, Ventilation, and Air Conditioning (HVAC) systems.

Through this research, it became evident that machine learning models offer a far more reliable, scalable, and data-driven alternative to traditional property valuation methods. Conventional methods, which have traditionally relied on manual assessments and historical data, often fall short in capturing the complexity of the real estate market. These models struggle to account for non-linear relationships between various property attributes (e.g., size, location, age) and market dynamics, such as economic shifts or social trends. The ML models employed in this study, by contrast, can process vast, multi-dimensional datasets and uncover hidden patterns, making them more adept at predicting property prices with greater accuracy. As a result, the findings highlight how the use of ML can provide real-time, more accurate insights for property buyers, sellers, and real estate agents, enabling them to make data-driven decisions that are reflective of the current market conditions.

Furthermore, the study also delved into the optimization of building systems through predictive maintenance. Traditional building management practices often rely on reactive maintenance schedules or inefficient manual inspections, which can lead to increased costs and tenant dissatisfaction. By integrating machine learning into building systems management, particularly HVAC systems, this research demonstrated how predictive maintenance can significantly reduce energy consumption, minimize downtime, and improve overall building efficiency. The ability to predict system failures before they occur allows for proactive scheduling of maintenance, reducing costs and enhancing tenant comfort by ensuring that critical systems operate at peak performance.

In terms of operational efficiency, the machine learning models employed in this study also performed well in enhancing the management of building systems, contributing to more sustainable building management practices. Predictive maintenance reduces the need for excessive energy consumption and repairs, leading to more energy-efficient buildings and ultimately contributing to sustainability goals by reducing the carbon footprint of building operations. These improvements not only benefit building owners and managers in terms of cost savings but also create a more comfortable living environment for tenants, thus improving the overall quality of life.

Despite these promising results, the study also acknowledges several challenges and limitations. One key challenge is the complexity and volume of data that must be handled in real estate and building management systems. The growing availability of real estate data, combined with the integration of advanced technologies such as IoT sensors, creates vast datasets that are difficult to manage and analyze effectively without sophisticated algorithms. Additionally, while machine learning can improve predictive accuracy, there remains a need for ongoing model training and updates to ensure that the predictions remain relevant over time, especially in dynamic environments like real estate markets.

Another challenge is the potential ethical issues associated with the use of machine learning in these sectors. Issues such as data privacy, transparency, and fairness need to be carefully managed to ensure that ML models do not inadvertently perpetuate biases or discriminate against certain groups of people. The use of tenant data, for example, raises concerns about privacy and security, which must be addressed through robust data protection policies and adherence to regulations such as GDPR.

In conclusion, this study has shown that machine learning has the potential to significantly improve property price predictions and building management systems, offering a more efficient, accurate, and sustainable approach compared to traditional methods. The ability of ML models to analyze complex, multi-dimensional data allows for a more nuanced understanding of the factors driving real estate markets and building system performance. However, the study also emphasizes the importance of continuously refining these models, addressing ethical concerns, and ensuring that the technologies are integrated in ways that are socially responsible and sustainable.

The findings of this research contribute to the growing body of knowledge on the application of machine learning in real estate and building management systems and provide a foundation for future research and development in these areas. As machine learning technologies continue to evolve, the real estate and building management sectors are poised to benefit from more intelligent, data-driven systems that optimize property valuations, energy usage, and tenant satisfaction. The future of these industries looks promising, with machine learning playing a key role in shaping smarter, more sustainable environments for both businesses and communities.

Future Works.

While the research presented in this study provides valuable insights into the application of machine learning in real estate and building management, several areas remain for future exploration and improvement:

1. **Integration of Real-Time Data**: Future research could focus on integrating even more dynamic, real-time data sources, such as weather data, social media trends, and online property searches, to improve the accuracy of property price prediction models and building performance analytics.
2. **Advanced Predictive Models**: As machine learning algorithms evolve, there is an opportunity to explore more sophisticated models, such as deep learning or reinforcement learning, to further optimize predictions and system operations, especially in large-scale applications like smart cities.
3. **Broader Application in Other Building Systems**: While this study focused on HVAC systems, predictive maintenance can be extended to other building systems, such as plumbing, electrical, and security systems, to improve overall building efficiency and tenant satisfaction.
4. **Scalability and Real-World Implementation**: Future work should address the scalability of the machine learning models used in this study. The models should be tested in real-world, large-scale environments to assess their robustness and adaptability to evolving market and building conditions.
5. **Ethical and Regulatory Considerations**: There is a growing need to address the ethical implications of using machine learning in real estate, particularly around issues of bias, data privacy, and

accountability. Future research should explore frameworks for ethical AI implementation, ensuring that predictive models are fair and transparent.

6. **Collaborations with Industry Stakeholders**: To further validate and refine the proposed models, partnerships with real estate firms, property managers, and facility management companies could be established. This would allow for the continuous testing and enhancement of the models in practical, real-world settings.

   By addressing these future directions, the application of machine learning in real estate and building management systems can be further optimized, making them more efficient, scalable, and ethically responsible.
