



الجامعة السورية الخاصة  
SYRIAN PRIVATE UNIVERSITY

**Syrian Private University**

**Faculty Of Artifical Intelligence Engineering**

## **BI VOICE AGENT**

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# Abstract

**BI Voice Agent** is an intelligent Business Intelligence (BI) system designed to enable users to interact with analytical databases using natural spoken language instead of traditional query interfaces. The primary objective of the system is to simplify data analysis for non-technical users by transforming voice-based questions into actionable insights in real time.

The system adopts a modular, service-oriented architecture that integrates Speech-to-Text, Natural Language Understanding, SQL generation, data processing, and visualization layers. User voice input is first transcribed using an automatic speech recognition module, after which the resulting text is analyzed to determine the intent and classify the query type. Analytical questions are then converted into structured SQL queries compatible with analytical databases, while non-analytical queries are filtered out early in the pipeline.

To support large-scale and real-time data analytics, BI Voice Agent relies on an ETL (Extract, Transform, Load) pipeline built on a distributed architecture. Data is ingested from heterogeneous sources, processed through streaming and transformation services, and stored in an analytical data warehouse optimized for fast querying. The system continuously monitors ETL execution states and metadata to ensure reliability, consistency, and accurate reporting.

The final results are presented to the user in the form of dynamic charts and dashboards, allowing seamless exploration of insights without requiring technical knowledge of SQL or BI tools. By combining voice interaction, data engineering, and intelligent query generation, BI Voice Agent provides an intuitive, scalable, and efficient solution for modern business intelligence applications.

## الملخص

**BI Voice Agent** هو نظام ذكاء أعمال (Business Intelligence) ذكي يهدف إلى تمكين المستخدمين من التفاعل مع قواعد البيانات التحليلية باستخدام اللغة الصوتية الطبيعية بدلاً من واجهات الاستعلام التقليدية. يهدف المشروع بشكل أساسي إلى تبسيط عملية تحليل البيانات، خاصة للمستخدمين غير التقنيين، من خلال تحويل الأسئلة الصوتية إلى نتائج تحليلية واضحة وبشكل فوري.

يعتمد النظام على بنية معمارية معيارية قائمة على الخدمات، حيث يتم دمج وحدات تحويل الصوت إلى نص، وفهم اللغة الطبيعية، وتوليد استعلامات SQL ، ومعالجة البيانات، وعرض النتائج. تبدأ العملية باستقبال صوت المستخدم وتحويله إلى نص، ثم تحليل النص لاستخراج نية السؤال وتحديد نوعه. في حال كان السؤال تحليليًا، يتم تحويله تلقائيًا إلى استعلام SQL متوافق مع قواعد البيانات التحليلية، بينما يتم إيقاف الأسئلة غير التحليلية في مراحل مبكرة من النظام.

لدعم تحليل البيانات الضخمة والزمن الحقيقي، يعتمد النظام على خط أنابيب ETL (الاستخلاص، التحويل، التحميل) مبني على بنية موزعة. يتم جلب البيانات من مصادر متعددة، معالجتها عبر خدمات بث وتحويل، ثم تحميلها إلى مستودع بيانات تحليلي عالي الأداء. كما يقوم النظام بتتبع حالات تنفيذ الـETL والبيانات الوصفية لضمان الاستقرار والدقة والموثوقية.

في المرحلة النهائية، يتم عرض النتائج للمستخدم على شكل رسوم بيانية ولوحات معلومات تفاعلية، مما يتيح استكشاف البيانات بسهولة دون الحاجة لمعرفة تقنية مسبقة بـ SQL أو أدوات ذكاء الأعمال. يجمع **BI Voice Agent** بين التفاعل الصوتي، وهندسة البيانات، والذكاء الاصطناعي ليقدم حلًا حديثاً، مرتناً، وقابلًا للتوسيع في مجال ذكاء الأعمال.

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# **Chapter 1 Introduction**

## **1. Introduction**

This chapter provides a general introduction to the BI Voice Agent project and establishes the foundation for the rest of the report. It begins by presenting the overall context and motivation behind the project, highlighting the challenges associated with traditional Business Intelligence systems. The chapter then defines the problem addressed by the project and clearly states the main objectives to be achieved.

In addition, this chapter introduces the proposed system at a high level, explaining its main components and general workflow without going into technical details. Finally, the chapter outlines the structure of the report and describes the content of each subsequent chapter to guide the reader through the document.

## **2. Problem Statement**

Despite the availability of powerful BI platforms, many organizations face difficulties in enabling users to effectively analyze data. The main challenges include the complexity of writing SQL queries, the need for technical expertise to interpret dashboards, and the lack of natural interaction with analytical systems. These limitations slow down decision-making processes and restrict access to data insights to a limited group of technical users.

Additionally, traditional BI systems do not provide seamless integration between voice-based interaction and real-time analytical querying. There is also a lack of intelligent pipelines that can automatically validate, process, and monitor analytical data while maintaining scalability and reliability.

Therefore, there is a need for a system that enables users to query analytical databases using voice commands, automatically interpret user intent, generate correct SQL queries, and present results in an understandable and visual form.

## **3. Project Objective**

The main objective of the **BI Voice Agent** project is to design and implement an intelligent voice-driven Business Intelligence system that simplifies data analysis and enhances accessibility for users of all technical levels.

The specific objectives of the project include:

- Enabling voice-based interaction with analytical databases.
- Automatically converting spoken questions into structured SQL queries.
- Classifying user questions to determine whether they are analytical or non-analytical.
- Integrating a scalable ETL pipeline for data ingestion, transformation, and loading.
- Providing real-time analytical results through visual dashboards and charts.
- Ensuring system scalability, reliability, and modularity.

#### ***4. Proposed System***

The proposed system is a multi-layered, service-oriented architecture that integrates voice processing, intelligent query generation, and data analytics. The system begins by capturing the user's voice input, which is converted into text using a speech recognition module. The text is then processed to extract intent and determine the type of query.

For analytical queries, the system generates SQL statements compatible with the analytical data warehouse. The data is processed through an ETL pipeline that ensures data consistency and quality. Finally, the query results are visualized using interactive charts and dashboards.

The architecture is designed to be modular, allowing each component to operate independently while maintaining seamless communication between services

#### ***5. Report Organization***

The report is structured as follows:

- Chapter 1: Introduction
- Chapter 2: Basic Concepts and Reference Study
- Chapter 3: Project Management
- Chapter 4: System Analysis

- Chapter 5: System Design
- Chapter 6: Practical Implementation
- Chapter 7: Report Overview

## ***6. Summary***

This chapter presented an overview of the BI Voice Agent project, including the motivation behind the system, the problem it addresses, the project objectives, and the proposed solution. It also outlined the structure of the report and provided a foundation for the technical and analytical discussions in the following chapters.

## **Chapter 2: Basic Concepts and Reference Study**

# I. Reference Study of Interactive AI Powered Business Intelligence Tools

## *1. Introduction*

This chapter provides a foundation for understanding the **BI Voice Agent** system by exploring the fundamental concepts and reviewing related studies in the field of intelligent business analytics. It examines essential terminology, key principles, and core technologies such as Business Intelligence systems, voice-based interaction, natural language processing, and data analytics pipelines. The chapter aims to present an overview of AI-driven and natural language-based business intelligence platforms, along with insights from existing solutions and research studies. These references help identify current capabilities and limitations in the field and provide guidance for the design and development of the proposed BI Voice Agent system.

## *2. Fundamental Concepts*

This section introduces the core concepts required to understand the design and functionality of the BI Voice Agent system.

- **Business Intelligence (BI):**

Business Intelligence refers to technologies and processes used to collect, integrate, analyze, and visualize data to support decision-making. Traditional BI systems rely heavily on dashboards, predefined reports, and structured queries such as SQL.

- **Natural Language Querying:**

Natural Language Querying allows users to interact with data systems using human language instead of formal query syntax. This approach improves accessibility, especially for non-technical users, but introduces challenges such as ambiguity, context understanding, and intent recognition.

- **Voice-Based Interaction:**

Voice-based interfaces extend natural language querying by enabling spoken input. Such systems require accurate speech-to-text processing and must handle variations in pronunciation, accents, and query structure.

- **Natural Language to SQL (NL2SQL):**  
NL2SQL systems automatically translate user questions into structured SQL queries. These systems must correctly map user intent to database schemas, tables, and columns while ensuring query correctness and security.
- **ETL and Data Pipelines:**  
ETL (Extract, Transform, Load) pipelines are responsible for ingesting data from multiple sources, cleaning and transforming it, and loading it into analytical data stores. Scalable and monitored ETL pipelines are essential for real-time and enterprise-level analytics.
- **Analytical Data Warehouses:**  
Analytical databases are optimized for read-heavy workloads and large-scale aggregations. They support fast execution of complex analytical queries and are commonly used in modern BI systems.

Together, these concepts form the technical foundation upon which voice-driven and AI-powered business analytics systems are built.

- **Large Language Models (LLMs)**  
LLMs are advanced AI models trained on large-scale textual data to understand and generate human-like language. In BI Voice Agent, LLMs play a key role in interpreting user intent, converting natural language queries into structured representations, and assisting in SQL generation.
- **Apache Kafka (Data Streaming)**  
Kafka is a distributed event-streaming platform used for building scalable and fault-tolerant data pipelines. It enables asynchronous communication between ETL components, ensuring reliable data flow and system decoupling.
- **ClickHouse (Analytical Data Warehouse)**  
Is a high-performance column-oriented analytical database optimized for large-scale read-heavy queries. It supports fast aggregation and real-time analytics, making it suitable for BI applications.
- **Metabase (Data Visualization)**  
Is an open-source business intelligence tool used for visualizing analytical query results. It allows users to explore data through dashboards and charts without requiring SQL expertise.
- **LangChain / LangGraph (AI Orchestration)**

Are frameworks designed to manage and orchestrate interactions between large language models and external tools. They enable structured reasoning flows, multi-step decision-making, and modular AI pipelines.

### **3. Literature Review for the system**

#### 1-ThoughtSpot – Interactive AI-Powered Business Analytics Platform

##### *1.1 Platform Description*

**ThoughtSpot** is an AI-powered business analytics platform that allows users to query data through a simple, search-like interface. Employees can ask questions in natural language and instantly get visual or tabular answers without SQL skills.

It features **SpotIQ** for automatic pattern and anomaly detection, and **SearchIQ** for natural language and voice queries that reveal hidden insights in large datasets.

Powered by the in-memory **Falcon** engine, ThoughtSpot delivers fast, real-time analytics at enterprise scale, with **API** and **SDK** integrations that embed its capabilities into other business applications and dashboards.

##### *1.2 System Actors*

The platform serves multiple roles within an organization:

- **Non-technical users** (e.g., sales, marketing, and business managers) can access analytics easily through an intuitive search-based interface.
- **Data analysts and data engineers** prepare and model the data, design *Worksheets*, and define relationships between tables to ensure accurate results.
- **System administrators (IT Managers)** integrate ThoughtSpot with data sources and manage security and permissions, with support for identity systems like Okta and Azure AD.
- **Developers** use ThoughtSpot APIs to embed its analytical capabilities into other applications or to build custom interactive dashboards.

##### *1.3 Core Functional Requirements*

ThoughtSpot relies on several core functional requirements to ensure high performance and usability within enterprise environments:

1. **Data Integration:** Connects to various data sources such as cloud warehouses, databases, and Excel files.
2. **Data Modeling:** The technical team prepares structured data models (e.g., Star Schema) for efficient querying.
3. **Real-Time Queries:** Runs live queries on connected data without permanent storage, using in-memory caching for speed.
4. **High Performance:** Requires a fast data warehouse or cloud setup to utilize the Falcon engine effectively.
5. **Multi-Device Access:** Accessible via web and mobile interfaces for flexible, on-the-go analytics.
6. **Natural Interaction:** *SearchIQ* enables voice and natural language queries for intuitive exploration.
7. **APIs and SDKs:** Allows embedding analytics and extracting results programmatically into other systems.
8. **Deployment Flexibility:** Offered as a managed cloud service or on-premises installation (AWS, GCP, Azure).
9. **Security & Compliance:** Uses encrypted, VPN-secured connections and adheres to SOC 2, ISO 27001, and GDPR standards.

## 2-Databricks AI/BI Genie – Natural Language Business Intelligence Platform

### 2.1 Platform Description

*Databricks AI/BI Genie* is a feature within the Databricks platform that allows users to ask questions about their data in natural language within the **Lakehouse** environment. Genie interprets business questions, converts them automatically into SQL queries, and displays the results as interactive tables or charts. It is powered by **Large Language Models (LLMs)** customized to each organization's data and terminology. As a **compound AI system**, Genie can ask clarifying questions and generate accurate analyses, acting as a virtual business intelligence analyst that delivers instant insights.

### 2.2 System Actors

- **Non-technical business users:** Ask questions and receive instant insights without writing SQL queries.
- **Data analysts and engineers:** Configure the *Genie Space* and provide contextual definitions and examples to train the model.

- **System administrators:** Integrate Genie with data sources via **Unity Catalog**, manage security, and ensure sufficient computing resources.
- **Developers:** Embed Genie's capabilities into external applications using APIs.
- 

### *2.3 Core Functional Requirements*

1. **Structured data organization:** Data must be registered in Unity Catalog with clear descriptions and defined relationships.
2. **Rich metadata and context:** Add organizational terms, KPIs, and definitions within *Genie Space* to improve understanding.
3. **SQL Warehouse connection:** Execute read-only SQL queries without modifying source data.
4. **Adequate computing resources:** Ensure fast query execution and scalability for multiple users.
5. **Integration with LLMs:** Genie operates using managed models like Dolly or Azure OpenAI.
6. **Security and governance:** Enforces Unity Catalog policies for access control and data privacy.
7. **Performance monitoring:** Tracks user queries and feedback to continuously improve accuracy and reliability.

## 3-Microsoft Power BI – Interactive Business Intelligence Platform by Microsoft

### *3.1 Platform Description*

*Microsoft Power BI* is a leading cloud-based business intelligence platform that helps users collect, transform, and visualize data through interactive dashboards and reports. It includes **Power BI Desktop** for report creation and **Power BI Service** for online sharing.

With **Q&A** and **Copilot**, users can analyze data and generate insights using natural language, making analytics accessible even to non-technical users.

### *3.2 System Actors*

- **Admin:** Manages the workspace, security, and data connections.
- **Creator:** Builds models and reports using Power Query and DAX.

- **Contributor:** Edits and updates shared reports.
- **Viewer:** Consumes reports and dashboards for decision-making.
- **Stakeholders:** Define data requirements and use insights strategically.
- 

### *3.3 Core Functional Requirements*

1. **Data Connectivity:** Links to on-premises and cloud sources (SQL, Azure, Excel, etc.).
2. **Flexible Query Modes:** Supports Import and DirectQuery for real-time or cached data.
3. **Data Modeling:** Cleans and structures data via Power Query using *Star Schema*.
4. **In-memory Engine:** Uses VertiPaq for high-speed data compression and analytics.
5. **Secure Gateway:** Syncs on-premises data with cloud services safely.
6. **Licensing & Capacity:** Requires Pro or Premium licensing for enterprise performance.
7. **Integration:** Embeds reports via APIs and connects with Azure, Office 365, and Teams.
8. **Security:** Applies encryption and Row-Level Security (RLS) for controlled access.
9. **Performance:** Scales efficiently through optimized models and Premium capacity.

## 4-Vanna.AI – Open-Source Interactive Data Intelligence Framework

### *4.1 Platform Description*

*Vanna.AI* is an open-source framework for building AI agents that analyze data through natural language. It allows users to ask questions directly to a database without writing SQL, translating queries automatically using **Large Language Models (LLMs)**.

*Vanna* employs the **Retrieval-Augmented Generation (RAG)** approach, enhancing accuracy by providing contextual knowledge such as database schema, table descriptions, and relationships. It returns interactive results as tables or visualizations using libraries like *Plotly*, enabling a conversational and intuitive data analysis experience.

## 4.2 System Actors

- **End User:** Non-technical employee or analyst who interacts with the system through a chat interface to retrieve insights.
- **Developer/Data Engineer:** Integrates Vanna with databases and configures connections to AI models and data sources.
- **Data Expert:** Trains the model on database structure, adds examples, and improves accuracy through feedback.
- **System/Security Administrator:** Manages API keys, access permissions, and ensures queries are executed securely in read-only mode.

## 4.3 Core Functional Requirements

1. **Structured Database:** Supports relational and modern databases such as PostgreSQL, MySQL, SQLite, Snowflake, and BigQuery.
2. **Reliable Connectivity:** Requires accessible JDBC/SQL connections between Vanna and the target database.
3. **Well-Documented Schema:** Tables and fields should be clearly defined to enhance training and query accuracy.
4. **Python Environment:** Install the Vanna package and link it to both the database and the chosen language model.
5. **LLM Integration:** Compatible with GPT-4, Claude, or locally hosted open-source models.
6. **Vector Database (optional):** Used for RAG context retrieval via Pinecone, Chroma, or FAISS.
7. **Access Control & Security:** Operates with read-only permissions and user identity tokens for authorization checks.
8. **Flexible Interface:** Deployable as a web app (Flask/Streamlit) or integrated with tools like Slack or Teams.
9. **Cloud Option:** *Vanna Cloud* provides monitoring, query logging, and secure connectivity to enterprise data sources.

## 5. Sequel.sh – AI-Native Business Intelligence Platform

### *1-Platform Description*

*Sequel.sh* is a modern **AI-native BI platform** built from the ground up for natural interaction with data. It allows users to ask questions in plain English and instantly receive visual, data-driven answers—without needing SQL knowledge.

The platform translates questions into optimized SQL queries executed directly on live databases, ensuring real-time insights. Sequel automatically understands database schemas, enabling accurate interpretation without manual setup.

Its chat-style interface lets users explore, save, and share insights within collaborative **Workspaces**, with smart features like **automated insights** and interactive trend analysis.

### 5.1 System Actors

- **Business Users:** Product managers, marketers, and analysts who ask questions and interact with visual results through an intuitive chat interface.
- **Data Analysts and Experts:** Use the built-in SQL editor to review or fine-tune AI-generated queries for higher accuracy.
- **Data Engineers and Administrators:** Connect Sequel to company databases securely, define user roles, and manage permissions.
- **Security Teams:** Monitor access, encryption, and activity logs to ensure compliance and data privacy.

### 5.2 Core Functional Requirements

1. **Database Connectivity:** Supports PostgreSQL, MySQL, and SQLite for direct querying without data migration.
2. **Secure Connection:** Requires SSL-encrypted communication and read-only database credentials.
3. **Optimized Performance:** Databases should be indexed and tuned for instant, real-time query responses.

4. **Cloud Setup (SaaS):** Operates fully in the cloud with simple initial configuration and workspace creation.
5. **Workspace Collaboration:** Enables team environments with role-based access (Viewer / Member).
6. **Single Sign-On (SSO):** Supports OAuth or SAML for enterprise identity integration.
7. **Hybrid Deployment Option:** Can use a local agent within the client's cloud to keep data within secure boundaries.
8. **AI Model Integration:** Uses built-in language models to convert natural language to SQL automatically.
9. **Usage & Cost Management:** Tracks queries and data volume to manage subscription limits effectively

## II. Comparative Analysis of AI-Powered Interactive BI Platforms

Criterion	ThoughtSpot	Databricks AI/BI Genie	Microsoft Power BI	Vanna.AI	Sequel.sh	BI Voice Agent (Our Project)
Platform Type	AI-driven search-based BI platform	AI assistant inside Databricks Lakehouse	Traditional BI with AI enhancements	Open-source AI analytics framework	AI-native BI for natural querying	Voice-controlled BI assistant for speech-to-dashboard automation
Main Purpose	Natural language search and instant analytics	Natural language analytics in Databricks	Create and share databases via natural language	Query databases via natural language	Provide instant AI-powered SQL insights	Convert voice input → SQL → dashboards automatically
Core Mechanism	NLP → SQL → Falcon engine	LLMs generate SQL with contextual understanding	Copilot Q&A + BI visualization	LLM + RAG → SQL	English → optimized SQL on live data	Whisper STT → LLM Text-to-SQL → ClickHouse → Metabase dashboards
AI Capabilities	SpotIQ, SearchIQ	Context-aware LLMs (Compound AI)	Copilot + Q&A	LLMs with RAG	Built-in LLM SQL translation	Speech recognition + LLM SQL generation + auto visualization
Primary Users	Managers & non-technical users	Analysts in Databricks	Analysts & employees	Developers & analysts	Business users & engineers	Managers, analysts, and business users who prefer voice commands
Additional Roles	Admins, devs, engineers	Domain experts, governors	Admin, Creator, Viewer	Developers, admins	Data engineers, security officers	Manager, Data Analyst, System Admin (defined in our system)
Deployment Model	Cloud / On-Prem	Databricks cloud	Cloud or Desktop	Local / Cloud	SaaS cloud or local agent	Local deployment using Docker + Kafka + ClickHouse + Flask

<b>Data Preparation</b>	Worksheets, Star Schema	Genie Space configuration	Power Query, Star Schema	Metadata training, schema enrichment	Auto schema detection	ETL pipeline (CSV → JSON → Kafka → ClickHouse) with cleaning & structuring
<b>Security &amp; Governance</b>	SSO, Encryption	Unity Catalog	Encryption, RLS	Token identity checks	SSL, activity logs	Role-based access + workspace isolation + secure DB access
<b>Integration Capabilities</b>	APIs & SDKs	APIs for Teams	Power BI Embedded	Slack, Teams, Jupyter	Export & integrations	Kafka streaming, ClickHouse, Metabase, Flask APIs
<b>User Interface</b>	Search bar + dashboards	Conversational UI	Interactive dashboards	Chat/web UI	Chat-like workspace	Voice-based interface + dashboard viewer in Metabase
<b>Key Features</b>	Instant insights	Multi-agent reasoning	Microsoft ecosystem	Model-agnostic	Real-time collab	Hands-free BI reporting, full automation, real-time voice-driven analysis
<b>Strengths</b>	Fast & intuitive	Enterprise precision	Stable & scalable	Flexible	Collaborative	Accessibility, simplicity, minimal user effort, full automation
<b>AI Operation Style</b>	NLP + pattern mining	Compound AI	Copilot automation	RAG agent	Real-time LLM	Speech → NLP → SQL → Visualization pipeline
<b>Target Audience</b>	Large enterprises	Tech firms	Enterprises & mid-size	Developers	Startups	Businesses wanting fast voice-driven insights without technical skills
<b>Cloud Integration</b>	AWS/Azure/GCP	Databricks Cloud	Azure	Any cloud/local	Sequel Cloud	Docker-based local system (future: cloud deployment)
<b>Output Format</b>	Dashboards	SQL + visuals	Reports, dashboards	Tables, charts	Interactive dashboards	Auto-generated dashboards + downloadable reports

*Table 1 : Comparative Analysis of Reference Studies*

## **4. Literature Review for Voice-Based Business Intelligence Systems**

### ***1. Abstract***

Voice-based Business Intelligence systems combine natural language processing, large language models, and analytical data platforms to enable intuitive access to data insights without requiring technical expertise. Recent studies and commercial platforms demonstrate the effectiveness of natural language and voice-driven analytics in reducing query complexity, improving decision-making speed, and increasing data accessibility across organizational roles.

Existing solutions leverage a variety of AI techniques, including rule-based natural language interfaces, neural language models, and Large Language Models (LLMs), with performance evaluated through query accuracy, execution correctness, response latency, and user satisfaction. Analytical platforms report high effectiveness in structured environments; however, challenges remain in scalability, real-time data processing, intent disambiguation, and tight integration with ETL pipelines.

Reported systems typically achieve high query interpretation accuracy in controlled environments, but often depend on well-prepared schemas, extensive metadata, and pre-modeled datasets. These findings highlight the need for modular, scalable, and voice-first BI systems capable of handling real-time analytics and heterogeneous data sources—motivating the development of the proposed **BI Voice Agent**.

### ***2. Review of Existing Systems***

Several AI-powered business intelligence platforms have been proposed to support natural language and voice-based data exploration. This review analyzes five representative systems based on their architecture, system actors, and functional requirements.

#### **2.1 ThoughtSpot – Interactive AI-Powered Business Analytics**

ThoughtSpot enables search-based and voice-driven querying over enterprise datasets using natural language. It employs in-memory query acceleration and automated insight discovery through SpotIQ. While highly performant, the system relies on structured data models prepared by technical teams and operates primarily in enterprise-managed environments.

## **2.2 Databricks AI/BI Genie – Natural Language Analytics in Lakehouse**

Databricks Genie integrates natural language querying directly within the Lakehouse architecture. Powered by LLMs, it converts business questions into SQL queries and executes them on governed data using Unity Catalog. The system offers strong governance and scalability but depends heavily on cloud infrastructure and pre-configured metadata.

## **2.3 Microsoft Power BI – AI-Enhanced Business Intelligence**

Power BI provides natural language querying through Q&A and Copilot features, allowing users to interact with dashboards and reports using conversational language. Although widely adopted, its natural language capabilities are limited to predefined models and dashboards, and voice interaction is not fully native.

## **2.4 Vanna.AI – Open-Source NL2SQL Framework**

Vanna.AI is an open-source framework that converts natural language questions into SQL queries using LLMs and Retrieval-Augmented Generation (RAG). It provides flexibility and transparency but requires careful schema documentation and manual model training to achieve reliable performance.

## **2.5 Sequel.sh – AI-Native BI Platform**

Sequel.sh offers a chat-based interface that translates natural language queries into optimized SQL executed on live databases. It emphasizes simplicity and real-time analytics but operates mainly as a SaaS solution with limited customization for complex ETL workflows.

### **3. Thematic Analysis: Evolution of AI Techniques in Voice-Based BI**

This thematic analysis examines the dominant AI approaches used in voice-based and natural language business intelligence systems, focusing on their strengths, challenges, and reported effectiveness.

Category	Key Features	Challenges	Typical Usage
Rule-Based and Search-Oriented Interfaces	Deterministic query mapping, predictable outputs	Limited flexibility, poor handling of ambiguity	Early BI systems and basic natural language interfaces
Traditional NL2SQL Systems	Structured intent parsing, schema mapping	Strong schema dependency, limited generalization	High-accuracy querying in constrained domains
LLM-Based BI Systems	Contextual understanding, flexible language handling	Hallucination risk, high computational cost, governance concerns	Advanced natural language analytics and improved user experience
Streaming and ETL-Integrated Analytics	Real-time data availability, scalable pipelines	Monitoring complexity, fault tolerance, metadata consistency	Enterprise-grade BI architectures
Visualization-Centric BI Platforms	Interactive dashboards, user-friendly interfaces	Dependency on predefined models and queries	Decision support and executive analytics

*Table 2 : Thematic Analysis of AI Techniques in Voice-Based Business Intelligence*

### **4. Summary of Findings**

The analysis reveals that:

- Most existing BI platforms rely on **pre-modeled data and structured schemas**
- LLM-based systems significantly improve **query flexibility and usability**
- Limited solutions provide **end-to-end voice interaction integrated with ETL**
- Real-time analytics and system observability remain key challenges
- Few systems offer **fully modular, service-oriented architectures**

These limitations highlight the need for a voice-first, modular, and scalable BI system that tightly integrates speech processing, intent analysis, SQL

generation, ETL monitoring, and visualization—addressed by the proposed **BI Voice Agent**.

### ***5. Positioning of the Proposed System***

Based on the reviewed literature and systems, **BI Voice Agent** distinguishes itself by:

- Providing **native voice-based interaction**
- Integrating **LLMs with structured reasoning (LangChain/LangGraph)**
- Supporting **real-time ETL pipelines (Kafka-based)**
- Utilizing a **high-performance analytical warehouse (ClickHouse)**
- Delivering insights through **dynamic visualization (Metabase)**

This positioning demonstrates how the proposed system addresses existing gaps while building upon proven concepts in AI-driven business intelligence.

# **Chapter 3 Project Management**

## **1. Introduction**

This chapter focuses on the project management aspects of the BI Voice Agent project, which play a crucial role in ensuring successful planning, execution, and delivery. It presents the key management documents and practices used to guide the project from initiation to completion.

The chapter covers the project charter, Statement of Work (SOW), roles and responsibilities, project resources, schedule, and risk management strategies. These elements provide a structured framework to control project scope, timeline, and quality while addressing potential risks that may arise during development.

## **2. Project Charter**

A project charter is a formal document that authorizes the initiation of a project and defines its high-level objectives, scope, and governance structure. It serves as a reference throughout the project lifecycle and supports informed decision-making.

Project Title: BI Voice Agent – Voice-Driven Business Intelligence System

Project Start Date: Oct 18, 2025

Projected Finish Date: Jan 1, 2026

Project Supervisors / Managers:

- Eng. Anas Abdulaziz

Project Objectives

- Design and develop a voice-based Business Intelligence system that allows users to query analytical data using natural language.
- Enable automatic conversion of voice queries into structured SQL queries.
- Integrate a scalable ETL pipeline for real-time data ingestion and analytics.
- Provide interactive visualizations and dashboards for data exploration.
- Improve accessibility of data analytics for non-technical users.

Approach

- Gather functional and non-functional requirements through analysis of BI use cases.
- Design a modular system architecture integrating voice processing, AI reasoning, and data analytics.
- Develop backend services, ETL components, and AI modules iteratively.
- Test system components individually and through end-to-end integration.
- Validate analytical results and visualization outputs.

## **Roles and Responsibilities**

Name	Role	Responsibilities
Eng. Anas Abdulaziz	Project Supervisor	Provide academic supervision, guide the project direction, and evaluate progress and deliverables. Oversee technical

		decisions, review system architecture, and support implementation challenges.
Massa nasri	AI & Data Sciences	Prepare and preprocess datasets, support ETL validation, design the AI pipeline, integrate LLMs, implement ETL services, and develop SQL generation mechanisms.
Ayman Alkotyfan	Backend & Frontend Developer	Design frontend components, dashboards, and visualization interfaces, and implement backend logic and system integrations.

*Table 3 : Roles and Responsibilities of Project Team Members*

### **3. Statement of Work (SOW)**

The Statement of Work defines the scope, objectives, deliverables, and responsibilities of the BI Voice Agent project. It establishes a clear understanding of what will be developed and the criteria for successful completion.

#### **1. Project Description and Objectives**

The project aims to develop a voice-driven Business Intelligence system that enables users to interact with analytical databases using spoken language. The system supports intelligent query interpretation, real-time analytics, and visual reporting.

#### **2. Project Scope**

The BI Voice Agent focuses on:

- Voice-to-text processing.
- Natural language understanding and intent classification.
- Automatic SQL generation for analytical queries.
- ETL pipeline integration using streaming technologies.
- Data visualization through interactive dashboards.

#### **3. Project Goals**

- Simplify data analytics for non-technical users.
- Provide accurate and real-time analytical insights.
- Ensure system scalability and modularity.
- Enable seamless integration between AI and data engineering components.

## Deliverables

- Project plan and timeline.
- Software Requirements Specification (SRS).
- System architecture and design documentation.
- Functional BI Voice Agent system.
- Final project report.

## **4. Project Requirements**

### Technology and Tools

- Programming Languages: Python, JavaScript, SQL
- Backend Framework: Django / FastAPI
- Frontend: React
- Data Streaming: Apache Kafka
- Analytical Database: ClickHouse
- Visualization: Metabase
- AI Frameworks: LangChain, LangGraph
- LLMs: OpenAI-compatible or local large language models

## **5. Assumptions**

- Continuous availability of supervisors for feedback and evaluation.
- Stable development environment and infrastructure.
- Access to required software tools and datasets.
- Incremental feedback during development milestones.

## **6. Project Resources**

### **Human Resources**

- Academic supervisors
- AI and data engineering developers
- Frontend and integration support

### **Technical Resources**

- Local and cloud-based development environments
- Version control and collaboration tools
- Analytical databases and streaming platforms

## **7. Schedule**

- Project Start Date: Oct 18, 2025
- Project End Date: Jan 1, 2026

## **8. Risk Management**

Risk Title	Risk Description	Tracking Frequency	Impact	Mitigation Plan
Limited team size	Project progress depends on a small team	Weekly	High	Cross-task collaboration and shared responsibilities
Complex system integration	Difficulty integrating AI, ETL, and BI components	Weekly	High	Incremental integration and early testing
LLM output inconsistency	AI-generated SQL may be incorrect or ambiguous	Weekly	High	Validation layers and schema-aware prompting
Data pipeline failures	Streaming or ETL issues may affect analytics	Weekly	Medium	Monitoring, logging, and retry mechanisms
Time constraints	Tight academic deadlines	Weekly	Medium	Task prioritization and milestone-based planning
Visualization mismatch	Results may not align with user expectations	Weekly	Medium	Iterative UI testing and feedback cycles

Table 4 : Risk Management Matrix

## 9. Gantt charts

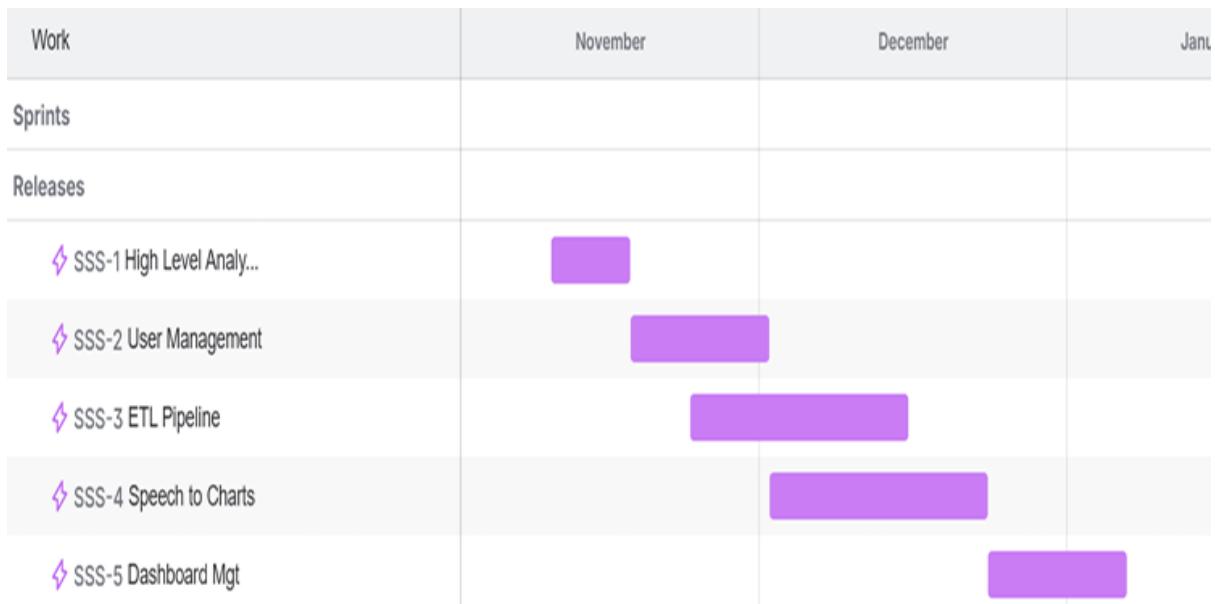


Figure 1 : Gantt Charts

## 10. Summary

This chapter presented the project management framework of the BI Voice Agent project, including the project charter, scope definition, roles, resources, schedule, and risk management plan. These management practices ensure structured development, controlled execution, and successful delivery of the project.

## **Chapter 4: System Analysis**

## **1. Introduction**

This chapter focuses on the detailed analysis of the **BI Voice Agent** system. It aims to define the system requirements, functionality, and operational context by analyzing user needs and system constraints. The chapter provides a clear understanding of how the proposed system will operate and how it addresses the challenges of traditional Business Intelligence systems.

The analysis includes an overview of the project timeline, sprint-based development approach, and the Software Requirements Specification (SRS). Functional and non-functional requirements are identified to ensure that the system meets performance, scalability, and usability objectives. This chapter serves as a foundation for the system design and implementation phases presented in the subsequent chapters.

## **2. Project Timeline**

The development of the **BI Voice Agent** project follows an iterative and incremental approach based on Agile methodology. The project is divided into five main sprints, each focusing on a specific subsystem or milestone. This approach allows continuous integration, early validation, and effective risk management throughout the development lifecycle.

Sprint	Duration	Time Period	Main Focus
<b>Sprint 1 (SSS-1)</b>	1 weeks	10 Nov – 17 Nov	High-Level Analysis and System Planning
<b>Sprint 2 (SSS-2)</b>	2 weeks	18 Nov – 2 Dec	User Management and Access Control
<b>Sprint 3 (SSS-3)</b>	3 weeks	23 Nov – 15 Dec	ETL Pipeline and Data Ingestion
<b>Sprint 4 (SSS-4)</b>	3 weeks	3 Dec – 25 Dec	Speech-to-Query and Chart Generation
<b>Sprint 5 (SSS-5)</b>	2 week	25 Dec – 10 Jan	Dashboard Management and System Integration

*Table 5 : Project Timeline and Sprint Planning*

### ***3. Software Requirement specification document ( SRS )***

## ***1. Introduction***

### **1.1 Purpose**

The purpose of this document is to specify the software requirements for the BI Voice Agent platform. This document provides a detailed description of the system's functional requirements, system actors, and interaction scenarios, with a particular focus on Sprint 1, which covers the User Management domain. This SRS serves as a foundational reference for modeling system use cases, defining system behavior, and guiding the design and implementation phases of the BI Voice Agent platform.

### **1.2 Project Scope**

The BI Voice Agent platform is designed to enable voice-driven interaction with Business Intelligence systems. It allows users to manage workspaces, authenticate securely, and collaborate within a shared analytical environment before accessing advanced BI capabilities such as voice-based querying and dashboard analytics.

This specification focuses on high-level requirements related to user authentication, workspace management, role-based access control, and collaboration features, which form the backbone of the platform.

#### **1.2.1 High-Level Requirements**

##### **• Authentication**

This requirement provides secure access to the BI Voice Agent platform. The system allows users to authenticate using valid credentials and ensures that only authorized users can access system functionalities. Authentication is mandatory for all user roles and serves as the entry point for interacting with dashboards, reports, and analytical features.

- **Profile Management**

The system allows authenticated users to view and manage their personal profile information. This includes updating basic details such as name, contact information, and account settings. Profile management ensures personalization while maintaining account security.

- **Workspace Management**

This functionality enables the Manager to create, configure, and manage workspaces. A workspace represents the logical boundary for dashboards, reports, members, and data sources. Workspace management ensures that analytical resources are organized and accessible only to authorized members.

- **Member Management**

The system allows the Manager to manage workspace members. This includes inviting users, assigning roles, and removing members when necessary. Member management ensures controlled collaboration and enforces role-based access within the workspace.

- **Workspace Governance**

This requirement defines rules and policies that control how the workspace operates. It includes managing access permissions, enforcing role boundaries, and ensuring that shared dashboards and reports follow governance constraints defined by the Manager.

- **Upload Database**

The system enables the Manager to upload and register databases or datasets that will be used for analytical purposes. Uploaded data becomes available for querying, analysis, and visualization within the workspace, forming the foundation of BI operations.

- **Voice Query**

This functionality allows users to interact with the system using spoken language. Voice input is captured, converted into text, and processed to generate analytical queries. This feature enables non-technical users to explore data intuitively without writing SQL queries.

- **Analysis**

The system provides analytical capabilities that allow Analysts to explore data, apply aggregations, filters, and metrics, and derive insights. This requirement supports interactive analysis using both traditional and AI-assisted approaches.

- **Report Generation**

The system allows users to generate reports based on analytical results. Reports present structured insights in a readable format and can be accessed by authorized users for review and decision-making purposes.

- **Dashboard Management**

This requirement enables the Manager to create, edit, and manage dashboards. Dashboards provide a visual representation of analytical data and can include charts, tables, and KPIs. Managed dashboards can be shared with other workspace members.

- **Access Shared Dashboard**

The system allows authorized users to access dashboards shared within the workspace. This ensures that Analysts, Executives, and Dashboard Viewers can consume insights without modifying dashboard content

## 1.2.2 Actors

The BI Voice Agent system defines the following actors based on the high-level use case diagram:

### 1. Manager

The Manager is the owner of the workspace and holds full administrative control.

Responsibilities:

- Manage workspaces and workspace settings
- Upload databases
- Manage members and assign roles

- Create and manage dashboards
- Perform voice queries
- Access reports and analysis
- Manage personal profile and authentication

## **2. Analyst**

The Analyst is a workspace member responsible for analyzing data and generating insights.

Responsibilities:

- Perform data analysis
- Generate and view reports
- Access shared dashboards
- Authenticate and manage personal profile

## **3. Executive**

The Executive is a high-level consumer of insights with read-only analytical access.

Responsibilities:

- View reports
- Access shared dashboards
- Authenticate and manage personal profile

## **4. Report Viewer**

The Report Viewer focuses on consuming reports generated by the system.

Responsibilities:

- View reports
- Authenticate to access reporting features

## **5. Dashboard Viewer**

The Dashboard Viewer is responsible for viewing dashboards shared within the workspace.

Responsibilities:

- Access shared dashboards
- Authenticate to view dashboard content

## **6. Common User**

The Common User represents shared behavior across all authenticated users.

Responsibilities:

- Authenticate into the system
- Manage personal profile information

## ***2. Overall Description***

### **2.1 Product Perspective**

The BI Voice Agent platform described in this document is a new, standalone system designed to enable voice-based interaction with Business Intelligence platforms. The system is built as a modular, service-oriented solution that integrates speech processing, AI-based reasoning, and analytical data platforms. The BI Voice Agent is not part of an existing product family, nor is it intended to replace a specific commercial BI tool. Instead, it complements traditional BI systems by providing an intuitive voice-driven interface that simplifies data exploration and decision-making for non-technical users.

### **2.2 Product Features**

#### **• User and Workspace Management**

- Create and manage workspaces.
- Invite users and assign roles (Manager, Analyst, Executive).
- Manage workspace members and permissions.

#### **• Authentication and Profile Management**

- Secure user authentication with role-based access.
- Email verification and session management.
- Profile viewing and editing for all users.

#### **• Voice-Based Querying**

- Allow users to submit analytical questions using voice input.
- Convert speech to text and process it for analysis.
- Enable natural language interaction without SQL knowledge.

#### **• Data Upload and Integration**

- Upload and register analytical databases.
- Prepare data for querying and visualization.

- **Data Analysis**

- Perform analytical operations such as filtering, aggregation, and trend analysis.
- Support interactive analysis for Analysts.

- **Report Generation**

- Generate structured analytical reports.
- Allow authorized users to view and consume reports.

- **Dashboard Management**

- Create and manage dashboards.
- Share dashboards with workspace members.

- **Access Shared Dashboards**

- Allow Executives and Viewers to access shared dashboards.
- Ensure read-only access for non-administrative users.

## **2.3 User Classes and Characteristics**

This section describes the different classes of users interacting with the **BI Voice Agent** system, along with their main characteristics, responsibilities, and access levels. Each user class is defined based on its role within the workspace and the functionalities it can access.

### **2.3.1 Manager**

The **Manager** is the primary administrative user and the owner of the workspace. This user class is responsible for configuring and governing the workspace environment and managing its members.

**Characteristics:**

- Has full administrative privileges within the workspace.
- Possesses decision-making authority over data sources, dashboards, and access control.
- Typically represents a business owner, team leader, or BI administrator.

#### **System Access:**

- Workspace management
- Member management and role assignment
- Database upload and integration
- Dashboard creation and management
- Voice-based querying
- Reports and analysis
- Authentication and profile management

#### **2.3.2 Analyst**

The **Analyst** is a technical or semi-technical user focused on data exploration and insight generation. Analysts use the system to perform in-depth analysis without managing workspace settings.

#### **Characteristics:**

- Skilled in data analysis and interpretation.
- Does not have administrative permissions.
- Works within the boundaries defined by the Manager.

#### **System Access:**

- Data analysis features
- Report generation and viewing
- Access to shared dashboards
- Authentication and profile management

#### **2.3.3 Executive**

The **Executive** is a high-level stakeholder who consumes insights for strategic decision-making. This user class focuses on reviewing results rather than performing analysis.

#### **Characteristics:**

- Non-technical or business-oriented user.
- Requires quick access to summarized insights.
- Limited interaction with system configuration.

#### **System Access:**

- View reports

- Access shared dashboards
- Authentication and profile management

#### **2.3.4 Report Viewer**

The **Report Viewer** is a user role dedicated to viewing and consuming reports generated by the system.

##### **Characteristics:**

- Read-only access to analytical reports.
- Does not perform analysis or data manipulation.
- Often represents external or internal stakeholders.

##### **System Access:**

- View reports
- Authentication

#### **2.3.5 Dashboard Viewer**

The **Dashboard Viewer** focuses on accessing and viewing dashboards shared within the workspace.

##### **Characteristics:**

- Read-only user.
- Uses dashboards for monitoring KPIs and performance indicators.
- No permission to modify dashboards or data.

##### **System Access:**

- Access shared dashboards
- Authentication

#### **2.3.6 Common User**

The **Common User** represents shared behavior across all authenticated users in the system.

##### **Characteristics:**

- Represents common system functionality available to all roles.
- Ensures consistent access to core services.

##### **System Access:**

- Authentication
- Profile management

### ***3. System Features***

## **3.1 Functional Requirements**

### **3.1.1 Authentication and Account Management**

#### **REQ-01: Sign Up**

The system shall allow any user to create a new account using a valid email address and password.

- **Actors:** Manager, Analyst, Executive
- **Category:** Authentication

#### **Sub-requirements:**

- **REQ-01.1:** The system shall display a registration form requesting name, email, and password.
- **REQ-01.2:** The system shall validate the email format and password strength.
- **REQ-01.3:** The system shall prevent account creation if the email already exists.
- **REQ-01.4:** If the user signs up as a Manager, the system shall automatically create a Workspace linked to the account.

#### **REQ-02: Email Verification**

The system shall verify the identity of newly registered users through an email verification process.

- **Actors:** All Users
- **Category:** Authentication

#### **Sub-requirements:**

- **REQ-02.1:** The system shall send a verification email upon successful registration.
- **REQ-02.2:** The system shall activate the account only after successful verification.
- **REQ-02.3:** The system shall prevent unverified users from logging in.
- **REQ-02.4:** The system shall allow resending the verification email if the link expires.

#### **REQ-03: Login**

The system shall allow users to log in using valid credentials.

- **Actors:** Manager, Analyst, Executive
- **Category:** Authentication

#### **Sub-requirements:**

- **REQ-03.1:** The system shall validate the entered email and password.
- **REQ-03.2:** The system shall ensure the account is verified and not suspended.
- **REQ-03.3:** The system shall create an authenticated session (JWT or session token).
- **REQ-03.4:** The system shall redirect users based on their role:
  - Manager → Workspace Dashboard
  - Analyst / Executive → Shared Dashboards

#### **REQ-04: Logout**

The system shall allow users to securely terminate their session.

- **Actors:** All Users
- **Category:** Authentication

#### **Sub-requirements:**

- **REQ-04.1:** The system shall invalidate the active session or authentication token.
- **REQ-04.2:** The system shall clear session data from cache or memory.
- **REQ-04.3:** The system shall redirect the user to the login page.

#### **3.1.2 Profile Management**

#### **REQ-05: Manage Profile**

The system shall allow users to view and update their personal profile information.

- **Actors:** All Users
- **Category:** User Management

#### **Sub-requirements:**

- **REQ-05.1:** The system shall display current profile information.
- **REQ-05.2:** The system shall allow editing personal data (name, photo, contact info).
- **REQ-05.3:** The system shall validate updated information before saving.
- **REQ-05.4:** The system shall confirm successful updates.

#### **REQ-06: Deactivate My Account**

The system shall allow users to deactivate their own account.

- **Actors:** All Users
- **Category:** User Management

**Sub-requirements:**

- **REQ-06.1:** The system shall request confirmation before deactivation.
- **REQ-06.2:** The system shall change account status to “Deactivated”.
- **REQ-06.3:** The system shall terminate all active sessions.
- **REQ-06.4:** Deactivated users shall not be able to log in.

### **3.1.3 Workspace Management**

#### **REQ-07: Edit Workspace Information**

The system shall allow the Manager to update Workspace details.

- **Actors:** Manager
- **Category:** Workspace Management

**Sub-requirements:**

- **REQ-07.1:** The system shall display current Workspace information.
- **REQ-07.2:** The system shall allow editing Workspace name and description.
- **REQ-07.3:** The system shall validate updated data.
- **REQ-07.4:** The system shall save and apply changes immediately.

#### **REQ-08: View Workspace Members List**

The system shall allow users to view all members within the Workspace.

- **Actors:** Manager, Analyst, Executive
- **Category:** Workspace Management

**Sub-requirements:**

- **REQ-08.1:** The system shall retrieve Workspace members from the database.
- **REQ-08.2:** The system shall display member name, email, role, and status.
- **REQ-08.3:** Access shall be restricted to members of the Workspace only.

#### **REQ-09: Invite Members**

The system shall allow the Manager to invite new members via email.

- **Actors:** Manager
- **Category:** Workspace Management

**Sub-requirements:**

- **REQ-09.1:** The system shall allow the Manager to enter an email and select a role.
- **REQ-09.2:** The system shall validate email uniqueness.

- **REQ-09.3:** The system shall send an invitation email.
- **REQ-09.4:** The system shall track invitation status.

## **REQ-10: Assign Roles**

The system shall allow the Manager to assign or modify member roles.

- **Actors:** Manager
- **Category:** Access Control

### **Sub-requirements:**

- **REQ-10.1:** The system shall display available roles.
- **REQ-10.2:** The system shall apply role changes immediately.
- **REQ-10.3:** Updated permissions shall take effect without re-login when possible.

## **REQ-11: Manage Members**

The system shall allow the Manager to remove members from the Workspace.

- **Actors:** Manager
- **Category:** Workspace Management

### **Sub-requirements:**

- **REQ-11.1:** The system shall request confirmation before removal.
- **REQ-11.2:** The system shall revoke Workspace access.
- **REQ-11.3:** The system shall terminate active sessions of the removed member.

## **REQ-12: Suspend Member**

The system shall allow the Manager to temporarily suspend a member.

- **Actors:** Manager
- **Category:** Access Control

### **Sub-requirements:**

- **REQ-12.1:** The system shall mark the member as “Suspended”.
- **REQ-12.2:** Suspended members shall be prevented from logging in.
- **REQ-12.3:** Active sessions shall be invalidated immediately.

## **REQ-13: Accept Invitation**

The system shall allow invited users to join a Workspace.

- **Actors:** Analyst, Executive
- **Category:** Workspace Management

### **Sub-requirements:**

- **REQ-13.1:** The system shall validate the invitation token.
- **REQ-13.2:** New users shall be prompted to register before joining.
- **REQ-13.3:** Existing users shall join directly.
- **REQ-13.4:** The system shall assign the predefined role automatically.

## ***4. Non-Functional Requirements***

This section describes the non-functional requirements of the **BI Voice Agent** system. These requirements define the quality attributes, performance constraints, and operational characteristics that ensure the system operates efficiently, securely, and reliably, while providing a high-quality user experience.

### **4.1 Performance Requirements**

- **NFR-01:** The system shall process voice input and return a response (SQL query or visualization) within an acceptable time frame.
- **NFR-02:** The system shall support concurrent users within a workspace without significant degradation in performance.
- **NFR-03:** The ETL pipeline shall ingest and process uploaded datasets efficiently, even for large-scale data sources.
- **NFR-04:** Analytical queries executed on ClickHouse shall return results with low latency suitable for interactive BI usage.

### **4.2 Scalability Requirements**

- **NFR-05:** The system shall be horizontally scalable to support an increasing number of users, workspaces, and datasets.
- **NFR-06:** The data ingestion and streaming components shall scale independently based on workload.
- **NFR-07:** The architecture shall support future expansion, such as adding new AI models or analytics components without major system redesign.

### **4.3 Security Requirements**

- **NFR-08:** The system shall enforce role-based access control (RBAC) to restrict functionality based on user roles (Manager, Analyst, Executive).
- **NFR-09:** All user authentication mechanisms shall follow secure standards, including encrypted password storage and secure session handling.

- **NFR-10:** Sensitive data, including credentials and tokens, shall be transmitted using secure communication protocols.
- **NFR-11:** Users shall only access data and dashboards associated with their authorized workspace.

#### **4.4 Reliability and Availability**

- **NFR-12:** The system shall maintain consistent operation during normal usage hours.
- **NFR-13:** In case of partial system failures (e.g., ETL service interruption), the system shall continue operating with graceful degradation.
- **NFR-14:** The system shall log errors and critical events to support monitoring and debugging.

#### **4.5 Usability Requirements**

- **NFR-15:** The system shall provide an intuitive and user-friendly interface suitable for both technical and non-technical users.
- **NFR-16:** Voice-based interaction shall be simple and require minimal user training.
- **NFR-17:** Dashboards and reports shall be presented in a clear and visually understandable manner.

#### **4.6 Maintainability Requirements**

- **NFR-18:** The system shall be modular, allowing individual components (ETL, AI modules, UI) to be maintained or upgraded independently.
- **NFR-19:** The codebase shall follow clear architectural and coding standards to facilitate future maintenance.
- **NFR-20:** System logs and monitoring data shall support issue diagnosis and system health tracking.

#### **4.7 Compatibility and Integration**

- **NFR-21:** The system shall integrate seamlessly with external BI tools such as Metabase.
- **NFR-22:** The system shall support integration with multiple database types through the ETL pipeline.

- **NFR-23:** The system shall be compatible with modern web browsers without requiring additional plugins.

#### 4.8 Portability

- **NFR-24:** The system shall be deployable in different environments (development, testing, production).
- **NFR-25:** The system shall support containerized deployment to simplify setup and scalability.

## 4. System Requirements

Req-ID	Requirement Title	Category	Priority
REQ-1.1	The system shall allow users to create an account using email and password.	Authentication	High
REQ-1.2	The system shall verify newly registered users via an email verification link.	Authentication	High
REQ-1.3	The system shall allow users to log in using valid credentials.	Authentication	High
REQ-1.4	The system shall allow users to securely log out and terminate their session.	Authentication	Medium
REQ-1.5	The system shall allow users to view and update their personal profile information.	User Management	Medium
REQ-1.6	The system shall allow users to deactivate their own account and revoke access.	User Management	Medium
REQ-2.1	The system shall automatically create a workspace when a Manager registers.	Workspace Management	High
REQ-2.2	The system shall allow the Manager to edit workspace information.	Workspace Management	High

REQ-2.3	The system shall allow all workspace members to view the list of workspace members.	Workspace Management	High
REQ-2.4	The system shall allow the Manager to invite Analyst and Executive users via email.	Workspace Management	High
REQ-2.5	The system shall allow invited users to accept workspace invitations.	Workspace Management	High
REQ-3.1	The system shall allow the Manager to assign roles to workspace members.	Access Control	High
REQ-3.2	The system shall allow the Manager to modify member roles.	Access Control	High
REQ-3.3	The system shall allow the Manager to remove members from the workspace.	Workspace Management	High
REQ-3.4	The system shall allow the Manager to suspend workspace members.	Access Control	Medium
REQ-4.1	The system shall allow the Manager to upload structured databases or datasets.	Data Management	High
REQ-4.2	The system shall process uploaded data through an ETL pipeline.	Data Processing	High
REQ-4.3	The system shall store processed data in an analytical database.	Data Management	High
REQ-4.4	The system shall track ETL execution status and metadata.	Data Processing	Medium
REQ-5.1	The system shall allow users to submit analytical questions using voice input.	Voice Interaction	High
REQ-5.2	The system shall convert voice input to text using speech-to-text processing.	Voice Interaction	High

REQ-5.3	The system shall analyze user queries to determine analytical intent.	Analysis	High
REQ-5.4	The system shall automatically generate SQL queries based on user intent.	Analysis	High
REQ-5.5	The system shall validate generated SQL queries before execution.	Analysis	Medium
REQ-6.1	The system shall generate interactive dashboards based on analytical queries.	Dashboard Management	High
REQ-6.2	The system shall allow the Manager to manage dashboards.	Dashboard Management	High
REQ-6.3	The system shall allow Analysts and Executives to access shared dashboards.	Dashboard Access	High
REQ-6.4	The system shall allow users to generate and view analytical reports.	Reporting	Medium
REQ-6.5	The system shall allow users to export reports in common formats.	Reporting	Medium

Table 6 System Requirements Specification (SRS)

## 5. Requirements modeling

### 5.1 Basic UML Diagrams

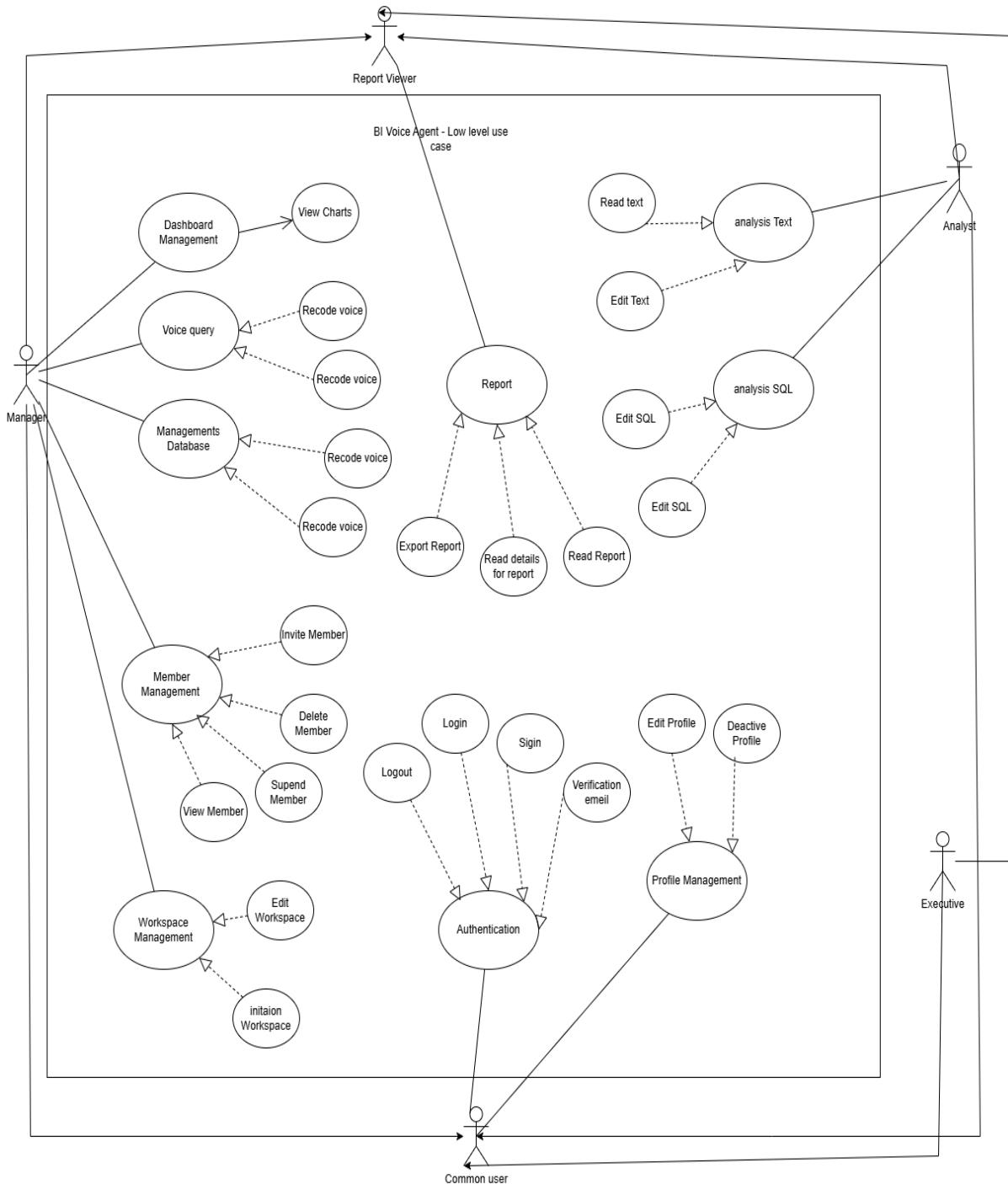


Figure 2 : Use case Diagram

## 5.2 System features (use case specifications - Sequence Diagrams):

- Sign Up

Field	Description
Requirement ID	R-01
Requirement Name	Sign Up
Actors	Manager – Analyst – Executive
Preconditions	1- The email address must not already exist in the system 2- The user must have a valid email address
Main Flow	1. The user opens the Sign-Up page. 2. The system displays the registration form. 3. The user enters the required information: name, email, and password. 4. The system validates the input data (email format, password strength, required fields, etc.). 5. The system checks whether the email address already exists in the system. 6. The system creates a new user account. 7. If the user is a Manager, the system automatically creates a Workspace linked to their account. 8. The system sends a verification email to the user. 9. The system displays a confirmation message: "Your account has been created. Please check your email to complete the verification process."
Alternative Flows	<i>A1 - Email Already Exists</i> 1. The user clicks the "Create Account" button. 2. The system detects that the email address is already registered. 3. The system displays an error message: "This email address is already in use." <i>A2 - Invalid Password</i> 1. The user submits the registration form. 2. The system identifies that the password does not meet security requirements. 3. The system displays an error message: "The password does not meet the required criteria."

<b>Postconditions</b>	<ol style="list-style-type: none"> <li>1. A new account is successfully created (Manager, Analyst, or Executive).</li> <li>2. If the user is a Manager, a Workspace is automatically created.</li> <li>3. A verification email is sent to the user</li> </ol>
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Table 7 : Use Case Specification for "Sign Up"

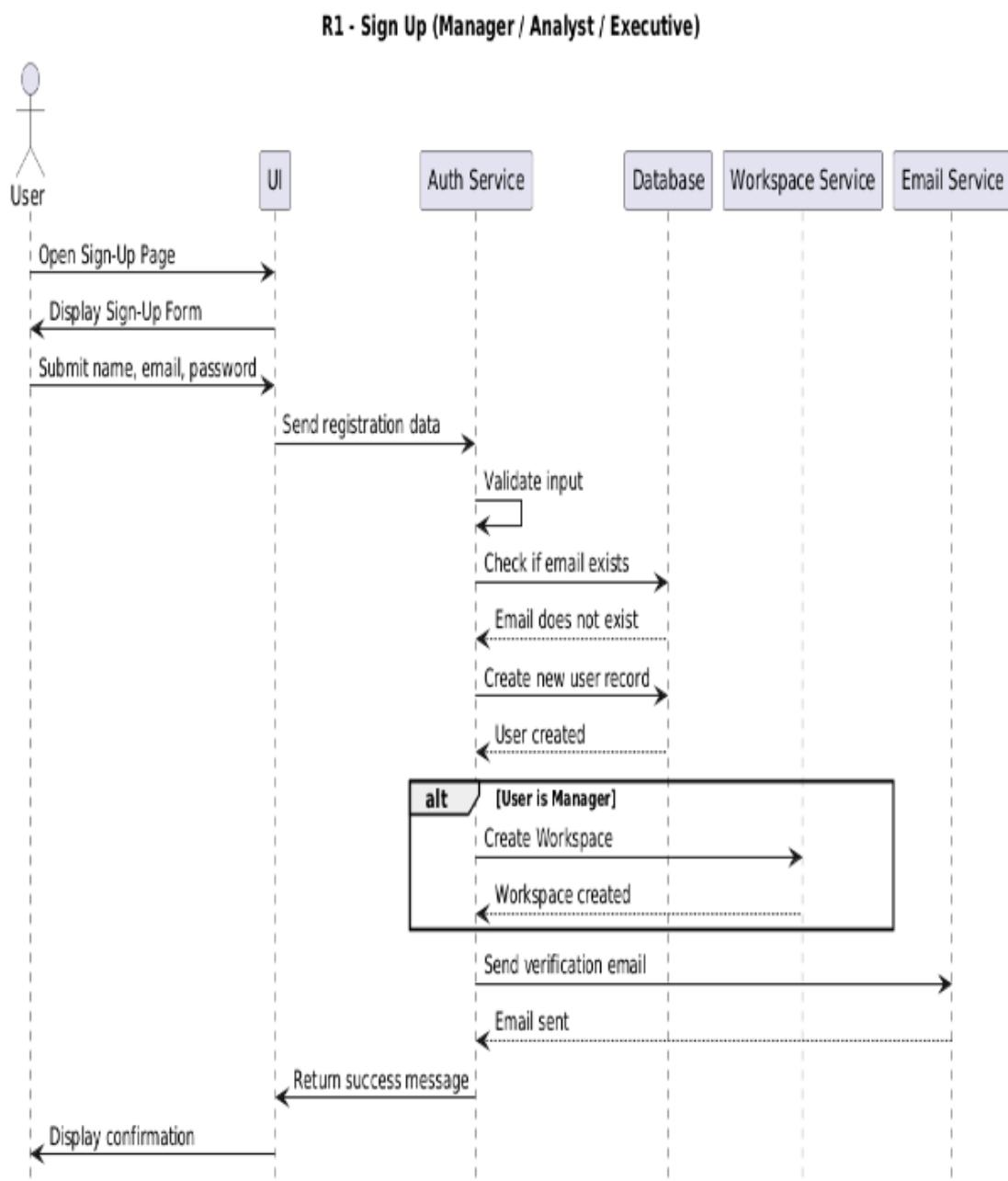


Figure 3 : Sequence Diagram for "Sign Up"

- **Email verification**

<b>Field</b>	<b>Description</b>
<b>Requirement ID</b>	<b>R-02</b>
<b>Requirement Name</b>	Email verification
<b>Actors</b>	Manager – Analyst – Executive
<b>Preconditions</b>	1. User has completed Sign Up 2. User account is in Unverified state
<b>Main Flow</b>	1. User checks their email inbox 2. User opens the verification email 3. User clicks the verification link 4. System receives the verification request 5. System validates the verification token 6. System activates the user account 7. System displays: “Your account has been successfully verified. You can now log in.”
<b>Alternative Flows</b>	<i>A1 - Expired Token</i> 1. User clicks the link 2. System detects the token is expired 3. System displays: “Verification link expired.” 4. System offers “Resend verification email.” <i>A2 - Already Verified</i> 1. User clicks the link 2. System detects the account is already activated 3. System displays: “Your account is already verified.”
<b>Postconditions</b>	1. User account is activated 2. User can log in to the system 3. Account status updated to Activated in the database

Table 8 : Use Case Specification for “Email Verification”

## R2 - Email Verification (Manager / Analyst / Executive)

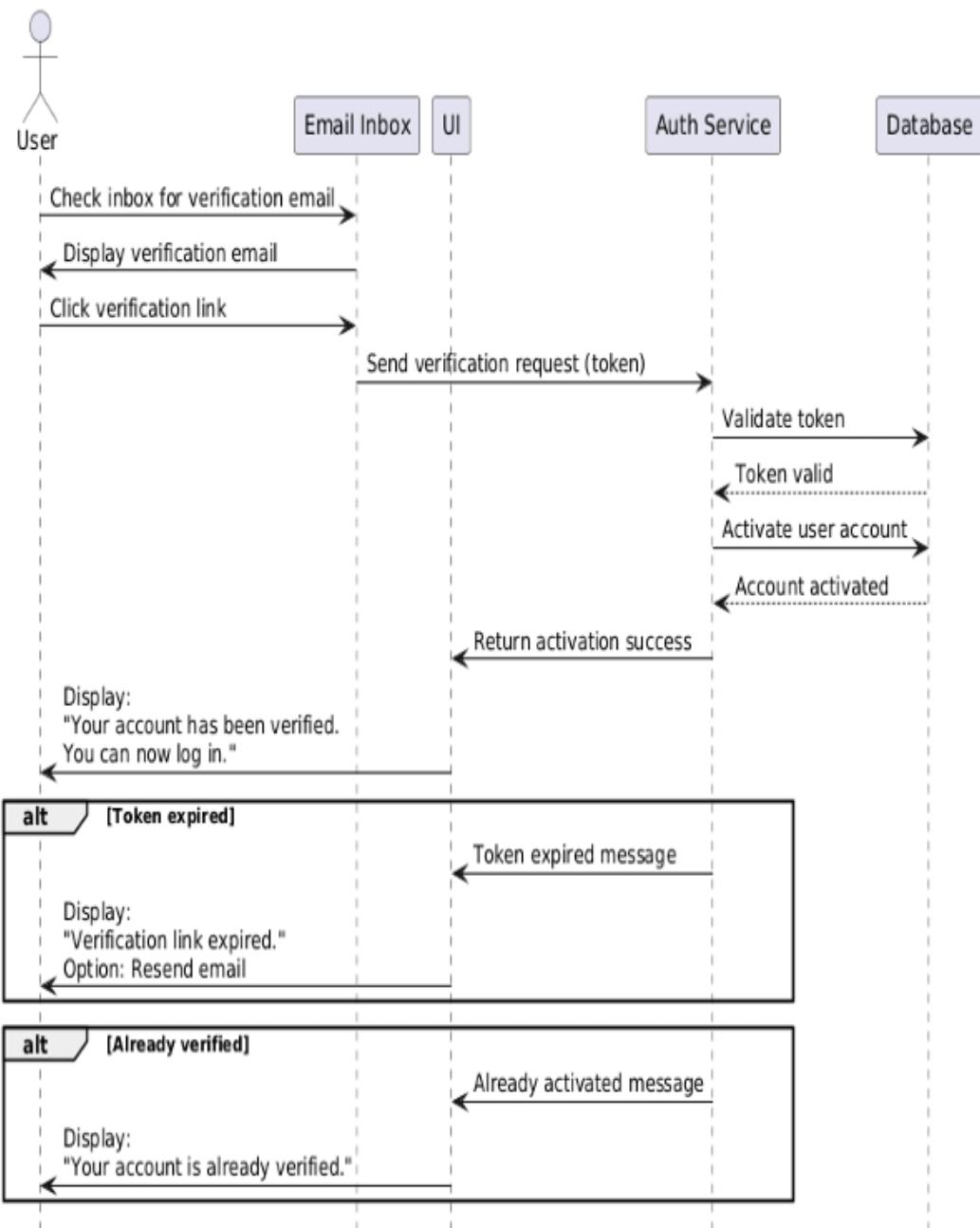


Figure 4 : Sequence Diagram for "Email Verification"

- **Login**

Field	Description
<b>Requirement ID</b>	<b>R-03</b>
<b>Requirement Name</b>	Login
<b>Actors</b>	Manager – Analyst – Executive
<b>Preconditions</b>	<ol style="list-style-type: none"> <li>1. The user must already have a registered account in the system</li> <li>User</li> <li>2. The user's account must be verified via email</li> </ol>
<b>Main Flow</b>	<ol style="list-style-type: none"> <li>1. The user opens the Login page</li> <li>2. The system displays the login form</li> <li>3. The user enters their email and password</li> <li>4. The user clicks the “Login” button</li> <li>5. The system validates the provided credentials</li> <li>6. The system checks for a matching account in the database</li> <li>7. The system verifies that the account is activated and not suspended</li> <li>8. If the credentials are correct, the system creates a login session (Session or JWT Token)</li> <li>9. The system redirects the user to the appropriate landing page based on their role: <ul style="list-style-type: none"> <li>• Manager : Workspace Dashboard</li> <li>• Analyst / Executive : Shared Dashboard</li> </ul> </li> <li>10. The system displays a success message or directly redirects the user to their dashboard</li> </ol>
<b>Alternative Flows</b>	<p><i>A1 - Invalid Credentials</i></p> <ol style="list-style-type: none"> <li>1. The user enters an incorrect email or password</li> <li>2. The system displays:“Invalid login credentials.”</li> </ol> <p><i>A2 - Account Not Verified</i></p> <ol style="list-style-type: none"> <li>1. The user attempts to log in before email verification</li> <li>2. The system displays:“Please verify your email before logging in.”</li> </ol> <p><i>A3 - Account Suspended</i></p> <ol style="list-style-type: none"> <li>1. The system checks the user’s status</li> <li>2. The system detects that the account is suspended by the Manager</li> </ol>

	3. The system displays: "Your account is suspended. You cannot log in."
<b>Postconditions</b>	4. User is successfully authenticated 5. A session (or JWT Token) is generated 6. User is redirected to the correct landing page according to their role

Table 9 : Use Case Specification for "Login"

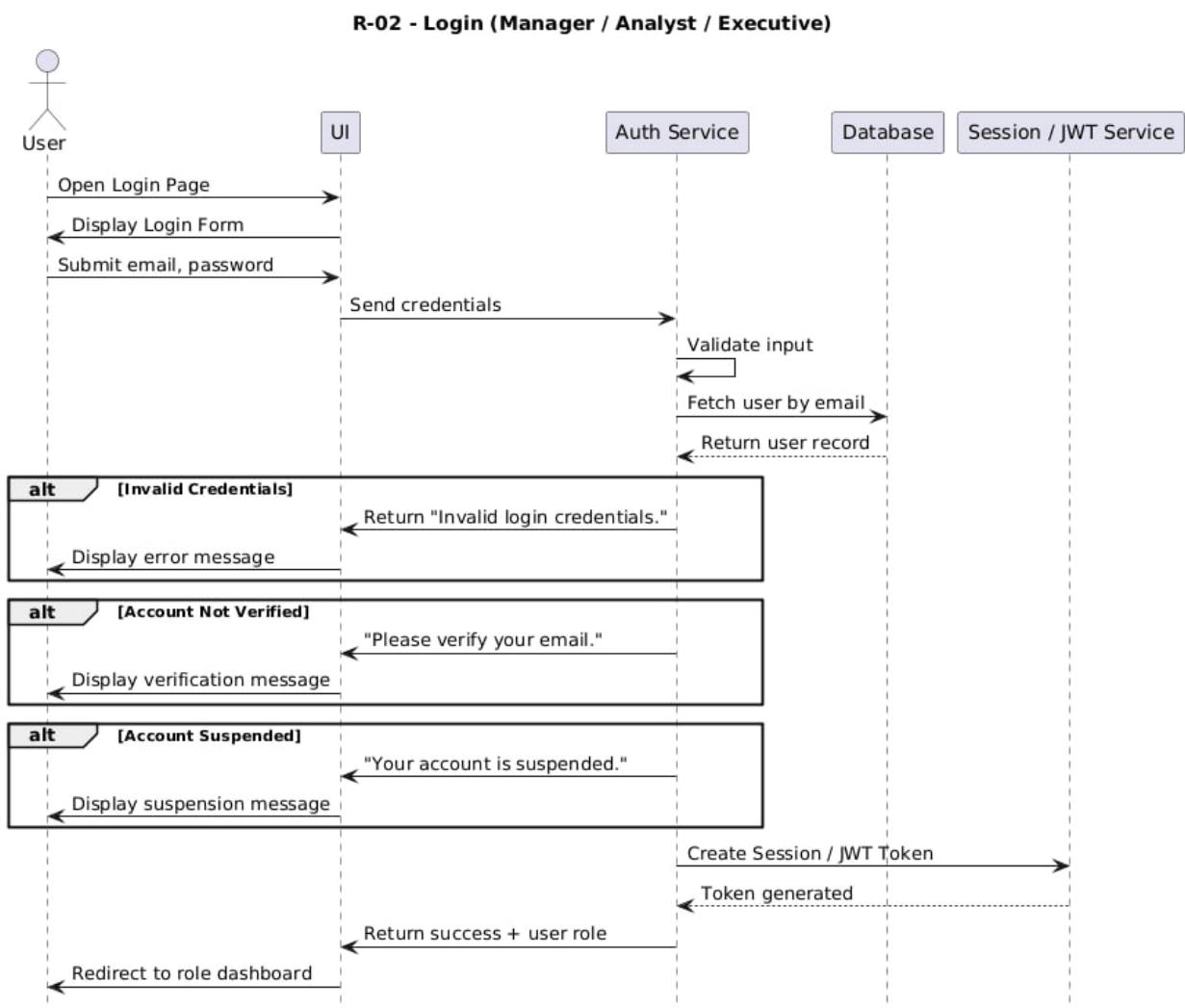


Figure 5 : Sequence Diagram for "Log in"

- **Logout**

<b>Field</b>	<b>Description</b>
<b>Requirement ID</b>	<b>R-04</b>
<b>Requirement Name</b>	Logout
<b>Actors</b>	Manager – Analyst – Executive
<b>Preconditions</b>	<ol style="list-style-type: none"> <li>1. The user must be currently logged in</li> <li>2. A valid session or authentication token must exist</li> </ol>
<b>Main Flow</b>	<ol style="list-style-type: none"> <li>1. The user clicks the “Logout” button</li> <li>2. The system receives the logout request</li> <li>3. The system invalidates the active session or authentication token</li> <li>4. The system clears any session-related data stored in memory or cache</li> <li>5. The system redirects the user to the login page or public home page</li> <li>6. The system displays a confirmation message: a. “You have been logged out successfully.”</li> </ol>
<b>Alternative Flows</b>	<p><i>A1 - Session Already Expired</i></p> <ol style="list-style-type: none"> <li>1. The user attempts to log out</li> <li>2. The system detects that the session has already expired</li> <li>3. The system redirects the user to the login page without showing an error message</li> </ol>
<b>Postconditions</b>	<ol style="list-style-type: none"> <li>1. The current user session is invalidated</li> <li>2. The user is no longer authenticated</li> <li>3. No protected actions can be performed until the user logs in again</li> </ol>

*Table 10 : Use Case Specification for “Logout”*

#### R-04 - Logout

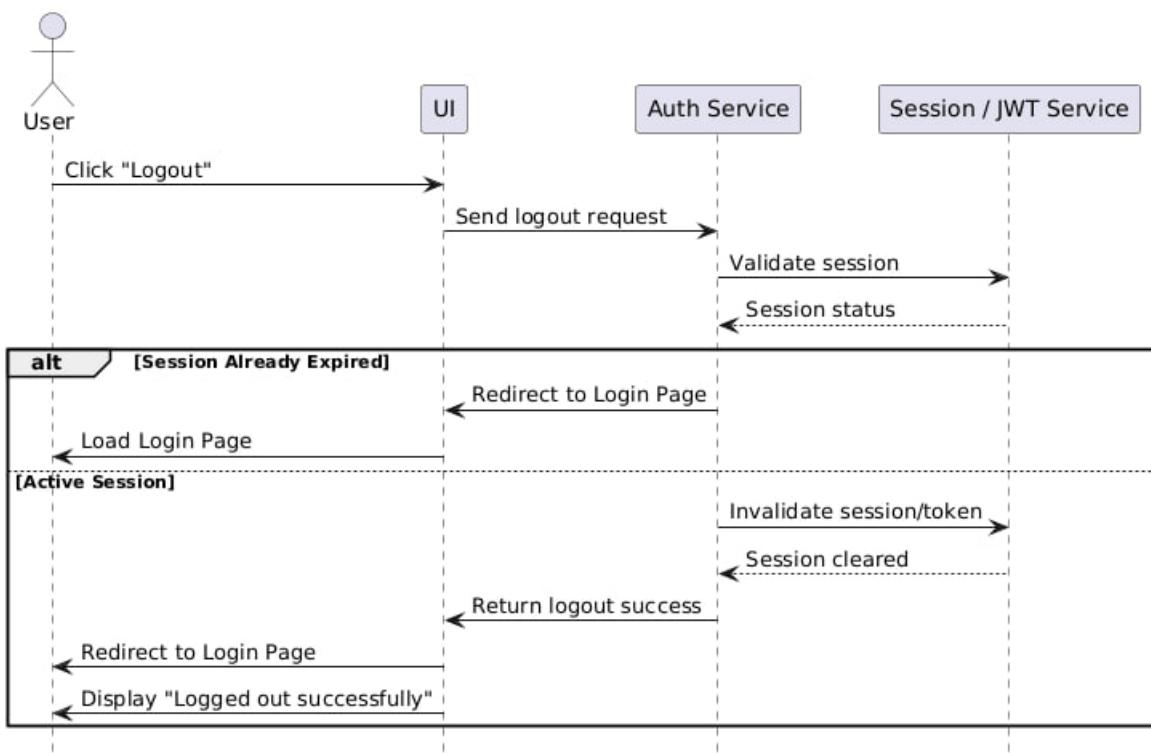


Figure 6 : Sequence Diagram for "Logout"

- **Manage Profile**

<b>Field</b>	<b>Description</b>
<b>Requirement ID</b>	<b>R-05</b>
<b>Requirement Name</b>	Manage Profile
<b>Actors</b>	Manager – Analyst – Executive
<b>Preconditions</b>	1. User is logged in 2. Account is active
<b>Main Flow</b>	1. User opens the Profile page 2. System retrieves and displays profile info 3. System shows editable fields (name, photo, phone...) 4. User updates fields and clicks Save 5. System validates updated data 6. System updates the database record 7. System shows success message
<b>Alternative Flows</b>	<i>A1 - Invalid Data</i> 1. User clicks Save 2. System detects invalid fields 3. System displays: “Invalid profile information.”
<b>Postconditions</b>	1. The current user session is invalidated 2. The user is no longer authenticated 3. No protected actions can be performed until the user logs in again

*Table 11 : Use Case Specification for “Manage Profile”*

### R-05 - Manage Profile

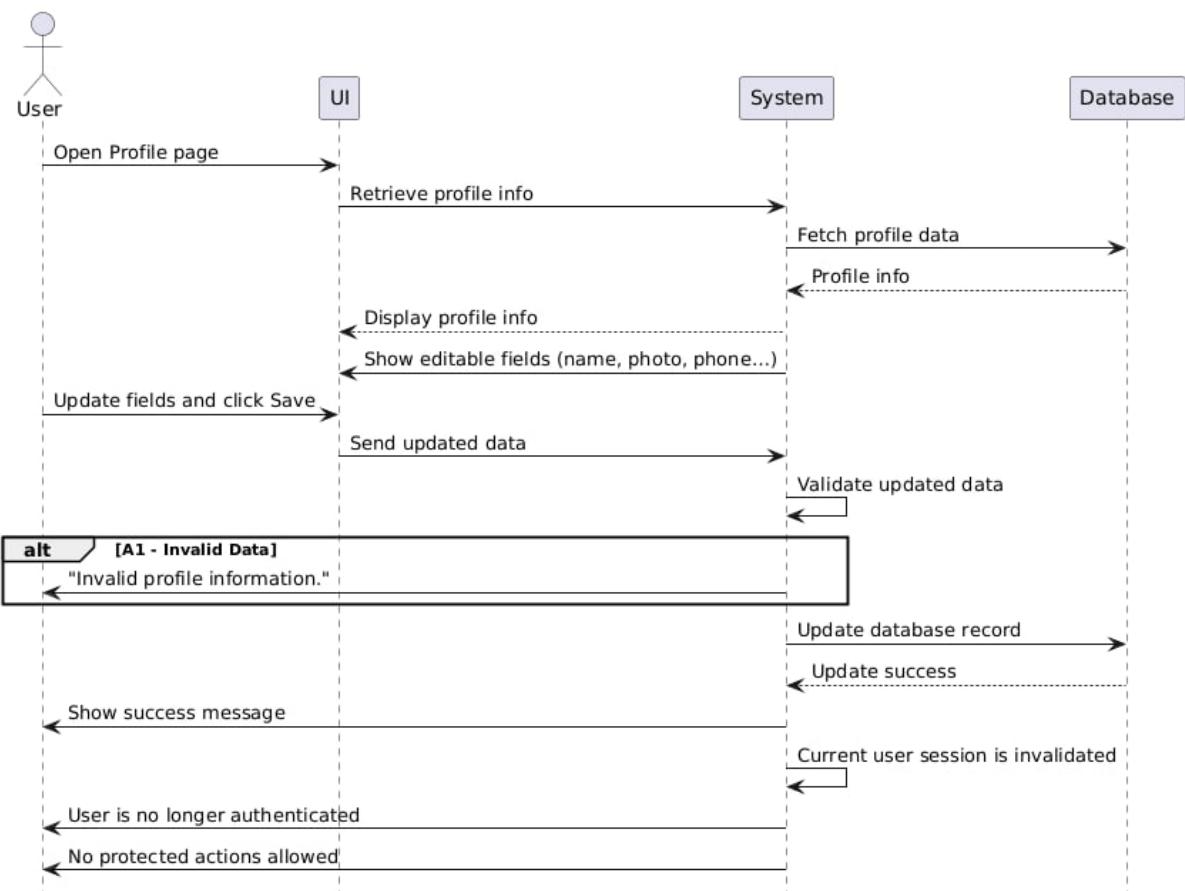


Figure 7 : Sequence Diagram for "Manage Profile"

- **Deactivate My Profile**

Field	Description
<b>Requirement ID</b>	<b>R-06</b>
<b>Requirement Name</b>	Deactivate My Profile
<b>Actors</b>	Manager – Analyst – Executive
<b>Preconditions</b>	1. User is logged in
<b>Main Flow</b>	<ol style="list-style-type: none"> <li>1. User opens Account Settings</li> <li>2. System displays account management options including "Deactivate Account"</li> <li>3. User selects "Deactivate Account"</li> <li>4. System shows a confirmation warning</li> <li>5. User confirms the request</li> <li>6. System verifies the user's identity</li> <li>7. System sets account status to "Deactivated"</li> <li>8. System terminates active sessions</li> <li>9. System shows a success message</li> </ol>
<b>Alternative Flows</b>	<p>A1 - User Cancellation</p> <ol style="list-style-type: none"> <li>1. User clicks "Deactivate Account"</li> <li>2. System shows confirmation</li> <li>3. User selects "Cancel"</li> <li>4. System returns to settings unchanged</li> </ol>
<b>Postconditions</b>	<ol style="list-style-type: none"> <li>1. Account is deactivated</li> <li>2. User cannot log in unless reactivation is supported</li> <li>3. All sessions are terminated</li> </ol>

Table 12 : Use Case Specification for "Deactive My Profile"

### R-06 - Deactivate My Profile

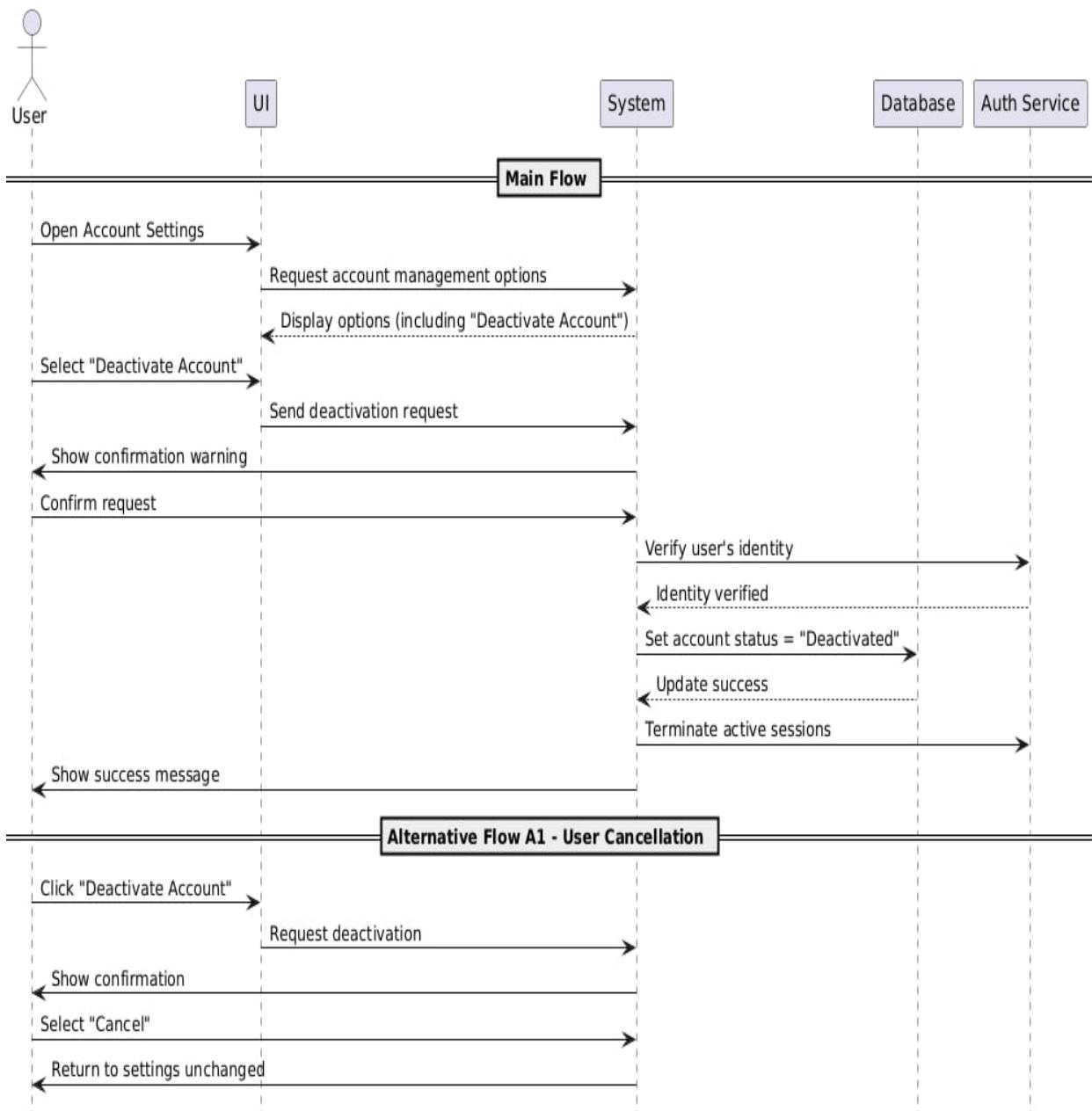


Figure 8 : Sequence Diagram for "Deactivate My Profile"

- **Edit Workspace Info**

Field	Description
<b>Requirement ID</b>	<b>R-07</b>
<b>Requirement Name</b>	Edit Workspace Info
<b>Actors</b>	Manager
<b>Preconditions</b>	1. manager is logged in
<b>Main Flow</b>	<ol style="list-style-type: none"> <li>1. Manager opens Workspace Settings</li> <li>2. System displays current workspace info</li> <li>3. Manager clicks “Edit Workspace Info”</li> <li>4. System shows editable fields</li> <li>5. Manager updates fields and clicks Save</li> <li>6. System validates updated data</li> <li>7. System updates the database</li> <li>8. System displays success message</li> </ol>
<b>Alternative Flows</b>	<p><i>A1 - Invalid Data</i></p> <ol style="list-style-type: none"> <li>1. Manager clicks Save</li> <li>2. System detects invalid data</li> <li>3. System shows: “Invalid input data.”</li> </ol>
<b>Postconditions</b>	<ol style="list-style-type: none"> <li>1. Workspace info updated</li> <li>2. Updated values displayed in manager UI</li> </ol>

Table 13 : Use Case Specification for "Edit Workspace Info "

## R-07 - Edit Workspace Info

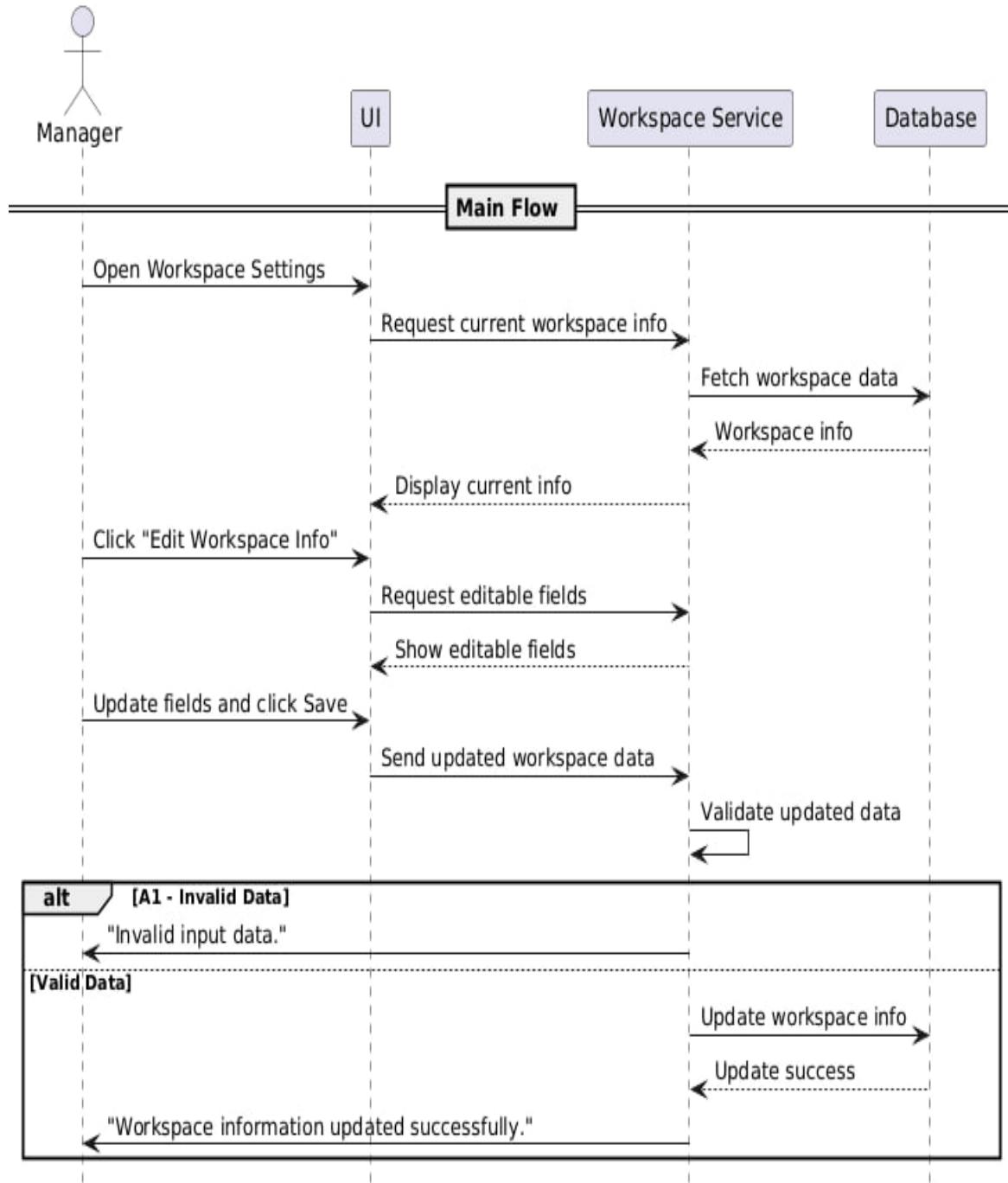


Figure 9 : Sequence Diagram for "Edit Workspace Info"

- **View Workspace Members List**

Field	Description
Requirement ID	R-08
Requirement Name	View Workspace Members List
Actors	Manager – Analyst – Executive
Preconditions	1. user is logged in 2. User is a member of the current workspace
Main Flow	1. User opens Workspace Members page 2. System verifies permission to view members 3. User stays on the same page 4. System retrieves workspace members from the database 5. System displays the list (name, email, role, status)
Alternative Flows	
Postconditions	1. Members list successfully retrieved 2. User can view workspace members

Table 14 : Use Case Specification for "View Workspace Member list"

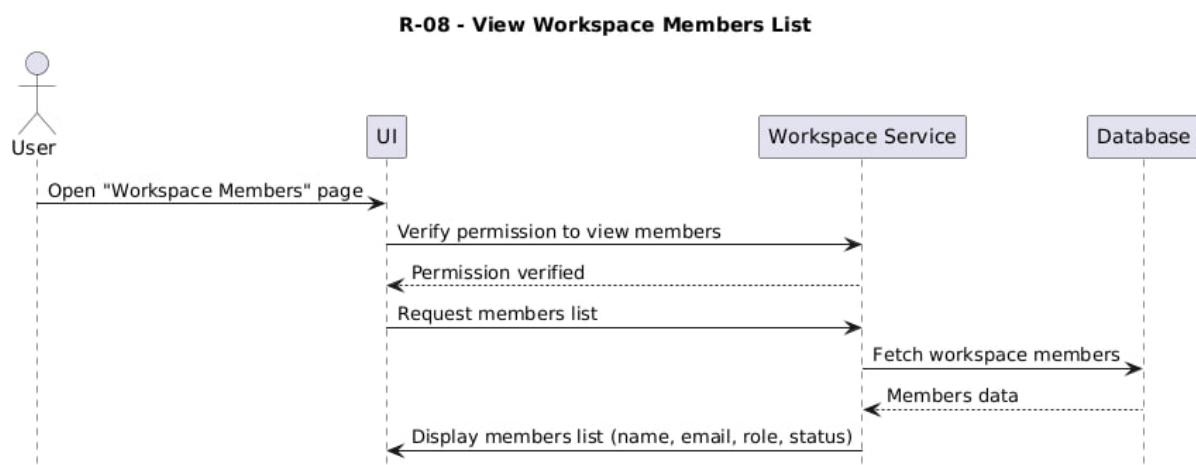


Figure 10 : Sequence Diagram for " View Workspace members list"

## • Invite Members

Field	Description
Requirement ID	R-09
Requirement Name	Invite Members
Actors	Manager
Preconditions	<ul style="list-style-type: none"> <li>1. manager is logged in</li> <li>2. New member's email is valid</li> </ul>
Main Flow	<ul style="list-style-type: none"> <li>1. Manager opens Members Management page</li> <li>2. System shows "Invite Member" option</li> <li>3. Manager clicks "Invite Member"</li> <li>4. System displays invitation form</li> <li>5. Manager enters email and selects role</li> <li>6. System validates email and role</li> <li>7. System creates invitation record</li> <li>8. System sends invitation email</li> <li>9. System shows success message</li> </ul>
Alternative Flows	<p><i>A1 - Invalid Email:</i></p> <ul style="list-style-type: none"> <li>1. Manager enters invalid email.</li> <li>2. System rejects it.</li> <li>3. System shows: "Invalid email address."</li> </ul> <p><i>A2 - Already Invited</i></p> <ul style="list-style-type: none"> <li>1. Manager enters previously invited email</li> <li>2. System detects existing invitation</li> <li>3. System shows: "Invitation already sent."</li> </ul> <p><i>A3 - User Already Exists</i></p> <ul style="list-style-type: none"> <li>1. Manager enters email of existing user</li> <li>2. System detects existing account</li> <li>3. System shows: "User already exists."</li> </ul>
Postconditions	<ul style="list-style-type: none"> <li>1. New invitation is created</li> <li>2. Invitation email is sent</li> </ul>

Table 15 : Use Case Specification for "Invite Member"

### R-09 - Invite Members

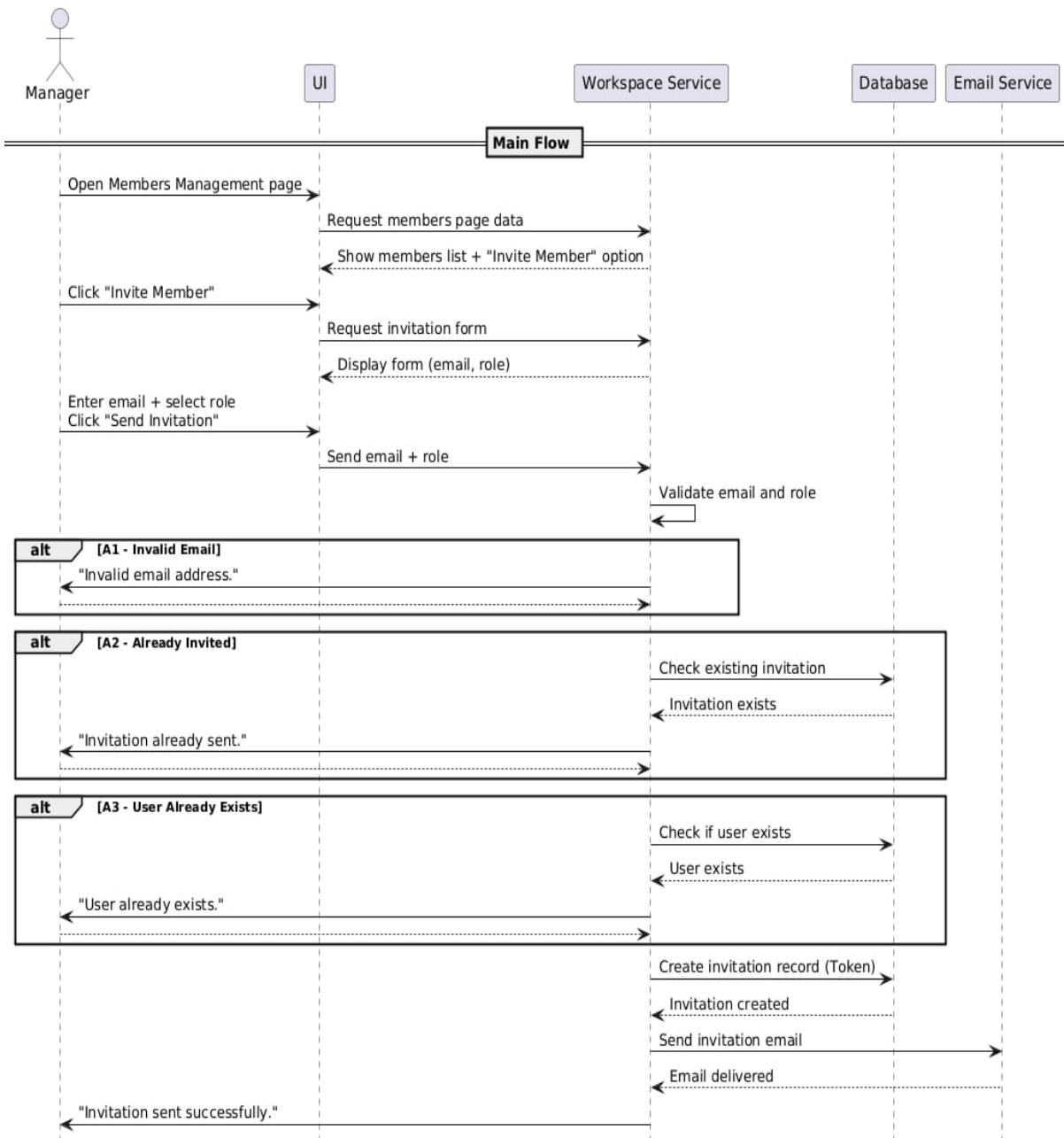


Figure 11 : Sequence Diagram for " invite members"

- **Assign Roles**

Field	Description
<b>Requirement ID</b>	<b>R-10</b>
<b>Requirement Name</b>	Assign Roles
<b>Actors</b>	Manager
<b>Preconditions</b>	1. manager is logged in 2. Member exists in the workspace
<b>Main Flow</b>	1. Manager opens Members Management page 2. System displays members and roles 3. Manager selects a member 4. System shows available actions including Change Role 5. Manager selects new role 6. System validates the role 7. System updates the role in the database 8. System shows success message
<b>Alternative Flows</b>	A1 - Member Not Found 1. Manager selects a member 2. System detects the member does not exist 3. System shows: "Member not found."
<b>Postconditions</b>	1. Role is updated in the database 2. New role appears immediately in the UI

*Table 16 : Use Case Specification for "Assign Roles"*

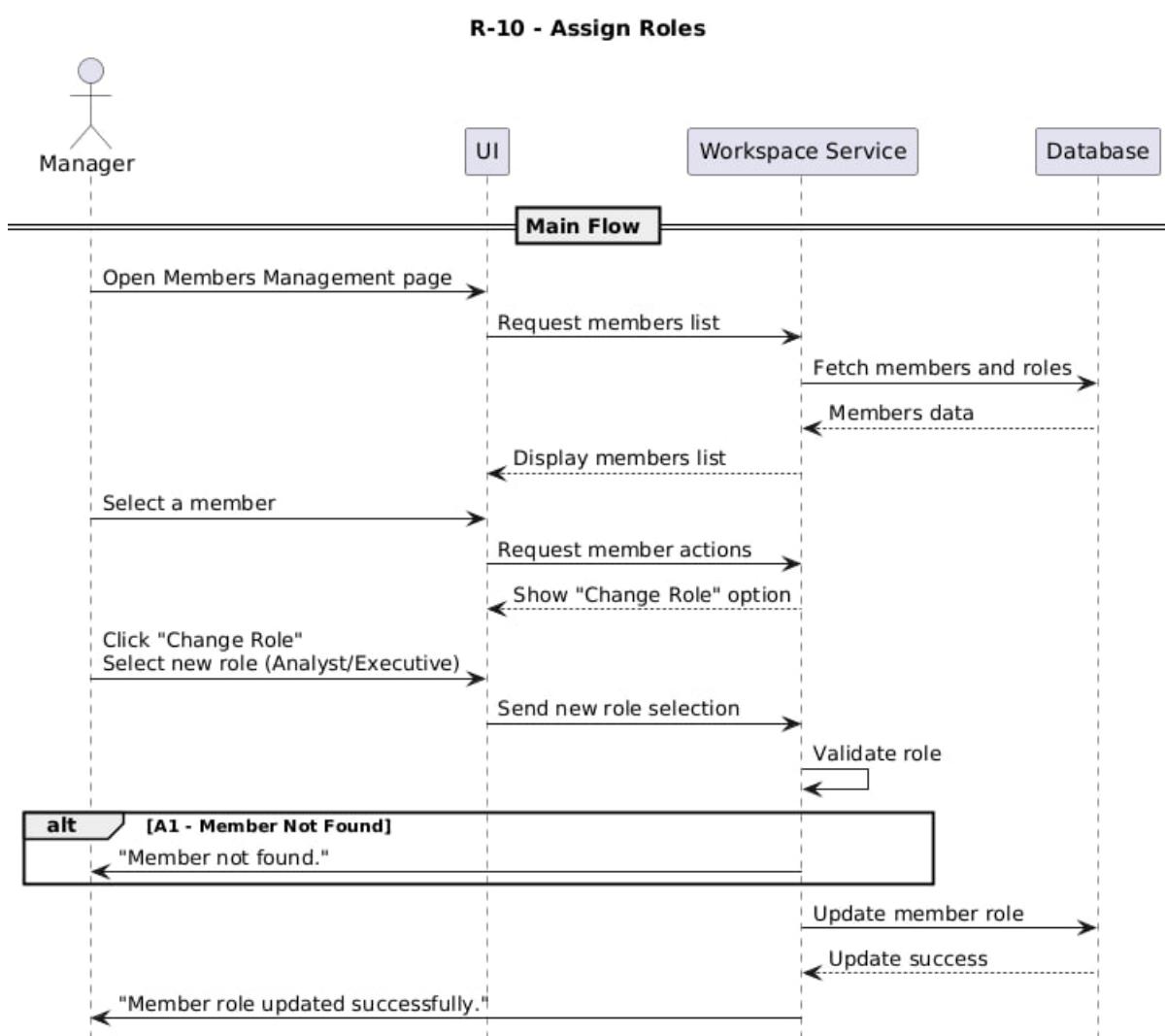


Figure 12 : Sequence Diagram for "Assign Roles"

## • Remove Members

Field	Description
Requirement ID	R-11
Requirement Name	Remove Members
Actors	Manager
Preconditions	1. manager is logged in 2. Member exists in the workspace
Main Flow	1. Manager opens Members Management page 2. System displays members with a Remove option 3. Manager selects a member and clicks “Remove” 4. System shows confirmation dialog 5. Manager confirms removal 6. System verifies permissions 7. System removes the member 8. System terminates active sessions 9. System shows success message
Alternative Flows	<i>A1 - Cancel Removal</i> 1. System displays confirmation dialog 2. Manager clicks “Cancel” 3. System returns to Members Management with no changes
Postconditions	1. Member is removed 2. Member loses workspace access

Table 17 : Use Case Specification for “Remove Members”

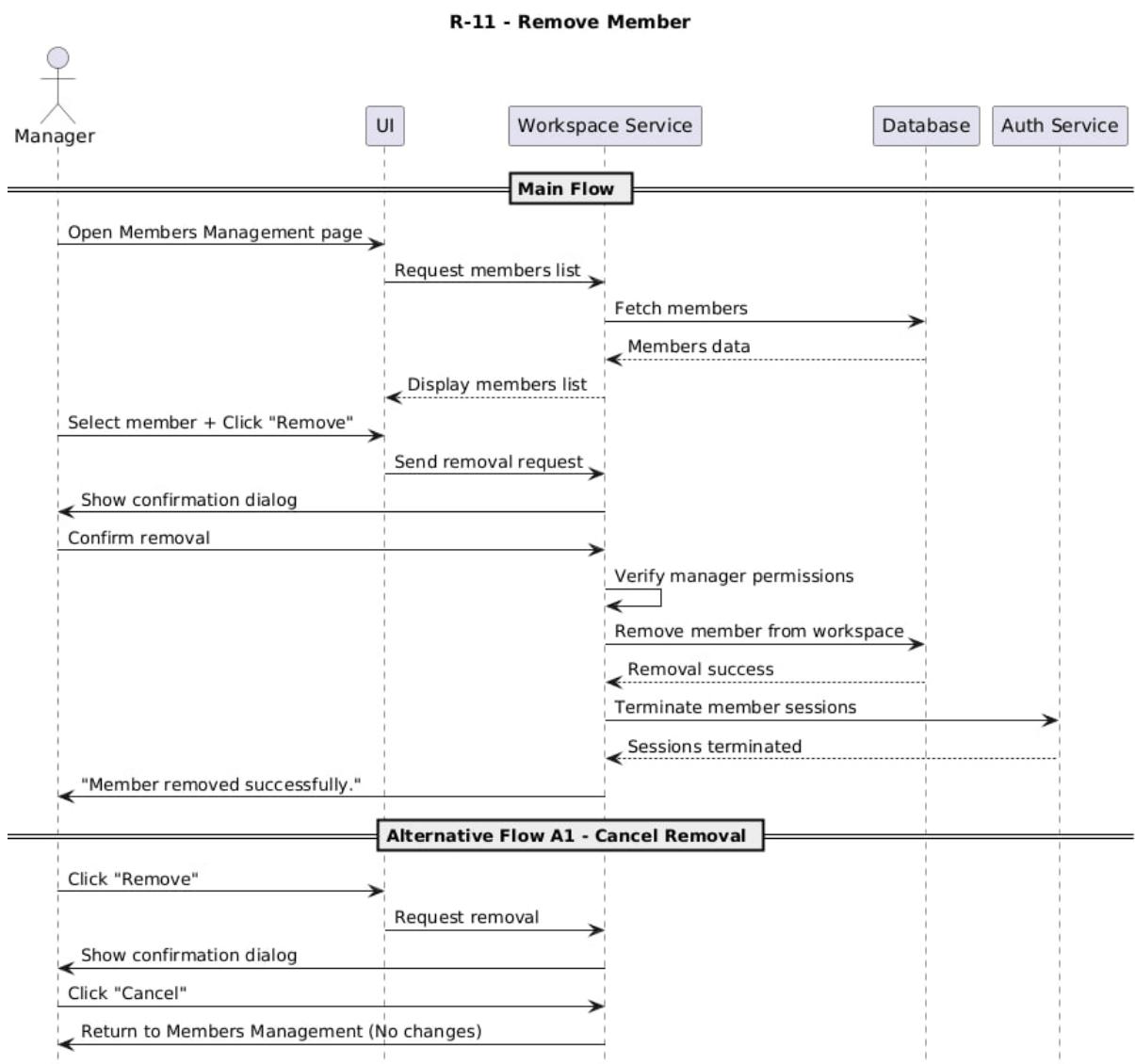


Figure 13 : Sequence Diagram for "Remove Member"

- **Suspend Member**

<b>Field</b>	<b>Description</b>
<b>Requirement ID</b>	<b>R-12</b>
<b>Requirement Name</b>	Suspend Member
<b>Actors</b>	Manager
<b>Preconditions</b>	<ol style="list-style-type: none"> <li>1. manager is logged in</li> <li>2. Member exists in the workspace</li> </ol>
<b>Main Flow</b>	<ol style="list-style-type: none"> <li>1. Manager opens Members Management page</li> <li>2. System shows members with status (Active/Suspended)</li> <li>3. Manager selects a member and views details</li> <li>4. System shows “Suspend Member” option</li> <li>5. Manager clicks “Suspend Member”</li> <li>6. System shows confirmation with impact explanation</li> <li>7. Manager confirms</li> <li>8. System updates member status to Suspended</li> <li>9. System invalidates member's session</li> <li>10. System shows success message</li> </ol>
<b>Alternative Flows</b>	<p><i>A1 - Member Already Suspended</i></p> <ol style="list-style-type: none"> <li>1. Manager selects the member</li> <li>2. System detects status : Suspended</li> <li>3. System shows: “Member is already suspended.”</li> </ol>
<b>Postconditions</b>	<ol style="list-style-type: none"> <li>1. Member is suspended</li> <li>2. Member cannot log in to the workspace</li> <li>3. Active sessions are terminated</li> </ol>

*Table 18 : Use Case Specification for “Suspend Member”*

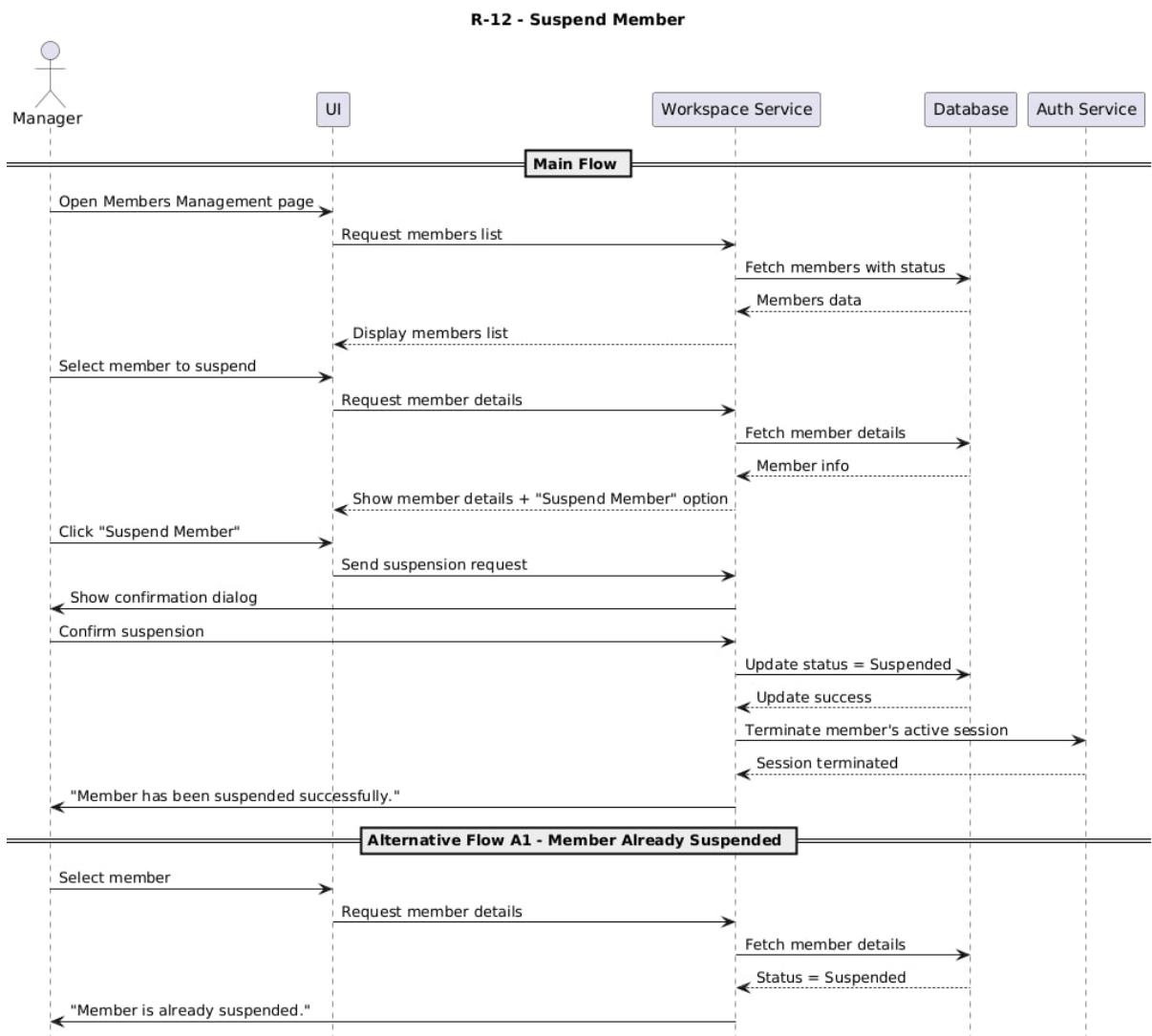


Figure 14 : Sequence Diagram for "Suspend Member"

- **Accept Invitation**

Field	Description
Requirement ID	R-13
Requirement Name	Accept Invitation
Actors	Analyst – Executive
Preconditions	<ol style="list-style-type: none"> <li>1. User has been invited by the manager</li> <li>2. User received the invitation email</li> <li>3. Invitation token is valid and unused</li> </ol>
Main Flow	<ol style="list-style-type: none"> <li>1. User opens invitation email</li> <li>2. System shows “Join Workspace” link</li> <li>3. User clicks the link</li> <li>4. System validates token</li> <li>5. System checks invitation validity and usage</li> <li>6. System displays one of two options: <ul style="list-style-type: none"> <li>• No account : Registration form</li> <li>• Existing account : Join button</li> </ul> </li> <li>7. User: <ul style="list-style-type: none"> <li>• New user : Register &amp; Join</li> <li>• Existing user : Join Now</li> </ul> </li> <li>8. System creates or links account</li> <li>9. System assigns the role</li> <li>10. System marks invitation as Used</li> <li>11. System displays success message</li> </ol>
Alternative Flows	<p><i>A1 - Invalid Link</i></p> <ol style="list-style-type: none"> <li>4. User clicks the link</li> <li>5. System checks invitation token</li> <li>6. Token is invalid</li> <li>7. System displays: “Invalid invitation link.”</li> </ol> <p><i>A2 - Invitation Expired</i></p> <ol style="list-style-type: none"> <li>1. User clicks the link</li> <li>2. System detects expired invitation</li> <li>3. System displays: “Invitation expired.”</li> </ol> <p><i>A3 - Invitation Already Used</i></p> <ol style="list-style-type: none"> <li>1. User opens the link</li> </ol>

	<p>2. System detects invitation status : Used      3. System displays: “This invitation was already used.”</p>
<b>Postconditions</b>	<p>1. User is added to the workspace      2. Invitation is marked as Used      3. User has the assigned role</p>

*Table 19 : Use Case Specification for “Accept Invitation”*

### R-13 - Accept Invitation

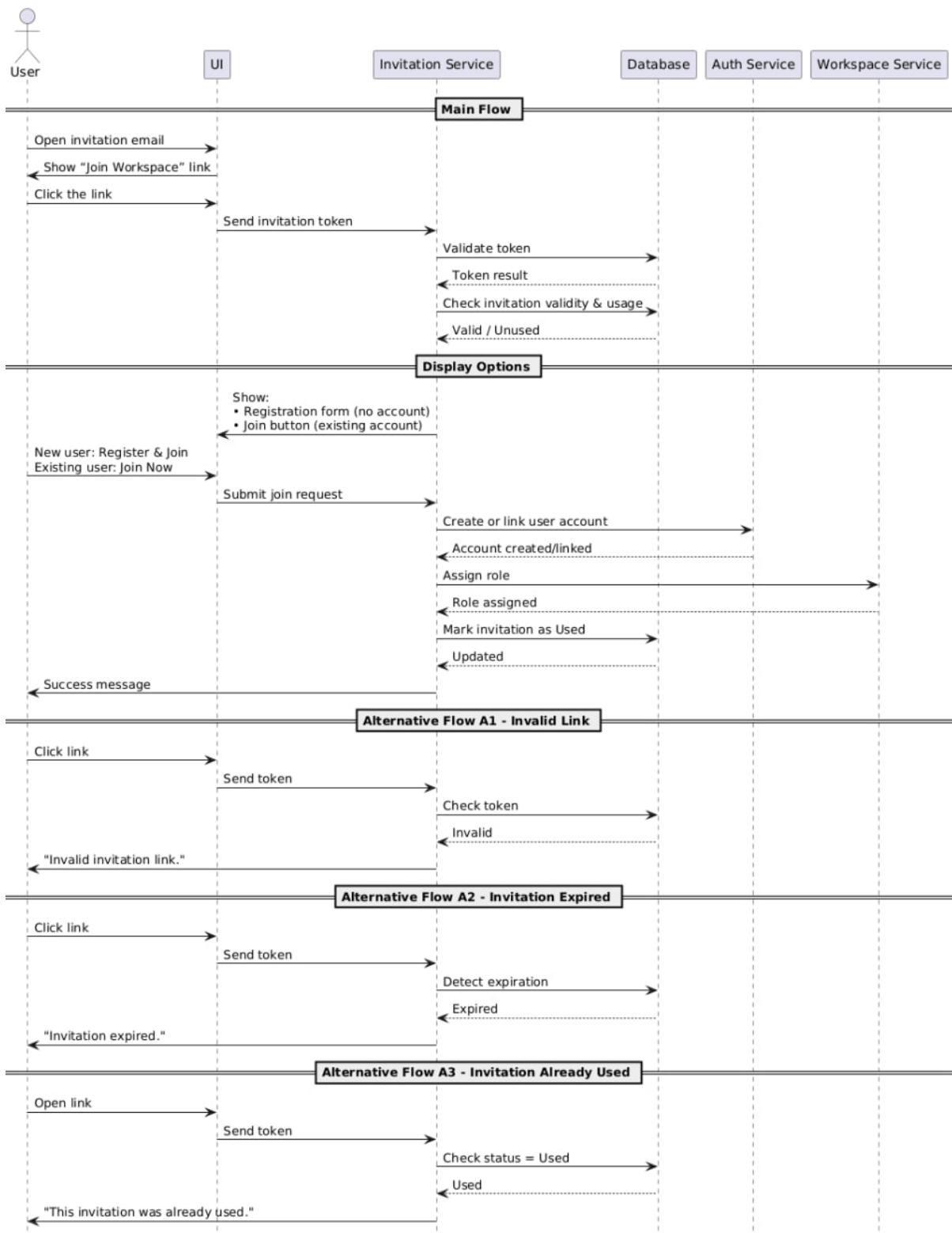


Figure 15 : Sequence Diagram for "Accept invitation"

- **Record Voice and Generate Report**

<b>Requirement ID</b>	R-14
<b>Requirement Name</b>	Record Voice and Generate Report
<b>Actors</b>	Manager
<b>Preconditions</b>	1. Manager is logged in 2. Microphone permission is granted
<b>Main Flow</b>	1. Manager opens Voice Input page 2. System displays “Record Voice” option 3. Manager clicks “Record” 4. System records audio 5. Manager clicks “Stop” 6. System sends audio to Whisper model 7. System converts voice to text 8. System sends text to LLM for SQL generation 9. System generates SQL query 10. System executes SQL on ClickHouse 11. System sends results to Metabase 12. Metabase generates chart and dashboard 13. System saves report metadata 14. System displays updated dashboard to Manager
<b>Alternative Flows</b>	A1 – Voice Processing Failed 1. System shows error message
<b>Postconditions</b>	1. Report is created 2. Report appears in Manager dashboard

Table 20 : Use Case Specification for “Record Voice”

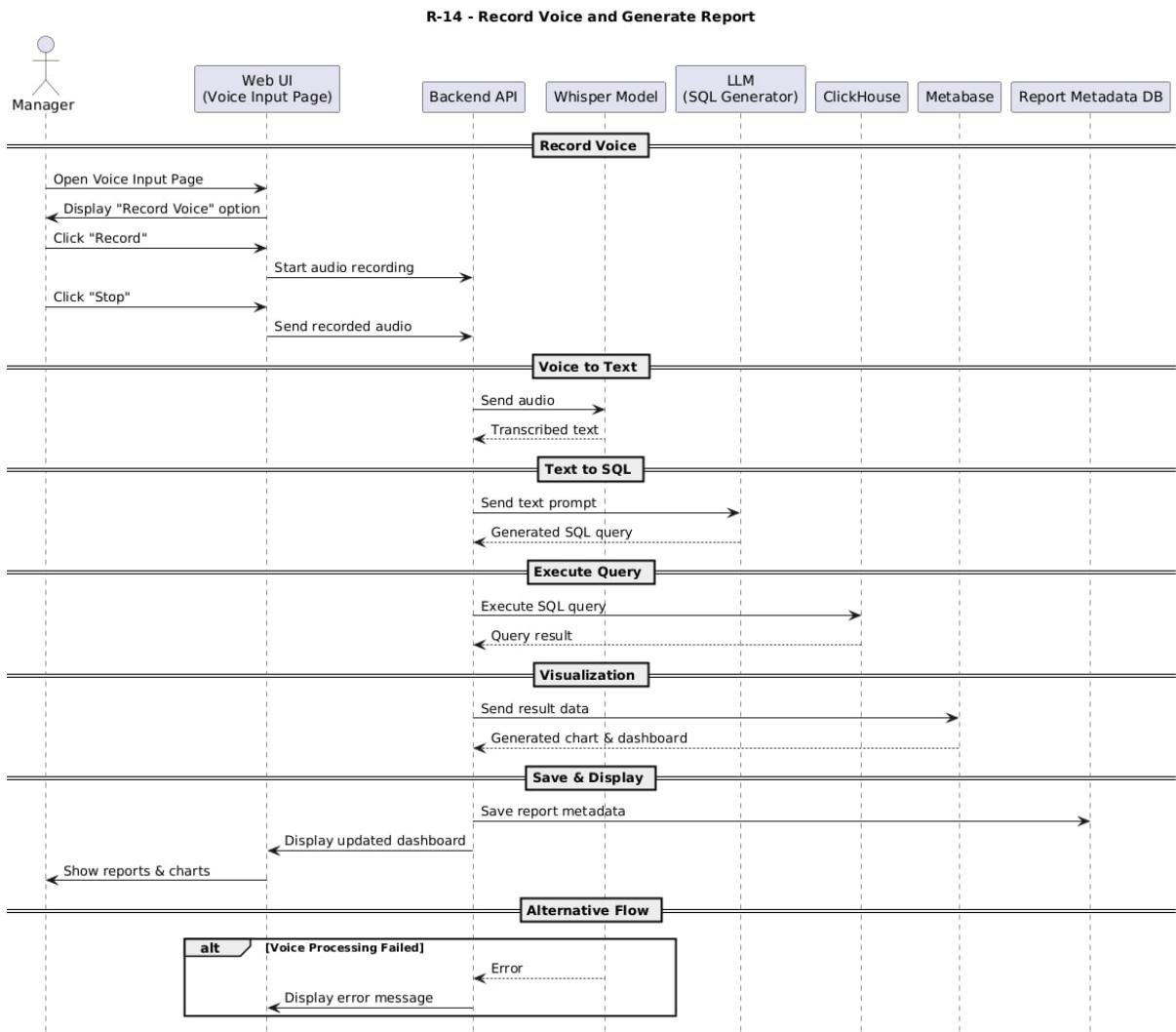


Figure 16 : Sequence Diagram for "Record voice"

- **Upload Voice and Generate Report**

<b>Requirement ID</b>	R-15
<b>Requirement Name</b>	Upload Voice and Generate Report
<b>Actors</b>	Manager
<b>Preconditions</b>	1. Manager is logged in 2. Audio file exists
<b>Main Flow</b>	1. Manager opens Upload Voice page 2. System displays upload interface 3. Manager uploads audio file 4. System validates file format 5. System sends audio to Whisper model 6. System converts voice to text 7. System sends text to LLM for SQL generation 8. System generates SQL query 9. System executes query on ClickHouse 10. System sends result to Metabase 11. Metabase generates visualization 12. System saves report and updates dashboard
<b>Alternative Flows</b>	A1 – Invalid Audio File 1. System rejects upload
<b>Postconditions</b>	1. Report is created 2. Report is visible on dashboard

*Table 21 : Use Case Specification for “Upload Voice”*

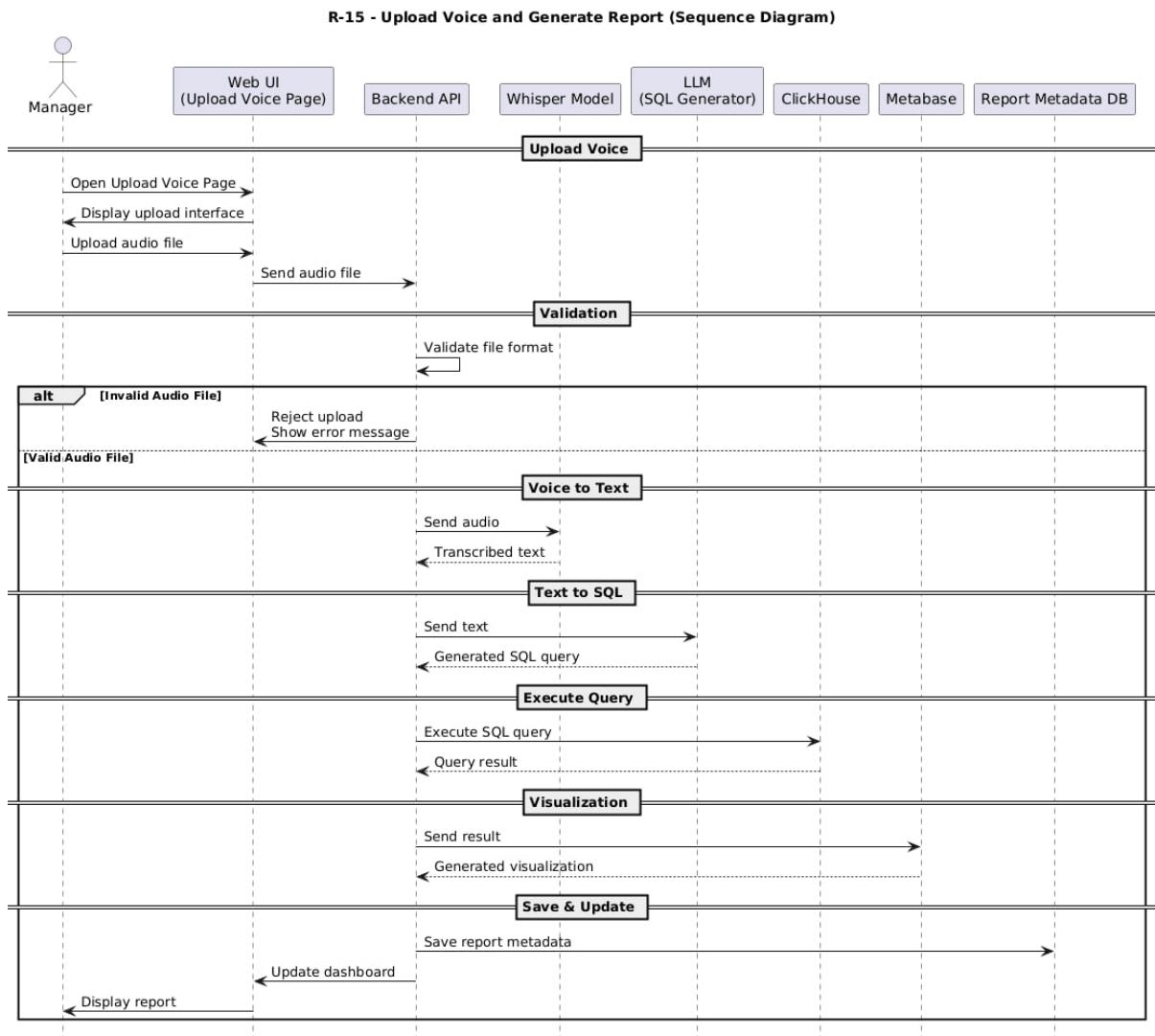


Figure 17 : Sequence Diagram for " Upload Voice"

## • View Dashboard Report

<b>Requirement ID</b>	R-16
<b>Requirement Name</b>	View Dashboard Reports
<b>Actors</b>	Manager, Analyst, Executive
<b>Preconditions</b>	1. User is logged in
<b>Main Flow</b>	<ol style="list-style-type: none"> <li>1. User logs into the system</li> <li>2. System identifies user role</li> <li>3. System redirects user to dashboard page</li> <li>4. System retrieves available reports from Metabase</li> <li>5. System displays dashboards and visual reports</li> </ol>
<b>Alternative Flows</b>	<p>A1 – No Reports Available</p> <ol style="list-style-type: none"> <li>1. System displays empty dashboard message</li> </ol>
<b>Postconditions</b>	1. Dashboard with reports is displayed to the user

Table 22 : Use Case Specification for "View Dashboard report"

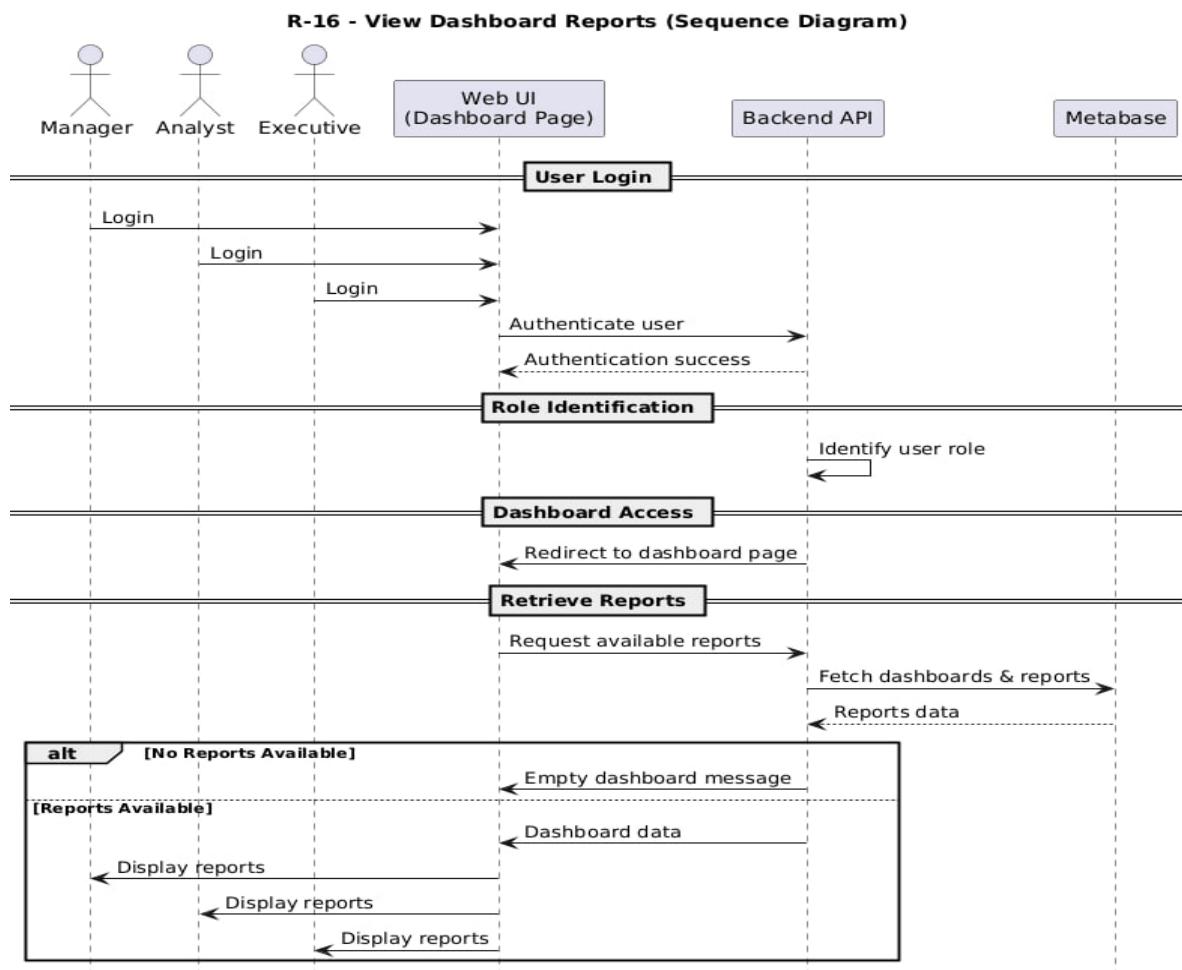


Figure 18 : Sequence Diagram for "View Dashboard Reports"

## • View Previous Reports

<b>Requirement ID</b>	R-17
<b>Requirement Name</b>	View Previous Reports
<b>Actors</b>	Manager, Analyst, Executive
<b>Preconditions</b>	1. Reports exist in the system
<b>Main Flow</b>	<ol style="list-style-type: none"> <li>1. User opens Reports section</li> <li>2. System retrieves report list based on user role</li> <li>3. System displays list of previous reports</li> <li>4. User selects a report</li> </ol>
<b>Alternative Flows</b>	A1 – Report Not Found <ol style="list-style-type: none"> <li>1. System displays error message</li> </ol>
<b>Postconditions</b>	1. Selected report is opened

Table 23 : Use Case Specification for "View Previous Reports"

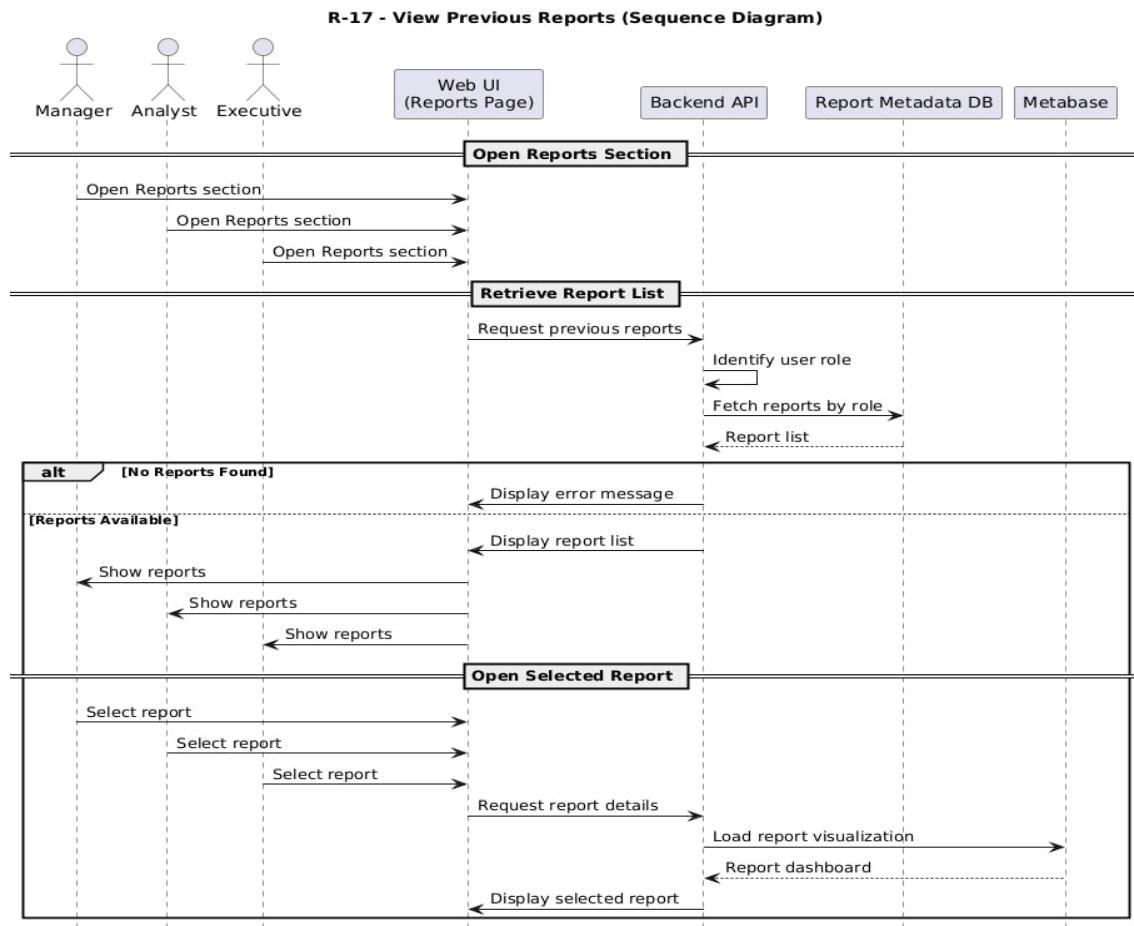


Figure 19 : Sequence Diagram for "View Previous Reports"

## • View Report Details

<b>Requirement ID</b>	R-18
<b>Requirement Name</b>	View Report Details
<b>Actors</b>	Manager, Analyst, Executive
<b>Preconditions</b>	1. Report exists
<b>Main Flow</b>	<ol style="list-style-type: none"> <li>1. User opens a specific report</li> <li>2. System displays report visualization (charts)</li> <li>3. System displays report metadata (date, source, title)</li> </ol>
<b>Alternative Flows</b>	<p>A1 – Visualization Not Available</p> <ol style="list-style-type: none"> <li>1. System displays warning message</li> </ol>
<b>Postconditions</b>	1. Report details are visible

Table 24 : Use Case Specification for "View Report Details"

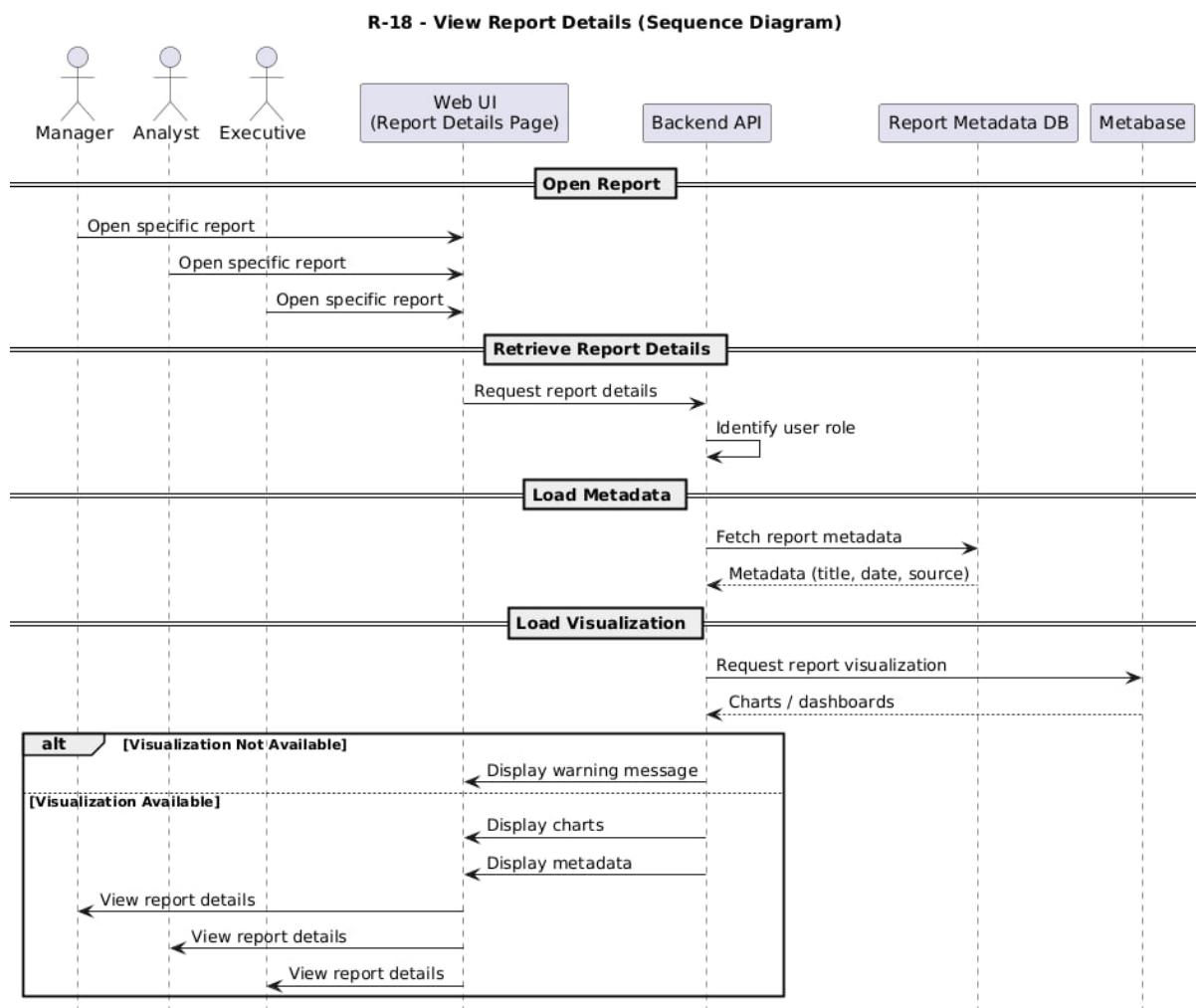


Figure 20 : Sequence Diagram for "View Reports Details"

- Edit SQL Query and Re-execute Rep

<b>Requirement ID</b>	R-19
<b>Requirement Name</b>	Edit SQL Query and Re-execute Report
<b>Actors</b>	Analyst
<b>Preconditions</b>	1. SQL query exists
<b>Main Flow</b>	<ol style="list-style-type: none"> <li>1. Analyst edits SQL query</li> <li>2. Analyst clicks “Execute”</li> <li>3. System validates SQL</li> <li>4. System executes query on ClickHouse</li> <li>5. System updates result in Metabase</li> <li>6. System refreshes dashboard</li> </ol>
<b>Alternative Flows</b>	A1 – SQL Error 1. System shows error details
<b>Postconditions</b>	1. Report is updated

Table 25 : Use Case Specification for “Edit SQL Query”

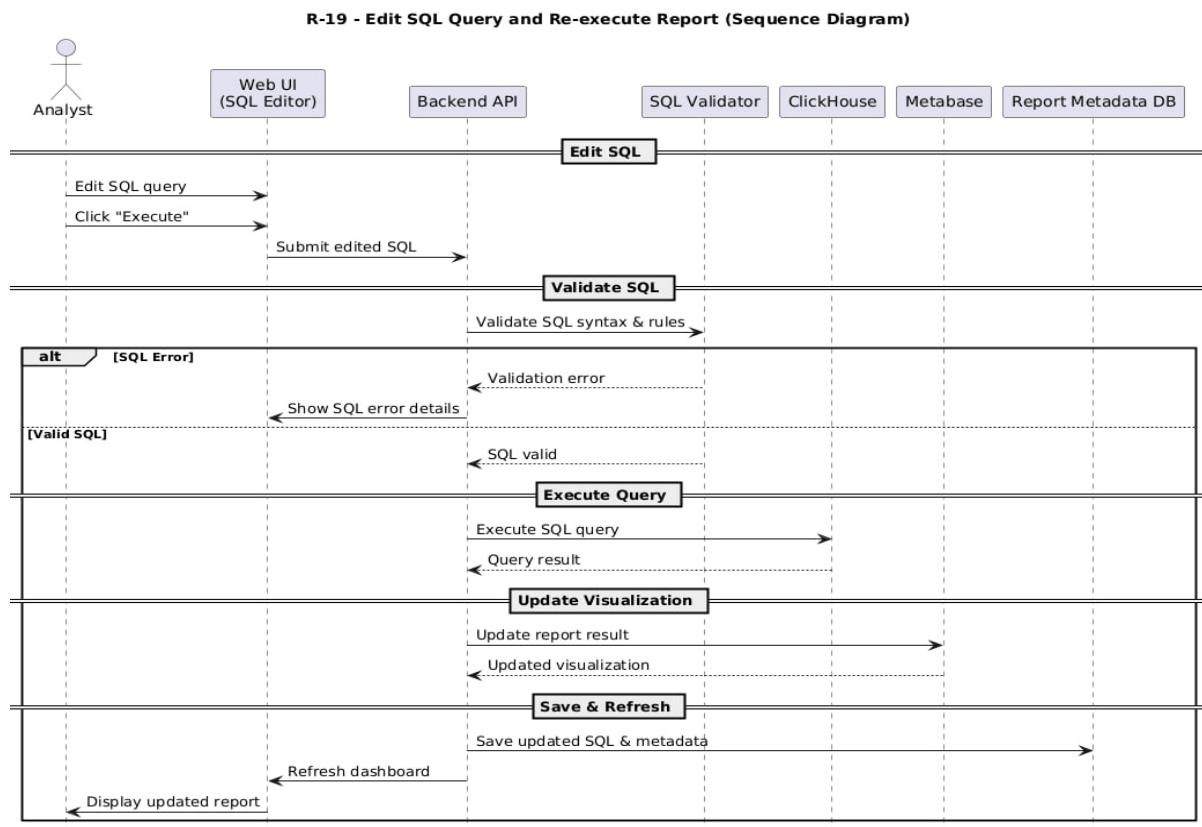


Figure 21 : Sequence Diagram for "Edit SQL"

- Edit Transcription and Regenerate Report

<b>Requirement ID</b>	R-20
<b>Requirement Name</b>	Edit Transcription and Regenerate Report
<b>Actors</b>	Analyst
<b>Preconditions</b>	1. Transcription exists
<b>Main Flow</b>	<ol style="list-style-type: none"> <li>1. Analyst edits transcription text</li> <li>2. Analyst clicks “Regenerate”</li> <li>3. System sends updated text to LLM</li> <li>4. System generates new SQL query</li> <li>5. System executes query on ClickHouse</li> <li>6. System updates Metabase visualization</li> </ol>
<b>Alternative Flows</b>	<p>A1 – Intent Not Clear</p> <ol style="list-style-type: none"> <li>1. System asks for clarification</li> </ol>
<b>Postconditions</b>	1. Updated report is saved

Table 26 : Use Case Specification for “Edit Transcription”

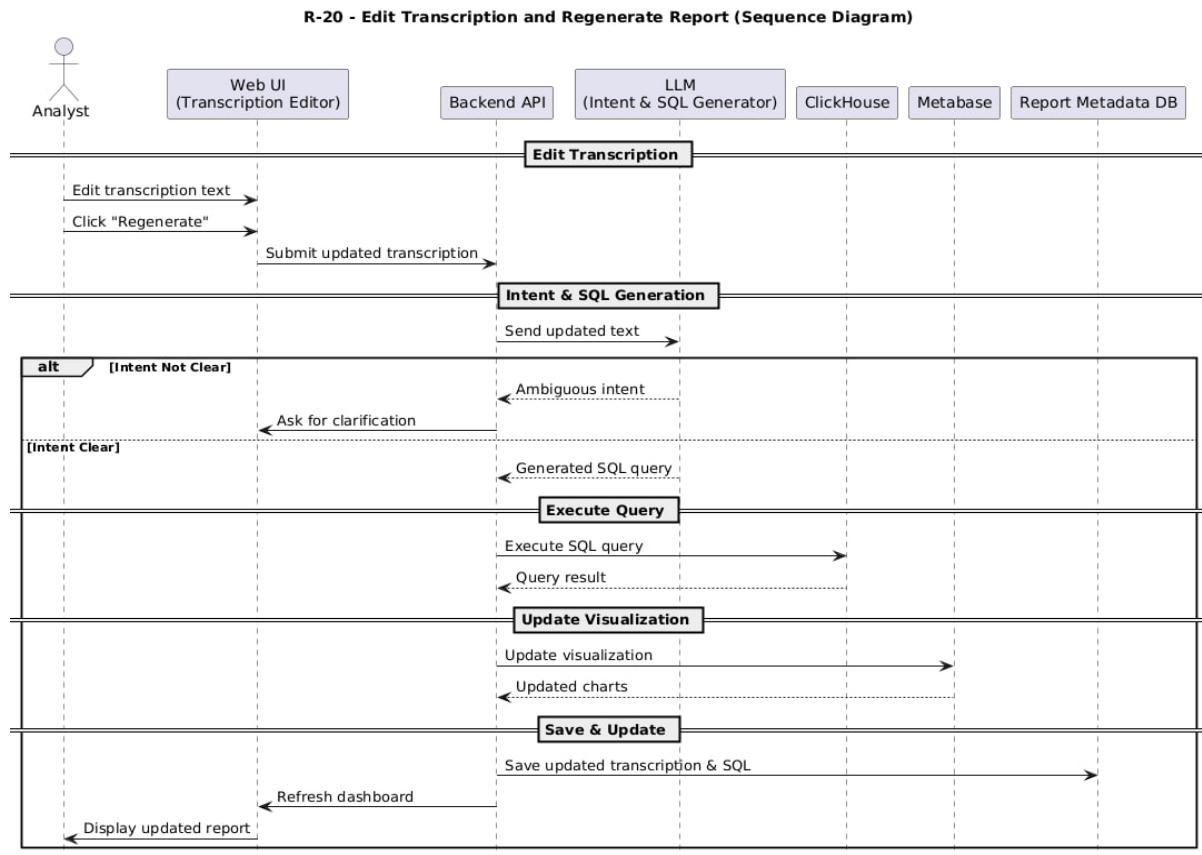


Figure 22: Sequence Diagram for “Edit Transcription”

## • Export Report as Image

<b>Requirement ID</b>	R-21
<b>Requirement Name</b>	Export Report as Image
<b>Actors</b>	Manager, Analyst, Executive
<b>Preconditions</b>	1. Report exists
<b>Main Flow</b>	1. User selects “Export as Image” option 2. System requests image export from Metabase 3. Metabase generates report image 4. System downloads image file to user device
<b>Alternative Flows</b>	A1 – Export Failed 1. System displays error message
<b>Postconditions</b>	1. Report image is saved locally

Table 27 : Use Case Specification for “Export Report”

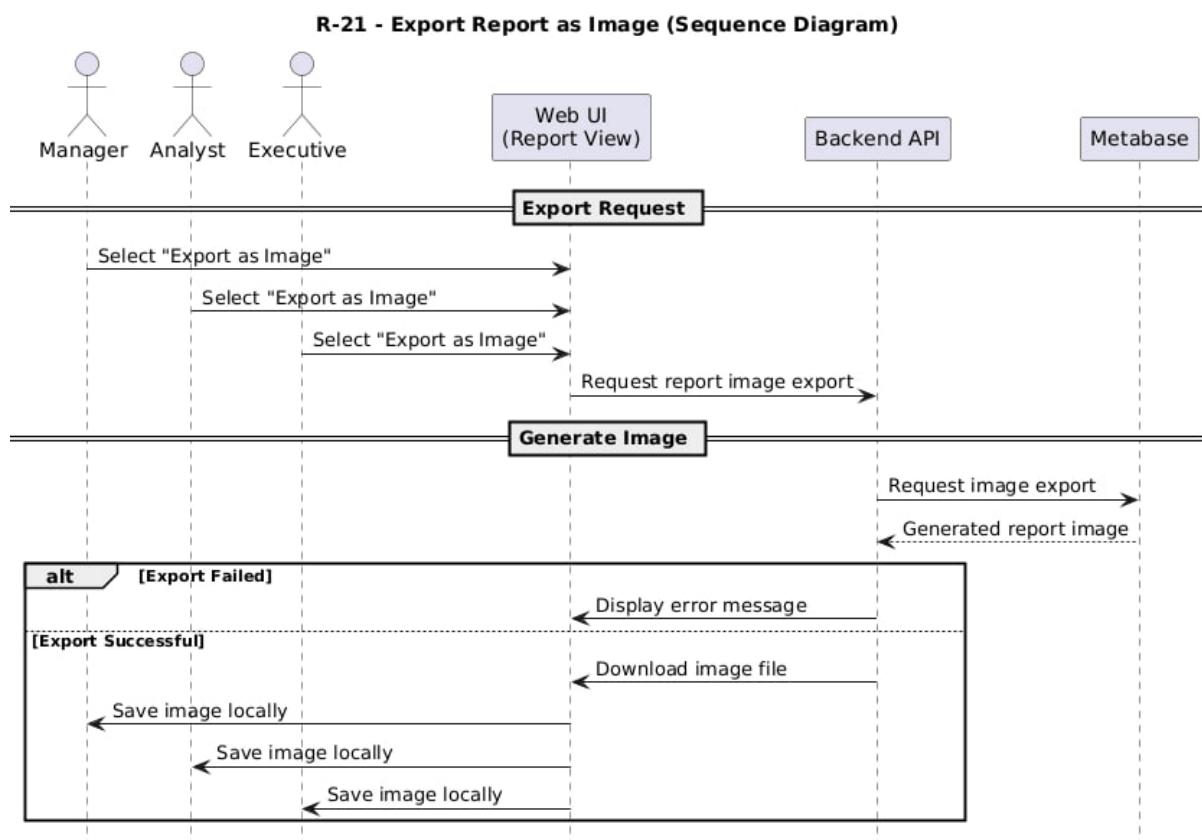


Figure 23 : Sequence Diagram for " Export Report"

- Delete Report

<b>Requirement ID</b>	R-22
<b>Requirement Name</b>	Delete Report
<b>Actors</b>	Manager
<b>Preconditions</b>	1. Report exists
<b>Main Flow</b>	1. Manager selects report 2. System displays confirmation dialog 3. Manager confirms deletion 4. System deletes report from Metabase and metadata store
<b>Alternative Flows</b>	A1 – Deletion Cancelled 1. System keeps report
<b>Postconditions</b>	1. Report is deleted

Table 28 : Use Case Specification for "Delete Report"

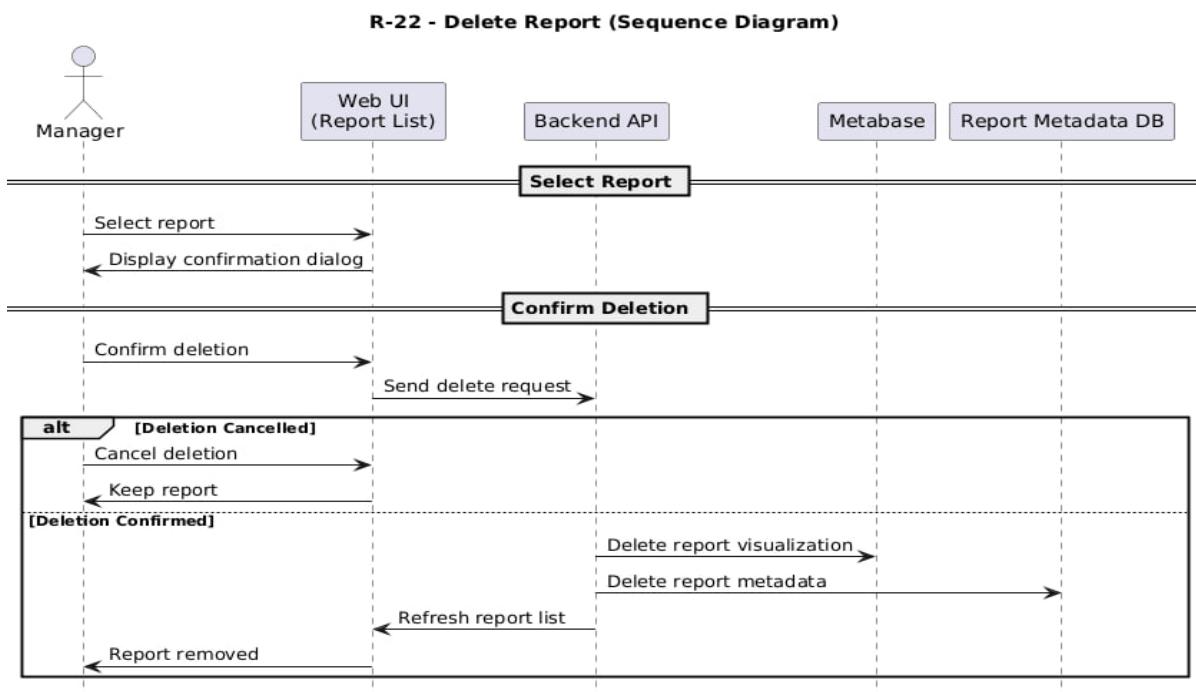


Figure 24: Sequence Diagram for "Delete Report"

- **Upload Database and Execute ETL Pipeline**

<b>Requirement ID</b>	R-23
<b>Requirement Name</b>	Upload Database and Execute ETL Pipeline
<b>Actors</b>	Manager
<b>Preconditions</b>	1. Manager is logged in 2. Database file exists
<b>Main Flow</b>	1. Manager opens Database Management page 2. System displays database upload interface 3. Manager uploads database file 4. System validates file format and schema 5. System starts ETL process 6. System extracts data from uploaded database (Extract) 7. System cleans and transforms data (Transform) 8. System loads processed data into ClickHouse (Load) 9. System verifies data loading success 10. System updates metadata and available datasets 11. System displays successful ETL completion message
<b>Alternative Flows</b>	A1 – ETL Failure 1. System detects ETL error 2. System logs error details 3. System displays failure message
<b>Postconditions</b>	1. Database is loaded into ClickHouse 2. Data is available for reporting 3. ETL status is stored

Table 29 : Use Case Specification for “Upload Database”

R-23 - Upload Database and Execute ETL Pipeline (Sequence Diagram)

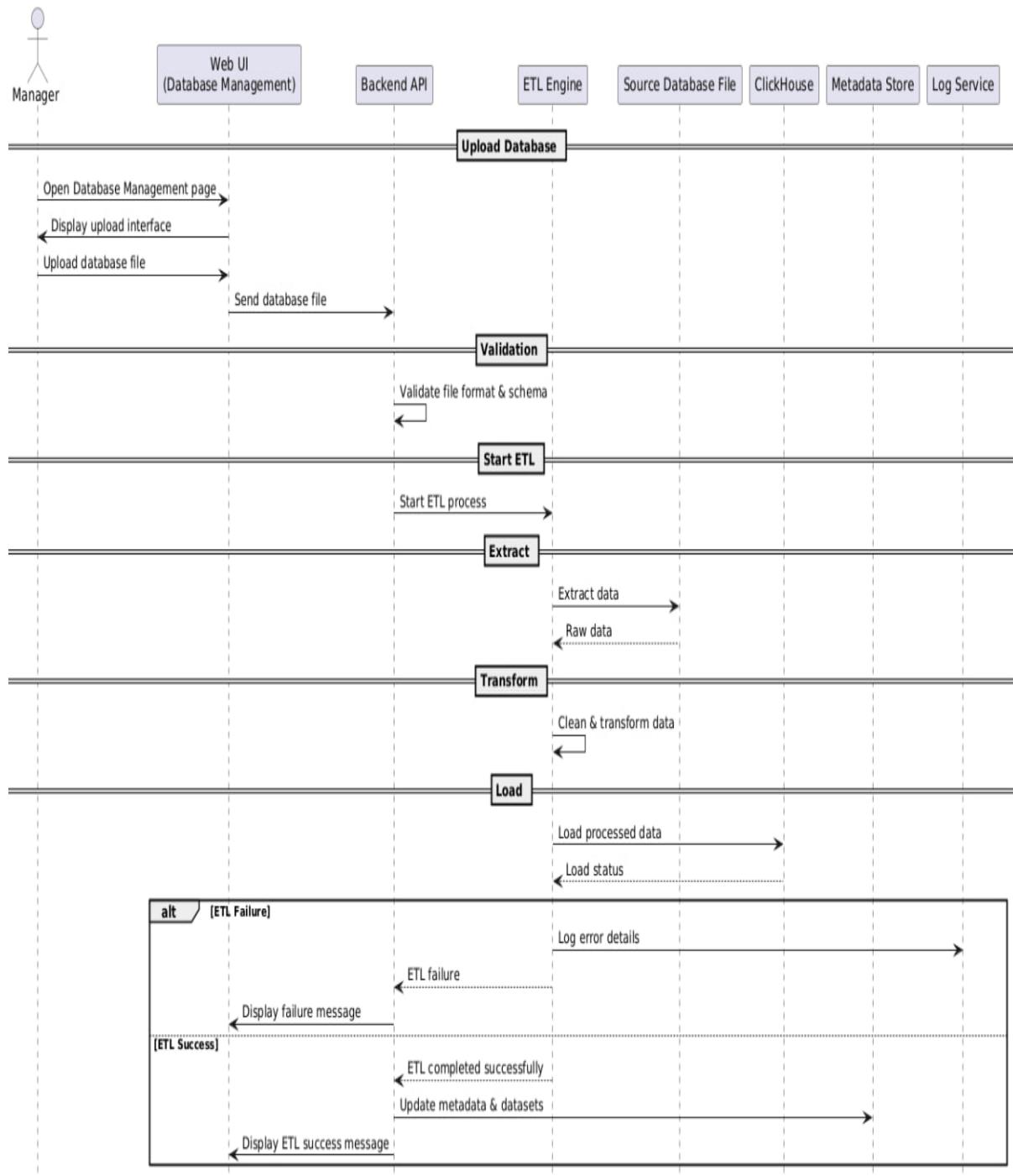


Figure 25 : Sequence Diagram for " Upload database"

- **Delete Database from ClickHouse**

<b>Requirement ID</b>	R-24
<b>Requirement Name</b>	Delete Database from ClickHouse
<b>Actors</b>	Manager
<b>Preconditions</b>	<ol style="list-style-type: none"> <li>1. Manager is logged in</li> <li>2. Database exists in ClickHouse</li> </ol>
<b>Main Flow</b>	<ol style="list-style-type: none"> <li>1. Manager opens Database Management page</li> <li>2. System displays list of databases</li> <li>3. Manager selects a database to delete</li> <li>4. System displays warning message explaining impact</li> <li>5. Manager confirms deletion</li> <li>6. System connects to ClickHouse</li> <li>7. System executes database deletion command</li> <li>8. System verifies deletion success</li> <li>9. System removes related metadata and reports</li> <li>10. System displays success message</li> </ol>
<b>Alternative Flows</b>	<p>A1 – Deletion Failed</p> <ol style="list-style-type: none"> <li>1. System detects deletion error</li> <li>2. System displays error message</li> </ol>
<b>Postconditions</b>	<ol style="list-style-type: none"> <li>1. Database is removed from ClickHouse</li> <li>2. Related reports become unavailable</li> <li>3. Metadata is updated</li> </ol>

*Table 30 : Use Case Specification for "Delete Database"*

R-24 - Delete Database from ClickHouse (Sequence Diagram)

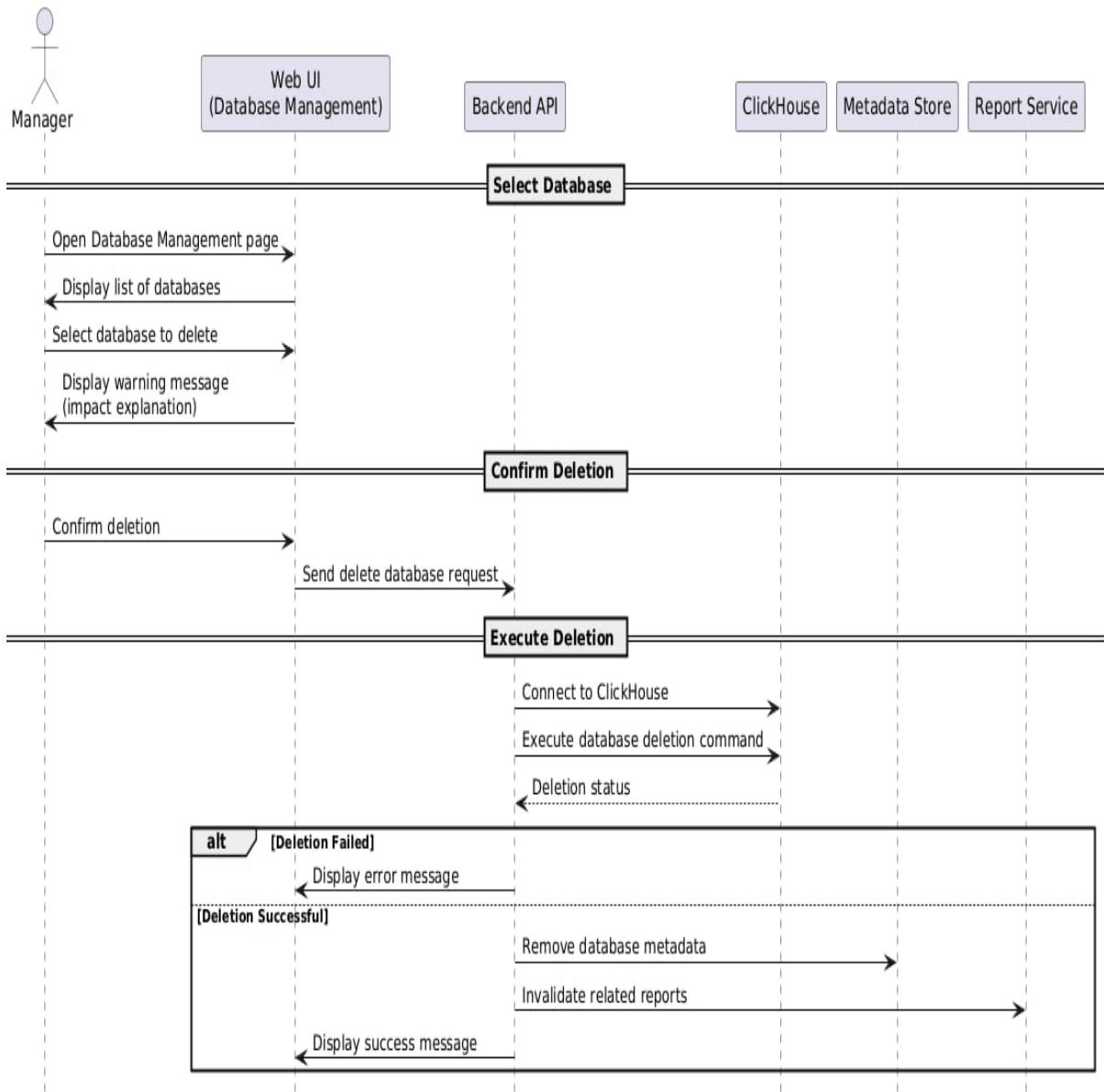


Figure 26 : Sequence Diagram for "Delete Database"

## 6. System architecture

- Class Diagram

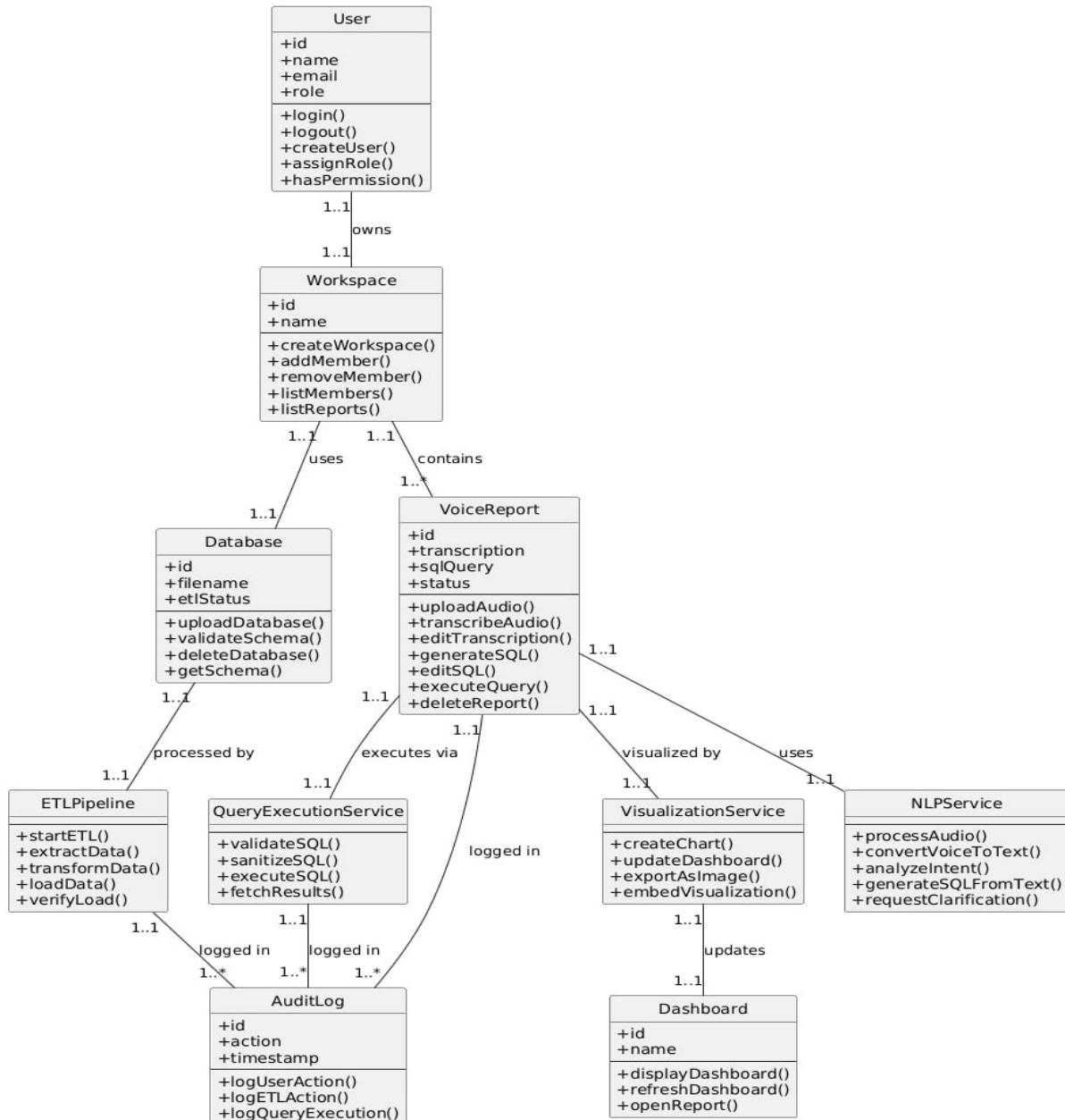


Figure 27 : Class Diagram

## • ERD Diagram

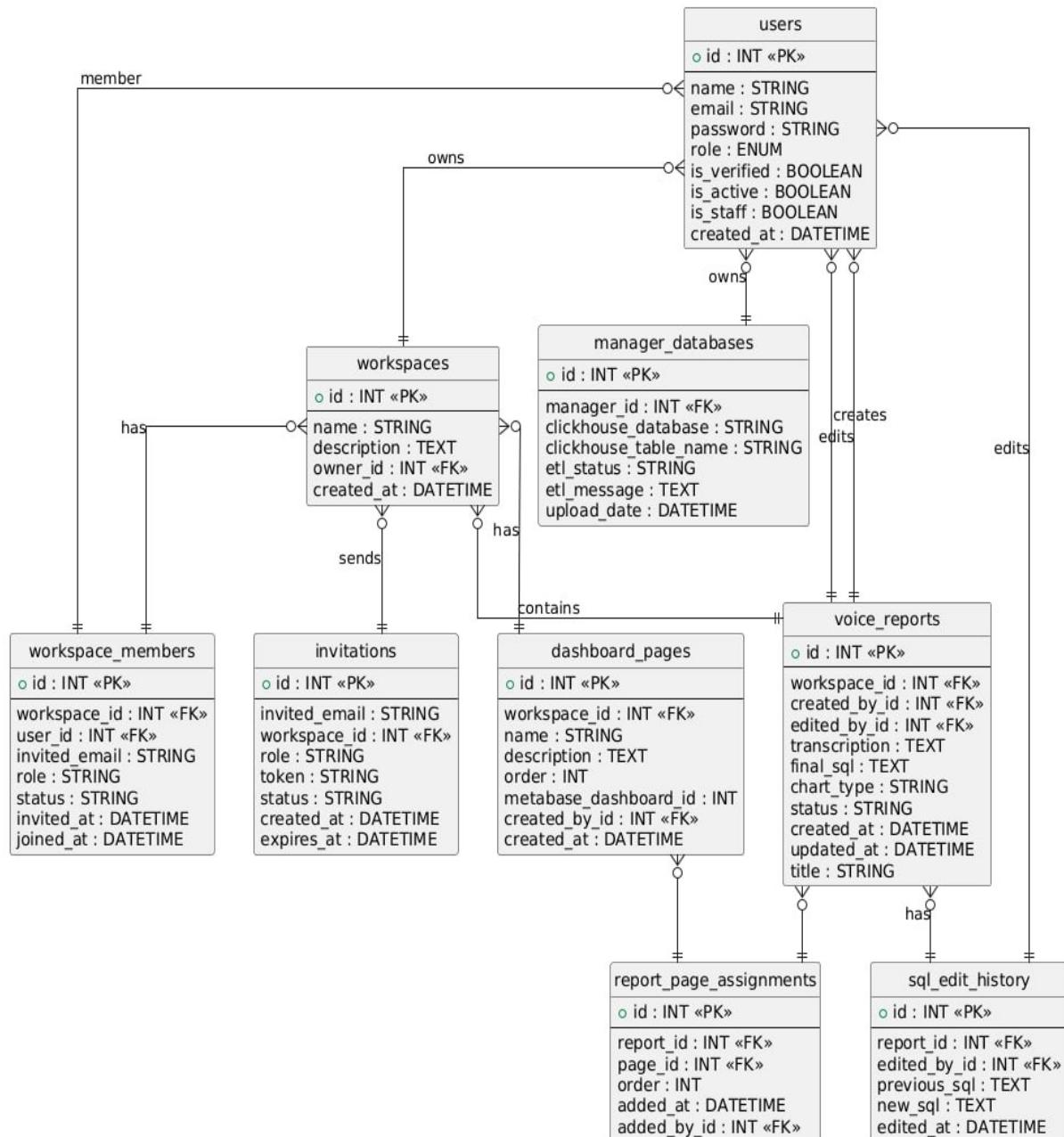


Figure 28 : ERD Diagram

## 7. Initial Test Cases

- Test cases for User Registration

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
TC-REG-001	User Registration	Valid user registration with all required fields	No user account exists with provided email	1. Navigate to signup page 2. Enter valid name (min 3 chars) 3. Enter unique email 4. Enter password (min 8 chars with uppercase/lowercase/number) 5. Select role (Manager/Analyst/Executive) 6. Click Register	User account created successfully; Verification email sent; User redirected to email verification page; Account status is unverified	Positive	High
TC-REG-002	User Registration	Registration with duplicate email address	User account already exists with provided email	1. Navigate to signup page 2. Enter name 3. Enter existing email 4. Enter password 5. Select role 6. Click Register	Registration fails; Error message displayed: "Email already exists"; User remains on signup page; No duplicate account created	Negative	High
TC-REG-003	User Registration	Registration with invalid email format	No user account exists	1. Navigate to signup page 2. Enter valid name 3. Enter invalid email (missing @ or domain) 4. Enter password 5. Select role 6. Click Register	Registration fails; Error message: "Invalid email format"; Email field highlighted with validation error	Negative	High
TC-REG-004	User Registration	Registration with weak password	No user account exists	1. Navigate to signup page 2. Enter valid name 3. Enter unique email 4. Enter weak password (less than 8 chars or missing uppercase/number) 5. Select role 6. Click Register	Registration fails; Error message: "Password must be at least 8 characters with uppercase, lowercase, and number";	Negative	High

					Password field highlighted		
<b>TC-REG-005</b>	User Registration	Manager auto-creates workspace on signup	No user account exists	1. Navigate to signup page 2. Enter valid name 3. Enter unique email 4. Enter valid password 5. Select role as Manager 6. Click Register 7. Verify email	User account created successfully; Workspace automatically created; User assigned as workspace owner; Workspace name defaults to “{UserName}’s Workspace”; User can access workspace after verification	Positive	High

Table 31 : Test cases for User Registration

- Test Cases for User Login

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
<b>TC-PASS-001</b>	Password Reset	Request password reset with valid registered email	User account exists and is verified	1. Navigate to Forgot Password page 2. Enter registered email 3. Click Reset Password	Password reset email sent successfully; Confirmation message displayed	Positive	High
<b>TC-PASS-002</b>	Password Reset	Request password reset with non-existent email	No account exists with provided email	1. Navigate to Forgot Password page 2. Enter non-existent email 3. Click Reset Password	Request rejected; Error message: “Email not found”; No email sent	Negative	High
<b>TC-PASS-003</b>	Password Reset	Reset password using valid token	Valid reset password link from email received via email	1. Open reset password link from email 2. Enter new valid password 3. Confirm password 4. Submit	Password updated successfully; User redirected to login page; Old password invalidated	Positive	High

<b>TC-PASS-004</b>	Password Reset	Reset password using expired or invalid token	Token is expired or invalid	1. Open reset link with expired/invalid token 2. Attempt to set new password	Reset fails; Error message: "Invalid or expired token"; User prompted to request new reset link	Negative	High
<b>TC-PASS-005</b>	Password Reset	Reset password with weak new password	Valid reset token exists	1. Open reset password link 2. Enter weak password 3. Submit	Reset fails; Password validation error shown; Password not updated	Negative	High

Table 32 : Test Cases for User Login

- Test Cases for Email Verification

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
<b>TC-EMAIL-001</b>	Email Verification	Valid email verification with correct token	User registered but not verified; Valid verification token sent	1. Receive verification email 2. Click verification link with token 3. System verifies token	Email verification successful; User is_verified = True; User can now login; Confirmation message displayed	Positive	High
<b>TC-EMAIL-002</b>	Email Verification	Email verification with expired token	Verification token has expired (>24 hours)	1. Receive verification email 2. Wait more than 24 hours 3. Click verification link	Verification fails; Error message: "Verification link expired"; User redirected to request new verification; Account remains unverified	Negative	High
<b>TC-EMAIL-003</b>	Email Verification	Email verification with invalid token	Verification token is malformed or tampered	1. Receive verification email 2. Modify token in URL 3. Click modified link	Verification fails; Error message: "Invalid verification link"; User redirected to signup/login; No verification occurs	Negative	High
<b>TC-EMAIL-004</b>	Email Verification	Email verification with already verified account	User account is already verified	1. User already verified 2. Click verification link again	Verification succeeds; Message displayed: "Your account is already verified"; No duplicate verification performed	Positive	High
<b>TC-EMAIL-005</b>	Email Verification	Email verification updates Workspace Member status	Invited user verifies email	1. Invited user receives verification email 2. Click verification link 3. Email verified	Email verified; WorkspaceMember status changes from pending_acceptance to active; joined_at timestamp set; User gains workspace access	Positive	High

Table 33 : Test Cases for Email Verification

- Test Cases for Authentication and Token Management

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
<b>TC-LOG OUT-001</b>	User Logout	Successful user logout	User is logged in with valid access and refresh tokens	1. User clicks Logout 2. System sends logout request with refresh token	Logout successful; Refresh token blacklisted; User session terminated; User redirected to login page	Positive	High
<b>TC-LOGOUT-002</b>	User Logout	Logout with already expired access token	Access token expired; Refresh token still valid	1. Access token expires 2. User clicks Logout	Logout succeeds; Refresh token blacklisted; No error displayed; User redirected to login	Positive	Medium
<b>TC-LOGOUT-003</b>	User Logout	Logout with invalid refresh token	Refresh token is invalid or tampered	1. User attempts logout with invalid refresh token	Logout fails; Error message: "Invalid token"; No token blacklisted; User prompted to re-login	Negative	High
<b>TC-LOGOUT-004</b>	User Logout	Logout from multiple active sessions	User logged in on multiple devices	1. User logs out from one device	Logout affects only current session; Other sessions remain active unless global logout is enabled	Positive	Medium
<b>TC-LOGOUT-005</b>	User Logout	Logout clears client-side session data	User is logged in	1. User clicks Logout	Access token removed from client storage; Refresh token removed; No authenticated data remains on client	Positive	High

Table 34 : Test Cases for Authentication and Token Management

- Test Cases for User Management by Admin

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
TC-ADMIN-001	User Management by Admin	Admin creates a new user account	Admin is logged in and has required permissions	1. Login as Admin 2. Navigate to User Management 3. Click “Create User” 4. Enter user details (name, email, role) 5. Click Save	User account created successfully; Invitation/verification email sent; User appears in user list with correct role	Positive	High
TC-ADMIN-002	User Management by Admin	Admin edits existing user details	User account exists	1. Login as Admin 2. Navigate to User Management 3. Select an existing user 4. Modify user details (name/role) 5. Click Save	User details updated successfully; Changes reflected immediately; Update logged in audit trail	Positive	High
TC-ADMIN-003	User Management by Admin	Admin deactivates a user account	User account exists and is active	1. Login as Admin 2. Navigate to User Management 3. Select user 4. Click Deactivate	User account deactivated; User cannot login; Status updated to inactive; Action logged in audit log	Positive	High
TC-ADMIN-004	User Management by Admin	Deactivated user attempts login	User account is deactivated	1. Navigate to login page 2. Enter deactivated user credentials	Login fails; Error message: “Your account has been deactivated”; No tokens issued	Negative	High
TC-ADMIN-005	User Management by Admin	Admin deletes a user account	User account exists; Admin has delete permission	1. Login as Admin 2. Navigate to User Management 3. Select user 4. Click Delete 5. Confirm deletion	User account deleted successfully; User removed from system; Related sessions invalidated; Action recorded in audit log	Positive	High

Table 35 : Test Cases for User Management by Admin

- Test Cases for Audit Logs and Activity Tracking

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
TC-AUD-IT-001	Audit Logs & Activity Tracking	Log user login activity	User account exists and is verified	1. Login with valid credentials	Login action recorded in audit log; Log includes user_id, action=LOGIN, timestamp, IP address	Positive	High
TC-AUD-IT-002	Audit Logs & Activity Tracking	Log failed login attempt	User account exists	1. Navigate to login page 2. Enter valid email 3. Enter incorrect password 4. Click Login	Failed login attempt recorded; Action=FAILED_LOGIN; Timestamp and IP stored	Positive	High
TC-AUD-IT-003	Audit Logs & Activity Tracking	Log user invitation action	Manager invites a new user	1. Login as Manager 2. Send invitation to new user	Invitation action logged; Log includes inviter_id, invitee_email, role, workspace_id	Positive	High
TC-AUD-IT-004	Audit Logs & Activity Tracking	Log workspace update action	Manager updates workspace settings	1. Login as Manager 2. Update workspace name or description	Workspace update recorded in audit log; Old and new values stored; Timestamp recorded	Positive	High
TC-AUD-IT-005	Audit Logs & Activity Tracking	Admin views audit logs	Admin is logged in with permission	1. Login as Admin 2. Navigate to Audit Logs page	Audit logs displayed successfully; Logs are sortable and filterable by date, user, and action	Positive	High
TC-AUD-IT-006	Audit Logs & Activity Tracking	Unauthorized user cannot access audit logs	User is Analyst or Executive	1. Login as Analyst/Executive 2. Attempt to access Audit Logs	Access denied; Error message: "Insufficient permissions"; No logs displayed	Negative	High

Table 36 : Test Cases for Audit Logs and Activity Tracking

- Test Cases for Accepting Workspace Invitations

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
<b>TC-ACCEP T-001</b>	Accept Workspace Invitation	Existing user accepts invitation	User has existing account; Valid invitation token received	1. Receive invitation email 2. Click acceptance link with token 3. System validates token 4. User logs in	Invitation accepted; WorkspaceMember status changes to active; User added to workspace; Role assigned; User can access workspace after login	Positive	High
<b>TC-ACCEP T-002</b>	Accept Workspace Invitation	New user accepts invitation and registers	User does not have account; Valid invitation token received	1. Receive invitation email 2. Click acceptance link with token 3. System redirects to signup 4. User registers with provided email and role	Invitation accepted; User account created; WorkspaceMember created with status=active; User can access workspace; Email and role pre-filled from invitation	Positive	High
<b>TC-ACCEP T-003</b>	Accept Workspace Invitation	Invitation acceptance with expired token	Invitation token has expired (>48 hours)	1. Receive invitation email 2. Wait more than 48 hours 3. Click acceptance link	Acceptance fails; Error message: "Invitation link expired"; User redirected to request new invitation; No workspace access granted	Negative	High
<b>TC-ACCEP T-004</b>	Accept Workspace Invitation	Invitation acceptance with invalid token	Invitation token is malformed or tampered	1. Receive invitation email 2. Modify token in URL 3. Click modified link	Acceptance fails; Error message: "Invalid invitation link"; User redirected; No workspace access granted	Negative	High
<b>TC-ACCEP T-005</b>	Accept Workspace Invitation	Cannot accept already accepted invitation	Invitation status is already accepted	1. Accept invitation 2. Attempt to accept same invitation again	Acceptance fails; Error message: "Invitation already accepted"; User remains in workspace; No duplicate membership created	Negative	High

Table 37 : Test Cases for Accepting Workspace Invitations

- Test Cases for Permission and Authorization Control

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
TC-PER-M-001	Permission & Authorization Control	Manager can view all workspace members	Manager is verified and workspace has members	1. Login as Manager 2. Navigate to Members page 3. View member list	All members displayed (accepted, pending, invited); Manager sees all statuses; Member details include name, email, role, status; List is complete and accurate	Positive	High
TC-PER-M-002	Permission & Authorization Control	Analyst can only view active members	Analyst is verified member of workspace	1. Login as Analyst 2. Navigate to Members page 3. View member list	Only active members displayed; Pending and invited members hidden; No member management actions available; Read-only access	Positive	High
TC-PER-M-003	Permission & Authorization Control	Manager can assign roles to members	Manager is verified; Member exists in workspace	1. Login as Manager 2. Navigate to Members 3. Select member 4. Click "Change Role" 5. Select new role (Analyst/Executive) 6. Click Save	Role updated successfully; Role updated in User and WorkspaceMember; Changes reflected immediately; Audit log recorded; Member notified	Positive	High
TC-PER-M-004	Permission & Authorization Control	Analyst cannot assign roles	User is Analyst	1. Login as Analyst 2. Navigate to Members 3. Attempt to change another member's role	Access denied; Role change option hidden or disabled; Error message: "Only managers can assign roles"; No changes applied	Negative	High
TC-PER-M-005	Permission & Authorization Control	Manager cannot demote self	Manager is the only manager in workspace	1. Login as Manager 2. Navigate to Members 3. Select own profile 4. Attempt to change own role to Analyst	Role change blocked; Error message: "Cannot change your own role"; Manager role remains unchanged; Workspace must always have at least one manager	Negative	High

Table 38 : Test Cases for Permission and Authorization Control

- Test Cases for Role & Permission Enforcement (Advanced Scenarios)

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
TC-PERM-006	Role & Permission Enforcement	Executive has read-only access to workspace data	Executive is verified member of workspace	1. Login as Executive 2. Navigate to Members page 3. Attempt to edit member details	Members list visible; No edit/delete actions available; Read-only access enforced	Positive	High
TC-PERM-007	Role & Permission Enforcement	Analyst cannot invite new members	Analyst is verified member of workspace	1. Login as Analyst 2. Navigate to Members 3. Attempt to invite new member	Access denied; Invite button hidden or disabled; Error message displayed	Negative	High
TC-PERM-008	Role & Permission Enforcement	Executive cannot invite new members	Executive is verified member of workspace	1. Login as Executive 2. Navigate to Members 3. Attempt to invite new member	Access denied; Invite functionality unavailable; No invitation sent	Negative	High
TC-PERM-009	Role & Permission Enforcement	Manager can remove workspace members	Manager is verified; Target member exists	1. Login as Manager 2. Navigate to Members 3. Select member 4. Click Remove	Member removed successfully; WorkspaceMember marked as removed; User loses workspace access; Action logged	Positive	High
TC-PERM-010	Role & Permission Enforcement	Analyst cannot remove workspace members	Analyst is verified member	1. Login as Analyst 2. Navigate to Members 3. Attempt to remove a member	Access denied; Remove option hidden; Error message displayed; No changes applied	Negative	High

Table 39 : Test Cases for Role & Permission Enforcement (Advanced Scenarios)

- Test Cases for Member Suspension Management

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
TC-SUSPEND-001	Suspend & Unsuspend Member	Manager suspends active member	Manager is verified; Member is active	1. Login as Manager 2. Navigate to Members 3. Select member 4. Click “Suspend”	Member suspended; is_active = False; Member cannot login; Member cannot access workspace; Status shows “suspended”	Positive	High
TC-SUSPEND-002	Suspend & Unsuspend Member	Suspended member cannot login	Member is suspended (is_active = False)	1. Attempt to login with suspended member credentials 2. Enter correct password 3. Click Login	Login fails; Error message: “Your account has been suspended”; No tokens issued; Member cannot access system	Negative	High
TC-SUSPEND-003	Suspend & Unsuspend Member	Manager unsuspends suspended member	Member is suspended	1. Login as Manager 2. Navigate to Members 3. Select suspended member 4. Click “Unsuspend”	Member unsuspended; is_active = True; Member can login again; Workspace access restored; Status shows “active”	Positive	High
TC-SUSPEND-004	Suspend & Unsuspend Member	Analyst cannot suspend members	User is Analyst	1. Login as Analyst 2. Navigate to Members 3. Attempt to suspend another member	Access denied; Suspend button hidden or disabled; Error message: “Only managers can suspend members”; No suspension occurs	Negative	High
TC-SUSPEND-005	Suspend & Unsuspend Member	Manager cannot suspend self	Manager is the only manager in workspace	1. Login as Manager 2. Navigate to Members 3. Select own profile 4. Click “Suspend”	Suspension blocked; Error message: “You cannot suspend yourself”; Manager remains active; Workspace retains at least one active manager	Negative	High

Table 40 : Test Cases for Member Suspension Management

- Test Cases for Data Processing (ETL Pipeline)

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
TC-ETL-001	Data Processing (ETL Pipeline)	Successful ETL pipeline execution on uploaded file	Valid CSV file uploaded; ETL services running	1. Upload valid CSV file 2. Trigger ETL process automatically 3. Monitor ETL status	ETL pipeline executes successfully; Data extracted, transformed, and loaded; Status changes to “completed”; Records inserted into database	Positive	High
TC-ETL-002	Data Processing (ETL Pipeline)	ETL fails due to invalid data values	CSV uploaded with invalid data (e.g., non-numeric in numeric column)	1. Upload CSV with invalid values 2. Trigger ETL process	ETL fails; Error logged with details; Status set to “failed”; Invalid rows reported; No partial load committed	Negative	High
TC-ETL-003	Data Processing (ETL Pipeline)	ETL retry after fixing data errors	Previous ETL attempt failed	1. Fix CSV file 2. Re-upload corrected file 3. Re-run ETL	ETL completes successfully; Status updated to “completed”; Corrected data loaded; Previous failed attempt archived	Positive	High
TC-ETL-004	Data Processing (ETL Pipeline)	ETL handles empty CSV file	CSV file contains headers only, no data rows	1. Upload empty CSV file 2. Trigger ETL process	ETL completes with warnings; No records loaded; Warning message displayed; System remains stable	Negative	Medium
TC-ETL-005	Data Processing (ETL Pipeline)	Unauthorized user cannot trigger ETL	User is Analyst or Executive	1. Login as Analyst/Executive 2. Attempt to trigger ETL on uploaded file	Access denied; Error message: “Only managers can process data”; ETL not started	Negative	High

Table 41 : Test Cases for Data Processing (ETL Pipeline)

- Test Cases for ETL Pipeline Execution (Detailed Stages)

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
TC-ETL-001	ETL Pipeline Execution	Successful ETL pipeline execution	Valid CSV file uploaded; All ETL services running	1. Upload valid CSV file 2. Trigger ETL pipeline 3. Monitor pipeline stages (Detector → Transformer → Loader)	Pipeline completes successfully; Status set to “completed”; Data loaded into ClickHouse; Execution logs stored; User notified	Positive	High
TC-ETL-002	ETL Pipeline Execution	ETL pipeline fails at Detector stage	CSV file has unrecognizable schema	1. Upload CSV with invalid/unknown schema 2. Monitor pipeline 3. Check Detector service logs	Pipeline fails at Detector; Error message: “Schema detection failed”; Status = “failed”; Error details logged; User notified; No data loaded	Negative	High
TC-ETL-003	ETL Pipeline Execution	ETL pipeline fails at Transformer stage	Data transformation rules fail	1. Upload CSV with data that fails transformation 2. Monitor pipeline 3. Check Transformer service logs	Pipeline fails at Transformer; Error message: “Data transformation failed”; Status = “failed”; Specific transformation error logged; Data not loaded; User can retry	Negative	High
TC-ETL-004	ETL Pipeline Execution	ETL pipeline fails at Loader stage	ClickHouse connection unavailable	1. Upload valid CSV 2. Stop ClickHouse service	Pipeline fails at Loader; Error message: “ClickHouse connection failed”; Status =	Negative	High

				3. Monitor pipeline 4. Check Loader service logs	“failed”; Retry mechanism triggered; Data queued for retry; User notified		
<b>TC-ETL-005</b>	ETL Pipeline Execution	ETL pipeline with large dataset (10M+ rows)	Valid CSV with 10M+ rows uploaded	1. Upload large CSV file 2. Monitor pipeline execution 3. Check memory usage 4. Verify data in ClickHouse	Pipeline completes successfully; All rows loaded; Execution time logged (expected 5–15 min); No memory leaks; Data integrity verified	Positive	High

Table 42 : Test Cases for ETL Pipeline Execution (Detailed Stages)

- Test Cases for ClickHouse Load & Data Integrity

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
<b>TC-CH-001</b>	ClickHouse Load & Data Integrity	Successful data load into ClickHouse table	ETL completed successfully; Target table exists	1. Complete ETL pipeline 2. Loader inserts data into ClickHouse 3. Query target table	Data loaded successfully; Row count matches transformed data; No errors during insert; Load metrics recorded	Positive	High
<b>TC-CH-002</b>	ClickHouse Load & Data Integrity	Data type mismatch during ClickHouse load	Transformed data has incompatible data types	1. Complete transformation 2. Attempt to load data into ClickHouse	Load fails; Error message: “Data type mismatch”; Loader stops operation; Error logged; No partial load committed	Negative	High
<b>TC-CH-003</b>	ClickHouse Load & Data Integrity	Partial failure handling during batch insert	Network interruption during load	1. Start data load 2. Interrupt network 3. Resume connection	Load rolled back or resumed based on strategy; No duplicate rows; Data consistency preserved; Retry logged	Negative	High
<b>TC-CH-004</b>	ClickHouse Load & Data Integrity	Verify primary key or unique constraint enforcement	Table has defined unique key	1. Load data with duplicate keys 2. Query table	Duplicate rows rejected or handled according to config; Constraint violations logged; Data integrity maintained	Positive	High

<b>TC-CH-005</b>	ClickHouse Load & Data Integrity	Large-scale data load performance	Large transformed dataset ready	1. Load large dataset into ClickHouse 2. Measure load time and resource usage	Load completes within acceptable time; CPU and memory usage within thresholds; No timeouts; Performance metrics logged	Positive	High
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Table 43 : Test Cases for ClickHouse Load & Data Integrity

- Test Cases for Metadata Management & Data Lineage

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
<b>TC-META-001</b>	Metadata Management & Data Lineage	Store metadata for uploaded data source	CSV file uploaded successfully	1. Upload CSV file 2. Complete upload process 3. Check metadata service	Metadata stored successfully; Includes source_name, file_id, uploader, upload_time, file_size, schema version	Positive	High
<b>TC-META-002</b>	Metadata Management & Data Lineage	Track schema evolution across versions	Multiple versions of same data source exist	1. Upload initial CSV (v1) 2. Upload updated CSV with schema change (v2) 3. View metadata history	Schema versions tracked correctly; Version numbers incremented; Changes recorded; Previous versions preserved	Positive	High
<b>TC-META-003</b>	Metadata Management & Data Lineage	Maintain end-to-end data lineage	ETL pipeline completed	1. Upload CSV 2. Run ETL pipeline 3. Inspect lineage graph	Lineage recorded from source → detector → transformer → loader → ClickHouse; Each stage timestamped; Traceability ensured	Positive	High
<b>TC-META-004</b>	Metadata Management & Data Lineage	Metadata consistency after ETL failure	ETL pipeline fails at any stage	1. Upload CSV 2. Trigger ETL 3. Force pipeline failure	Metadata reflects failed status; Failure stage recorded; No inconsistent or orphan metadata entries	Negative	High
<b>TC-META-005</b>	Metadata Management & Data Lineage	Unauthorized user cannot view metadata	User is Analyst or Executive	1. Login as Analyst/Executive 2. Attempt to access metadata page	Access denied; Error message: "Insufficient permissions"; Metadata not exposed	Negative	High

Table 44 : Test Cases for Metadata Management & Data Lineage

- Test Cases for System Performance & Scalability

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
TC-PERF-001	System Performance & Scalability	System handles high number of concurrent uploads	System deployed; Multiple users available	1. Simulate 50+ users uploading CSV files concurrently 2. Monitor system performance 3. Check upload completion	All uploads processed successfully; No system crash; Acceptable response times; Queueing handled correctly; No data loss	Positive	High
TC-PERF-002	System Performance & Scalability	ETL pipeline performance under heavy load	Large datasets uploaded concurrently	1. Upload multiple large CSV files 2. Trigger ETL pipelines in parallel 3. Monitor CPU, memory, and processing time	ETL pipelines complete within acceptable SLA; Resource usage within limits; No memory leaks; ETL queues balanced	Positive	High
TC-PERF-003	System Performance & Scalability	Query performance with concurrent BI queries	ClickHouse contains large datasets	1. Execute multiple aggregation queries concurrently 2. Monitor query latency	Queries return correct results; Average latency within acceptable threshold; No query failures; System remains responsive	Positive	High
TC-PERF-004	System Performance & Scalability	System scalability with horizontal scaling	Additional worker nodes available	1. Add new ETL worker node 2. Trigger multiple pipelines 3. Compare throughput	Throughput increases after scaling; Load distributed evenly; No configuration issues; System scales horizontally	Positive	Medium

				before and after scaling			
<b>TC-PERF-005</b>	System Performance & Scalability	Stress test beyond system capacity	Load exceeds designed limits	1. Simulate extreme load beyond capacity 2. Monitor system behavior	System degrades gracefully; Requests throttled or queued; No data corruption; Clear error messages returned; System recovers after load reduced	Negative	High

Table 45 : Test Cases for System Performance & Scalability

- Test Cases for Voice-to-SQL Processing & Intent Detection

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
<b>TC-VSQL-001</b>	Voice-to-SQL Processing & Intent Detection	Correct intent classification for analytical question	Transcribed text available	1. Upload audio asking analytical question 2. Transcription completed 3. NLP module analyzes intent	Intent correctly classified as <i>analytical</i> ; SQL generation triggered; Intent confidence score recorded	Positive	High
<b>TC-VSQL-002</b>	Voice-to-SQL Processing & Intent Detection	Correct intent classification for conversational question	Transcribed text available	1. Upload audio asking conversational question 2. Transcription completed 3. NLP module analyzes intent	Intent classified as <i>conversational</i> ; No SQL generated; Textual response prepared; Status updated accordingly	Positive	High
<b>TC-VSQL-003</b>	Voice-to-SQL Processing & Intent Detection	SQL generation for valid analytical query	Intent classified as analytical; Schema metadata available	1. Transcribe audio 2. Detect intent 3. Generate SQL query	SQL generated successfully; Query syntactically valid; Uses correct table and columns; SQL stored with report	Positive	High
<b>TC-VSQL-004</b>	Voice-to-SQL Processing & Intent Detection	SQL generation failure due to ambiguous intent	Transcribed text ambiguous	1. Upload ambiguous analytical question 2. Attempt SQL generation	SQL generation skipped; Error message: “Ambiguous query”; User prompted for clarification; No execution performed	Negative	High
<b>TC-VSQL-005</b>	Voice-to-SQL Processing	SQL validation before execution	SQL generated from voice query	1. Generate SQL 2. Run SQL validator	SQL validated successfully; Injection-safe; Compatible with	Positive	High

	& Intent Detection				ClickHouse; Execution allowed		
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Table 46 : Test Cases for Voice-to-SQL Processing & Intent Detection

- Test Cases for Chart Generation & Visualization

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
TC-CHART-001	Chart Generation & Visualization	Automatic chart type recommendation	SQL query executed successfully; Result set available	1. Execute SQL query 2. Navigate to Visualization tab	System recommends appropriate chart type (bar/line/pie) based on result schema; Recommendation confidence shown; User can accept or change	Positive	High
TC-CHART-002	Chart Generation & Visualization	Generate bar chart for categorical aggregation	SQL result contains category + metric	1. Execute aggregation query 2. Select Bar Chart	Bar chart generated correctly; Axes labeled; Data matches query results; Chart renders without errors	Positive	High
TC-CHART-003	Chart Generation & Visualization	Generate line chart for time-series data	SQL result contains date/time + metric	1. Execute time-based query 2. Select Line Chart	Line chart rendered correctly; Time axis ordered; No missing points; Chart interactive (hover/zoom)	Positive	High
TC-CHART-004	Chart Generation & Visualization	Handle incompatible chart selection	SQL result incompatible with selected chart	1. Execute query 2. Select incompatible chart type	Chart generation blocked; Error message: "Selected chart type is not compatible with data"; User prompted to choose another type	Negative	High
TC-CHART-005	Chart Generation & Visualization	Chart performance with large result set	Query returns large dataset	1. Execute query with large result 2. Generate chart	Chart renders within acceptable time; Data sampling or pagination applied; UI remains responsive; No browser crash	Positive	Medium

Table 47 : Test Cases for Chart Generation & Visualization

- Test Cases for Dashboard Creation & Management

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
TC-DASH-001	Dashboard Creation & Management	Create dashboard from executed report	Report executed successfully; Results available	1. Login as Manager 2. Open executed report 3. Click “Add to Dashboard” 4. Enter dashboard name 5. Save	Dashboard created successfully; Chart added to dashboard; Dashboard visible in dashboard list; Ownership assigned to creator	Positive	High
TC-DASH-002	Dashboard Creation & Management	Add multiple charts to same dashboard	Dashboard exists; Multiple reports executed	1. Login as Manager 2. Open another executed report 3. Add chart to existing dashboard	Chart added successfully; Layout auto-adjusted; All charts render correctly	Positive	High
TC-DASH-003	Dashboard Creation & Management	Edit dashboard layout	Dashboard exists with charts	1. Login as Manager 2. Open dashboard 3. Rearrange or resize charts 4. Save layout	Layout updated successfully; New layout persisted; Charts render correctly after reload	Positive	Medium
TC-DASH-004	Dashboard Creation & Management	Analyst cannot modify dashboard	User is Analyst	1. Login as Analyst 2. Open dashboard 3. Attempt to add/remove charts or edit layout	Access denied; Edit controls hidden or disabled; Error message displayed; Dashboard unchanged	Negative	High
TC-DASH-005	Dashboard Creation & Management	Delete dashboard	Dashboard exists; User is Manager	1. Login as Manager 2. Open dashboard 3. Click “Delete Dashboard” 4. Confirm deletion	Dashboard deleted successfully; Removed from list; Charts not deleted from reports; Action logged	Positive	High

Table 48 : Test Cases for Dashboard Creation & Management

- Test Cases for Dashboard Sharing & Access Control

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
<b>TC-SHARE-001</b>	Dashboard Sharing & Access Control	Manager shares dashboard with workspace members	Dashboard exists; User is Manager	1. Login as Manager 2. Open dashboard 3. Click “Share” 4. Select workspace members 5. Set access level (view-only) 6. Save	Dashboard shared successfully; Selected members can view dashboard; Share permissions stored; Members notified	Positive	High
<b>TC-SHARE-002</b>	Dashboard Sharing & Access Control	Analyst can view shared dashboard	Dashboard shared with Analyst	1. Login as Analyst 2. Navigate to Dashboards	Shared dashboard visible; Dashboard loads correctly; Charts rendered; View-only access enforced	Positive	High
<b>TC-SHARE-003</b>	Dashboard Sharing & Access Control	Analyst cannot edit shared dashboard	Dashboard shared as view-only	1. Login as Analyst 2. Open shared dashboard 3. Attempt to edit layout or charts	Edit controls hidden or disabled; Error message displayed; Dashboard remains unchanged	Negative	High
<b>TC-SHARE-004</b>	Dashboard Sharing & Access Control	Unauthorized user cannot access dashboard	User not member of workspace	1. Attempt to access dashboard URL directly	Access denied; Error message: “Unauthorized access”; No dashboard data exposed; Attempt logged	Security	High
<b>TC-SHARE-005</b>	Dashboard Sharing & Access Control	Revoke dashboard sharing	Dashboard shared previously	1. Login as Manager 2. Open dashboard sharing settings 3. Remove member access	Access revoked successfully; Member no longer sees dashboard; Revocation logged; No cached access remains	Positive	High

- Test Cases for Notification & Messaging Management

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
TC-NOTIF-001	Notification & Messaging Management	Receive notification on workspace invitation	User invited to workspace	1. Invite user to workspace 2. User logs in 3. Check notifications panel	Notification received successfully; Notification shows inviter name, workspace name, timestamp; Status marked as unread	Positive	High
TC-NOTIF-002	Notification & Messaging Management	Mark notification as read	User has unread notification	1. Login 2. Open notifications panel 3. Click notification	Notification marked as read; Visual indicator updated; Read timestamp stored	Positive	Medium
TC-NOTIF-003	Notification & Messaging Management	Notification generated on role change	Manager changes member role	1. Login as Manager 2. Change role of member	Notification sent to affected member; Notification includes old role and new role; Action logged	Positive	High
TC-NOTIF-004	Notification & Messaging Management	Notification generated on report execution completion	Report execution finishes	1. Execute report 2. Wait for completion	Notification sent to report owner; Includes execution status and duration; Link to report provided	Positive	Medium
TC-NOTIF-005	Notification & Messaging Management	Unauthorized user cannot send notifications	User is Analyst or Executive	1. Login as Analyst/Executive 2. Attempt to send system notification	Access denied; Error message displayed; No notification sent	Negative	High

- Test Cases for Account Deletion & Data Retention Policy

Test Case ID	Requirement Name	Description	Preconditions	Test Steps	Expected Result	Test Type	Priority
TC-DEL-001	Account Deletion & Data Retention	Admin permanently deletes user account	Account is deactivated; User exists	1. Login as Admin 2. Navigate to User Management 3. Select deactivated user 4. Click “Delete Account” 5. Confirm deletion	Account deleted permanently; User record removed; Login impossible; Deletion logged; No orphan references	Positive	High
TC-DEL-002	Account Deletion & Data Retention	Deleted user cannot authenticate	User account deleted	1. Attempt login with deleted user credentials	Login fails; Error message: “Account does not exist”; No tokens issued; Authentication blocked	Negative	High
TC-DEL-003	Account Deletion & Data Retention	User data retention after account deletion	User has historical reports and audit logs	1. Delete user account 2. Check reports, audit logs, and ETL history	Reports and audit logs preserved according to retention policy; User ID anonymized; Data integrity maintained	Positive	High
TC-DEL-004	Account Deletion & Data Retention	Prevent deletion of last active workspace manager	User is last active manager in workspace	1. Login as Admin 2. Attempt to delete last manager account	Deletion blocked; Error message: “Workspace must have at least one active manager”; Account preserved	Negative	High
TC-DEL-005	Account Deletion & Data Retention	Unauthorized user cannot delete account	User is Analyst or Executive	1. Login as Analyst/Executive 2. Attempt to access account deletion endpoint	Access denied; Error message displayed; No deletion performed; Attempt logged	Security	High

Table 49 : Test Cases for Account Deletion & Data Retention Policy

# **Chapter 5**

# **System Design**

## ***1-Introduction***

- The purpose of this section is to provide a comprehensive description of the full system architecture of the BI Voice Agent platform. The platform is designed to convert voice input into SQL queries, execute analytical operations on the data using ClickHouse, and present the results through interactive dashboards
- This section outlines the core system components, architectural layers, microservices, external integrations, and the end-to-end data flow across the entire system

## ***2-High-Level System Design***

The platform is built using a Microservices architecture, divided into several functional domains. It includes a front-end interface, an API gateway, independent service servers, an ETL pipeline powered by Kafka, multiple data storage layers, and external analytics tools such as Metabase

## • Microservices

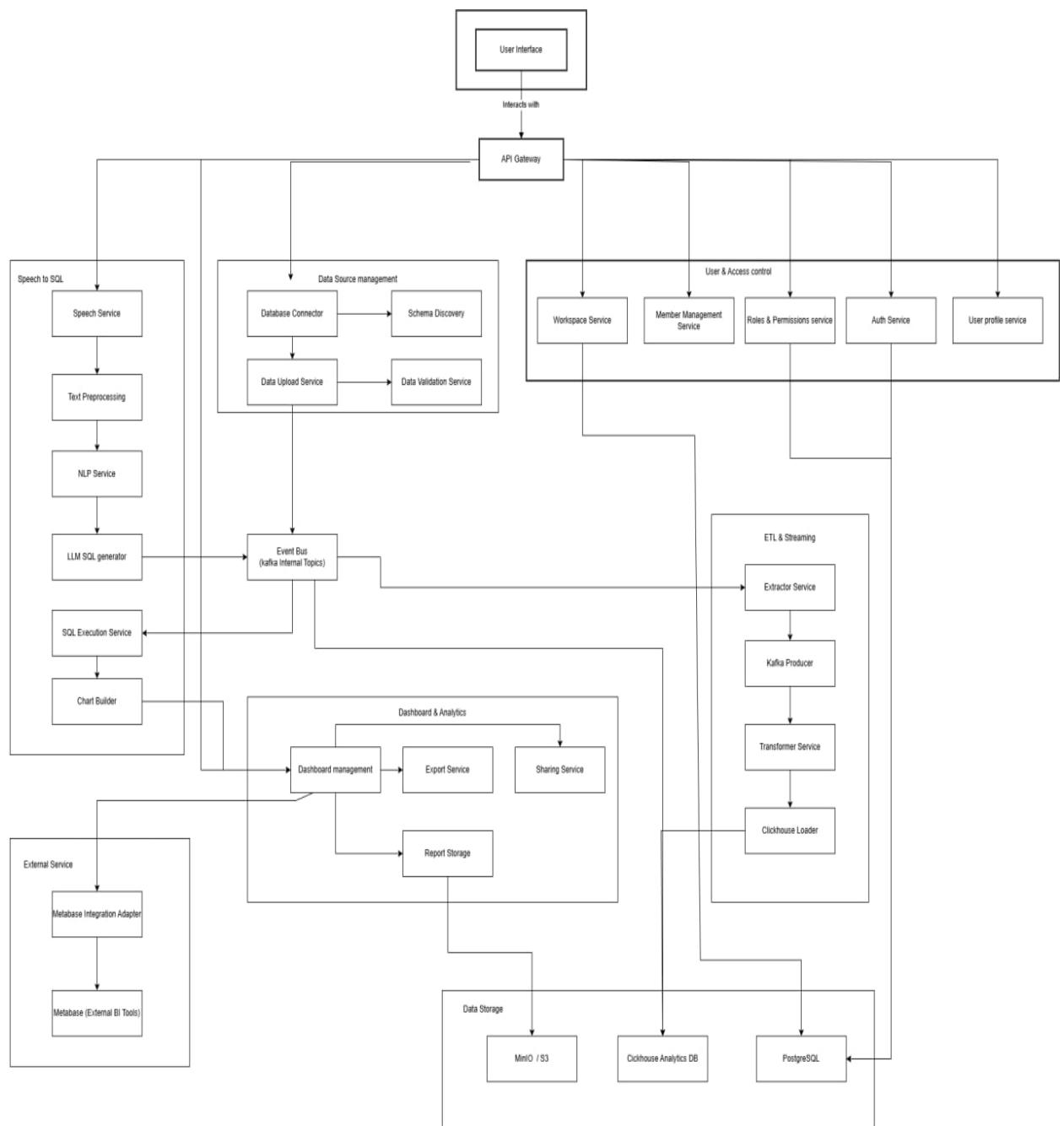


Figure 29 : System Architecture

## **3-Architecture Layers**

### **1-Client**

This layer includes the Web User Interface (Web UI)

Users interact with the system through this interface by performing actions such as logging in, uploading databases, submitting voice queries, viewing analytical results, and creating dashboards

### **2- API Gateway**

The API Gateway serves as the single entry point for all incoming requests

It handles routing, basic validation, and request forwarding. It also isolates the front-end from the internal microservices, ensuring a clean separation of concerns and secure communication

### **3- Microservices Layer**

#### - Speech-to-SQL Domain

- **Speech Service:** Converts voice input into text using Whisper
- **Text Preprocessing:** Cleans, normalizes, and prepares the text
- **NLP Service:** Analyzes user intent and extracts semantic context
- **LLM SQL Generator:** Generates an SQL query using a Large Language Model
- **SQL Execution Service:** Executes the generated SQL query on ClickHouse
- **Chart Builder:** Produces initial charts and tables from the query results

#### - Data Source Management Domain

- **Database Connector:** Connects to the user's external database
- **Data Upload Service:** Receives and processes uploaded CSV/SQL files
- **Schema Discovery:** Identifies tables, fields, and relationships
- **Data Validation Service:** Validates data formats, consistency, and correctness

- User & Access Control Domain
  - **Auth Service:** Handles login, authentication, and session management
  - **User Profile Service:** Manages user profile information
  - **Roles & Permissions Service:** Controls roles, access levels, and authorization
  - **Workspace Service:** Creates and manages user workspaces
  - **Member Management Service:** Manages invitations, role assignments, and member updates
- Dashboard & Analytics Domain
  - **Dashboard Management:** Creates and edits dashboards, and manages chart placement
  - **Export Service:** Exports reports as PDF, Excel, or image files
  - **Sharing Service:** Manages report sharing with Workspace members
  - **Report Storage:** Stores generated charts, tables, and analytical outputs
- ETL & Streaming Domain
  - **Extractor Service:** Reads and extracts raw input data
  - **Kafka Producer:** Sends extracted data into Kafka topics
  - **Transformer Service:** Cleans, structures, and transforms data in transit
  - **ClickHouse Loader:** Loads processed data into the ClickHouse database
- Data Storage
  - **ClickHouse Analytics DB** — the primary analytical data warehouse
  - **PostgreSQL** — stores users, roles, invitations, dashboards, and metadata
  - **MinIO / S3** — stores uploaded files, generated results, and assets
- External Integrations Layer
  - Metabase Integration Adapter
  - Metabase (External BI Tool)

## ***4. Detailed design for system component***

In this section we will dive into the detailed design for each component of the system, also mentions the design principles and patterns used to build a strong software system that fulfills its requirements.

### **4.1-Design class diagram**

#### **4.1.1 - User Authentication**

This class diagram illustrates the relationships and responsibilities between the components of the User Authentication module in the system. This module is responsible for managing user accounts and handling authentication-related operations such as registration, login, logout, and email verification. It includes the following primary entities:

- **UserRepository:**

Handles all database operations related to user management, including creating users, retrieving user data, updating user information, and deactivating user accounts.

- **AuthService:**

Provides core authentication services and business logic. It uses the UserRepository to perform user-related operations such as user registration, login, logout, and email verification.

- **BaseAuthView:**

A base class for all authentication-related views. It provides access to the authentication services and ensures a unified structure for authentication endpoints.

`SignUpView`, `LoginView`, `LogoutView`, and `EmailVerificationView`: Represent the API endpoints responsible for user registration, login, logout, and email verification, respectively. Each view handles HTTP requests and delegates authentication logic to the service layer.

## Relationships

### 1. Dependency:

`AuthService` depends on `UserRepository` for all user data operations.

`BaseAuthView` depends on `AuthService` to access authentication functionality.

### 2. Inheritance:

`SignUpView`, `LoginView`, `LogoutView`, and `EmailVerificationView` inherit from `BaseAuthView`, allowing them to reuse common authentication behavior and maintain consistency across the authentication module.

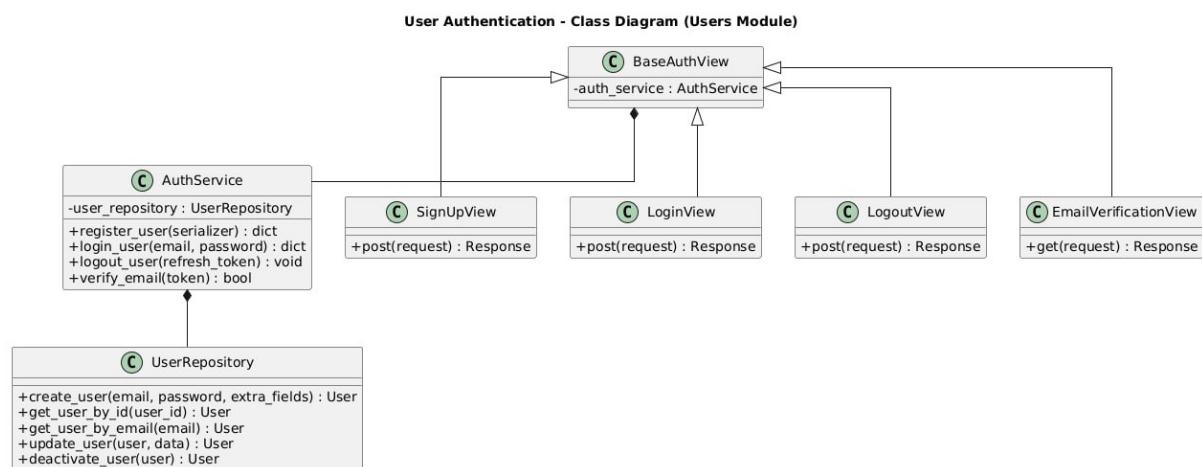


Figure 30 : Class diagram for user auth

## 4.1.2 - User Management

This class diagram illustrates the relationships and responsibilities between the components of the User Management module in the system. This module is responsible for managing users within a workspace, including creating users, updating their information, managing roles, activating or suspending accounts, and deleting users. It includes the following primary entities:

- **UserManagementService:**

Handles the core business logic related to user management. It coordinates user-related operations by interacting with both user and workspace member repositories.

- **UserRepository:**

Handles database operations related to user entities, such as retrieving users, creating new users, updating user data, deactivating users, and deleting user accounts.

- **WorkspaceMemberRepository:**

Manages workspace membership data, including assigning roles to users within a workspace, updating member status, and removing users from a workspace.

- **BaseUserManagementView:**

A base class for all user management-related views. It provides access to user management services and ensures a consistent structure for user management endpoints.

**UserListView, UserCreateView, UserUpdateView, UserSuspendView, UserActivateView, and UserDeleteView:**

Represent API endpoints for listing users, creating new users, updating user information, suspending users, activating suspended users, and deleting users, respectively.

### Relationships

#### 1. Dependency:

UserManagementService depends on UserRepository and WorkspaceMemberRepository to perform all user and workspace-related data operations.

BaseUserManagementView depends on UserManagementService to access user management functionality.

## 2. Inheritance:

UserListView, UsercreateView, UserUpdateView, UserSuspendView, UserActivateView, and UserDeleteView inherit from BaseUserManagementView, allowing them to reuse common logic and maintain consistency across user management endpoints.

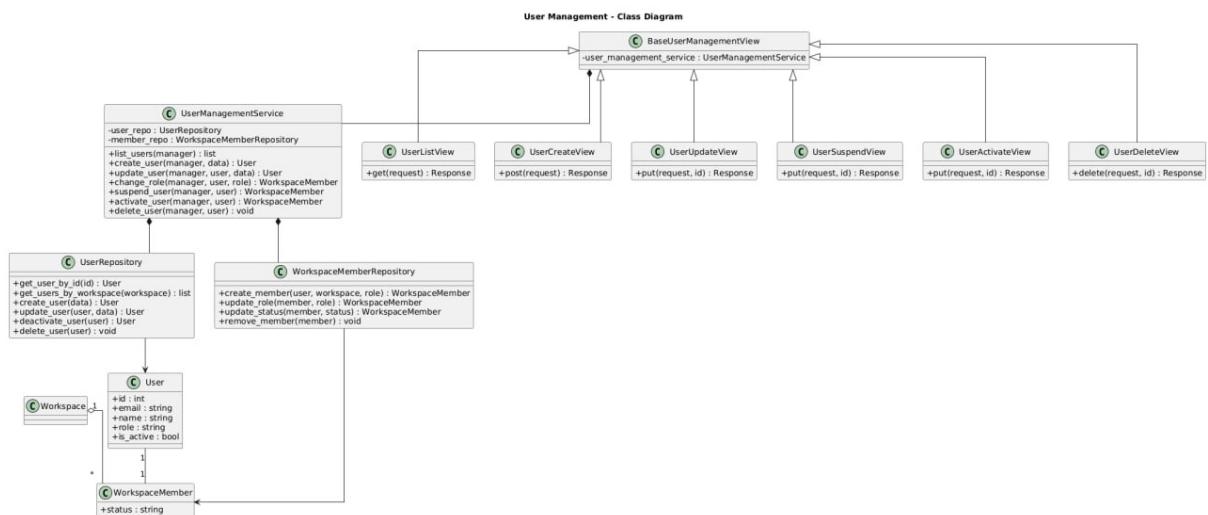


Figure 31 : class diagram for User managements

### 4.1.3 - Workspace Management

This class diagram illustrates the relationships and responsibilities between the components of the Workspace Management module in the system. This module is responsible for managing workspaces and their members, including updating workspace information, handling member roles, sending invitations, accepting invitations, and controlling member status within a workspace. It includes the following primary entities:

- **WorkspaceService:**

Handles the core business logic related to workspace management. It coordinates workspace operations and member management by interacting with workspace and invitation repositories.

- **WorkspaceRepository:**

Handles database operations related to workspaces, such as retrieving workspace information, updating workspace data, managing workspace members, and removing users from a workspace.

- **InvitationRepository:**

Manages invitation-related data, including creating invitations, retrieving invitations by token, and expiring invitations.

- **InvitationService:**

Provides invitation-specific business logic, including inviting new members to a workspace and accepting workspace invitations using secure tokens.

- **BaseWorkspaceView:**

A base class for all workspace-related views. It provides access to workspace services and ensures a unified structure for workspace management endpoints.

`WorkspaceUpdateView`, `WorkspaceMembersView`, `InvitationView`, `RoleAssignmentView`, `MemberManageView`, `MemberSuspendView`, `MemberUnsuspendView`, and `AcceptInvitationView`:

Represent API endpoints for updating workspace details, listing workspace members, inviting users, assigning roles, managing members, suspending or unsuspending members, and accepting workspace invitations, respectively.

## Relationships

### 1. Dependency:

`WorkspaceService` depends on `WorkspaceRepository` and `InvitationRepository` to perform workspace and member-related data operations.

`InvitationService` depends on `InvitationRepository` to manage invitation lifecycle operations.

`BaseWorkspaceView` depends on `WorkspaceService` to access workspace management functionality.

`AcceptInvitationView` depends on `InvitationService` to handle invitation acceptance.

### 2. Inheritance:

`WorkspaceUpdateView`, `WorkspaceMembersView`, `InvitationView`, `RoleAssignmentView`, `MemberManageView`, `MemberSuspendView`, and `MemberUnsuspendView` inherit from `BaseWorkspaceView`, ensuring consistent behavior and reuse of shared workspace logic across all workspace management endpoints.

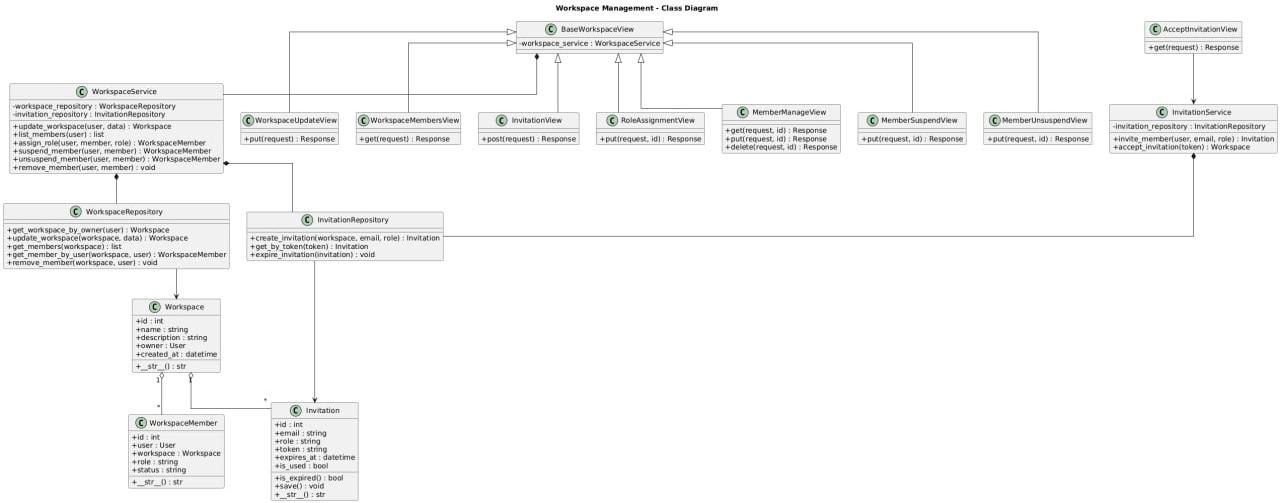


Figure 32 : class diagram for Workspace managements

#### 4.1.4 - Database Management

This class diagram illustrates the relationships and responsibilities between the components of the Database Management module in the system. This module is responsible for handling user-uploaded databases, managing their lifecycle, interacting with the analytical database engine, and providing database preview and status functionalities. It includes the following primary entities:

- **DatabaseService:**

Handles the core business logic related to database management. It coordinates database upload, replacement, deletion, preview generation, and status checking by interacting with the database repository and the analytical database client.

- **DatabaseRepository:**

Handles database-related persistence operations, including creating database records, retrieving databases by workspace, updating database status and metadata, and deleting databases.

- **ClickHouseClient:**

Provides an abstraction layer for interacting with the ClickHouse analytical database engine. It is responsible for executing queries, retrieving table previews, schemas, row counts, and checking table existence.

- DatabaseUtils:

Provides utility functions related to database processing, such as cleaning database data and formatting file sizes for display purposes.

- BaseDatabaseView:

A base class for all database-related views. It provides access to database services and ensures a unified structure for database management endpoints.

DatabaseUploadView, DatabaseDetailView, DatabasePreviewView, DatabaseStatusView, and DatabaseHealthCheckView:

Represent API endpoints for uploading databases, retrieving or deleting database details, previewing database content, checking database status, and performing database health checks, respectively.

## Relationships

### 1. Dependency:

DatabaseService depends on DatabaseRepository to perform database-related persistence operations.

DatabaseService depends on ClickHouseClient to interact with the analytical database engine.

BaseDatabaseView depends on DatabaseService to access database management functionality.

DatabaseService utilizes DatabaseUtils for auxiliary database processing tasks.

### 2. Inheritance:

DatabaseUploadView, DatabaseDetailView, DatabasePreviewView, DatabaseStatusView, and DatabaseHealthCheckView inherit from

BaseDatabaseView, ensuring consistency and reuse of shared logic across all database management endpoints.

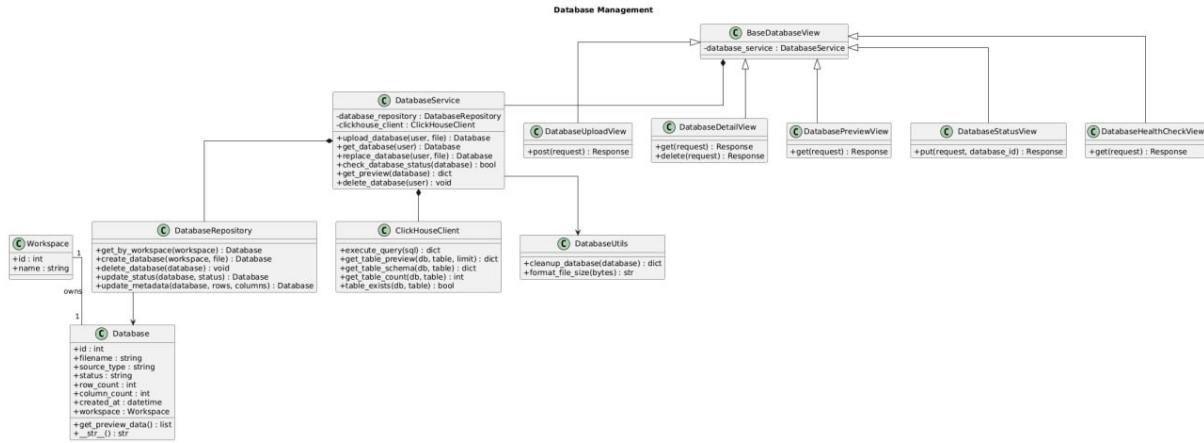


Figure 33 : class diagram for Database Managements

## 4.1.5 - AI Services

This class diagram illustrates the relationships and responsibilities between the components of the AI Services module in the system. This module is responsible for processing voice-based analytical requests, transforming spoken input into structured queries, and ensuring the correctness and security of generated SQL queries. It includes the following primary entities:

- AIProcessingService:

Handles the core AI processing pipeline. It orchestrates the entire flow of voice request processing, starting from audio transcription and ending with validated SQL query generation. It integrates multiple AI and validation components to ensure accurate and secure query generation.

- WhisperService:

Responsible for transcribing audio input into text using a speech-to-text model.

- **QuestionClassifier:**

Classifies the transcribed text to identify the type of analytical question being asked.

- **IntentService:**

Extracts structured analytical intent from the transcribed text, including metrics, dimensions, and filters.

- **IntentValidator:**

Validates the extracted intent semantically, checks schema compatibility, and ensures SQL executability.

- **SQLCompiler:**

Compiles validated intent into executable SQL queries while applying appropriate casting and formatting rules.

- **SQLGuard:**

Performs security validation on generated SQL queries to prevent unsafe or unauthorized query execution.

- **VoiceRequestRepository:**

Handles persistence operations for voice requests, including storing audio files, transcriptions, intents, generated SQL queries, and request status updates.

- **AIServiceView:**

Represents the API endpoint responsible for receiving voice-based requests and triggering the AI processing workflow.

## Relationships

### 1. Dependency:

AIProcessingService depends on WhisperService, QuestionClassifier, IntentService, IntentValidator, SQLCompiler, and SQLGuard to execute the AI processing pipeline.

AIProcessingService depends on VoiceRequestRepository to store and update voice request data throughout processing stages.

AIServiceView depends on AIProcessingService to initiate voice request processing.

## 2. Association and Ownership:

A User with a manager role owns voice requests and is allowed to initiate voice-based analytical queries within a Workspace.

A Workspace contains multiple VoiceRequest entities representing historical voice queries and their results

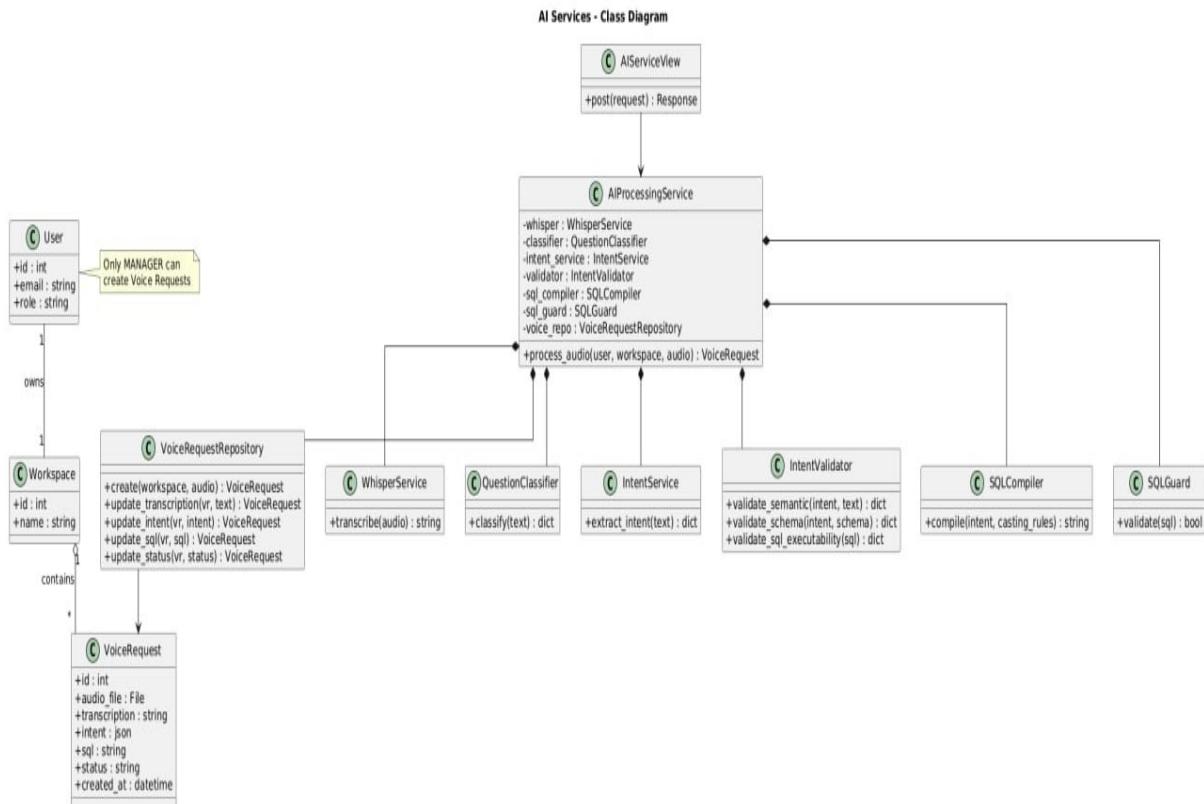


Figure 34 : Class Diagram for AI Services

#### 4.1.6 - Voice Reports

This class diagram illustrates the relationships and responsibilities between the components of the Voice Reports module in the system. This module is responsible for managing voice-based analytical reports, starting from audio upload and processing, passing through query execution and validation, and ending with report visualization and dashboard integration. It includes the following primary entities:

- **VoiceReportService:**

Handles the core business logic related to voice reports. It coordinates audio upload, AI processing, SQL execution, report management, and integration with dashboards and visualization services.

- **VoiceReportRepository:**

Handles persistence operations for voice reports, including creating reports, updating transcription, intent, SQL queries, report status, and retrieving reports by workspace.

- **AIServiceClient:**

Acts as a client interface to the AI Services module, responsible for processing audio input and returning structured analytical results.

- **ClickHouseExecutor:**

Executes validated SQL queries against the analytical database engine and returns query results.

- **SQLGuard:**

Ensures the security and validity of SQL queries before execution.

- **MetabaseService:**

Integrates the system with Metabase to create analytical questions, dashboards, and associate reports with visual dashboards.

- **JWTEmbeddingService:**

Generates secure embedded URLs for dashboards, allowing controlled access to visual reports.

- **SQLEditHistoryRepository:**

Stores the history of SQL edits applied to voice reports, enabling traceability and auditability of query modifications.

- **BaseVoiceReportView:**

A base class for all voice report-related views. It provides access to voice report services and ensures a consistent structure for report-related endpoints.

`VoiceUploadView`, `QueryExecuteView`, `SQLEditView`, `ReportListView`, `ReportDetailView`, and `WorkspaceDashboardView`:

Represent API endpoints for uploading voice input, executing queries, editing SQL queries, listing reports, viewing or deleting report details, and displaying workspace dashboards, respectively.

## Relationships

### 1. Dependency:

`VoiceReportService` depends on `VoiceReportRepository`, `SQLEditHistoryRepository`, `AIServiceClient`, `ClickHouseExecutor`, `SQLGuard`, `MetabaseService`, and `JWTEmbeddingService` to perform report processing, execution, validation, and visualization tasks.

`BaseVoiceReportView` depends on `VoiceReportService` to access voice report functionality.

### 2. Association and Ownership:

A User creates and manages voice reports within a Workspace.

A Workspace contains multiple `VoiceReport` entities representing generated analytical reports.

Each `VoiceReport` may have multiple SQL edit history records to track modifications over time.

### 3. Inheritance:

`VoiceUploadView`, `QueryExecuteView`, `SQLEditView`, `ReportListView`, `ReportDetailView`, and `WorkspaceDashboardView` inherit from `BaseVoiceReportView`, ensuring reuse of common logic and consistency across all voice report endpoints.

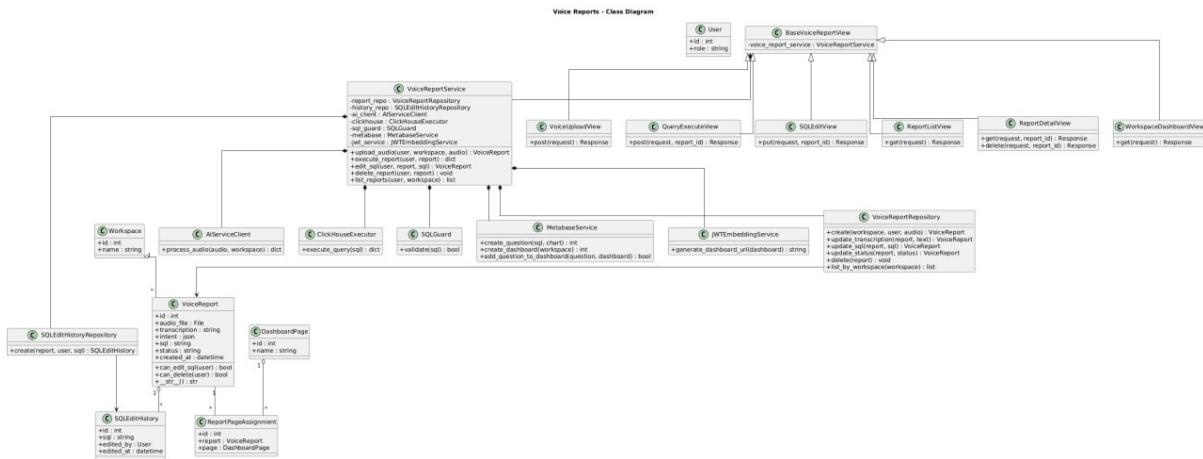


Figure 35 : class diagram for Voice Managements

# **Chapter 6**

# **Artificial Intelligence**

# **1. Introduction**

## **1.1 Purpose of the AI Component**

The Artificial Intelligence component in the BI Voice Agent system is designed to enable intelligent interaction between users and analytical data through natural language. Its primary purpose is to interpret user voice input, understand the analytical intent behind the request, and translate this intent into structured operations that can be executed on analytical data sources. By doing so, the AI component removes the technical barrier traditionally associated with data querying and allows non-technical users to interact with business intelligence systems in an intuitive and efficient manner.

## **1.2 Motivation for Using AI in Business Intelligence Systems**

Traditional business intelligence systems rely heavily on predefined dashboards and manually written queries, which limits flexibility and slows down the decision-making process. In dynamic environments, decision-makers often need immediate answers to ad-hoc questions that were not anticipated during dashboard design. Integrating artificial intelligence enables the system to dynamically interpret user questions and generate analytical queries on demand. This capability significantly enhances system usability, supports exploratory data analysis, and improves the responsiveness of business intelligence platforms.

## **1.3 Scope of the AI**

This section focuses on the artificial intelligence and data science aspects of the BI Voice Agent system. It covers the conceptual foundations, processing stages, and integration mechanisms that enable voice-based analytical querying. The section explains how voice input is transformed into text, how user intent is extracted and structured, how analytical queries are generated, and how results are prepared for visualization. Implementation-level details are described conceptually without delving into source code, ensuring clarity and alignment with academic documentation standards.

## **2. Role of AI in Voice-Based Analytical Systems**

### **2.1 Voice as a Natural Interface for Data Interaction**

Voice-based interaction represents one of the most natural forms of communication between humans and machines. In the context of business intelligence systems, using voice as an interface allows users to express analytical needs in the same way they would ask questions during meetings or discussions. Artificial intelligence plays a crucial role in enabling this interaction by converting unstructured spoken language into structured representations that machines can understand and process. This approach reduces cognitive load on users and supports more spontaneous and exploratory data analysis.

### **2.2 From Spoken Questions to Analytical Intent**

A spoken question typically contains ambiguity, implicit assumptions, and contextual references. Artificial intelligence techniques, particularly natural language processing, are required to interpret such questions and extract their analytical meaning. This involves identifying key entities such as metrics, dimensions, filters, and time constraints, and organising them into a structured analytical intent. The ability to accurately infer this intent is essential for generating meaningful and correct analytical queries that reflect the user's actual information needs.

### **2.3 Enhancing Accessibility and Decision-Making**

By enabling voice-based analytical interaction, artificial intelligence significantly enhances accessibility to data-driven insights. Users who lack technical expertise in databases or query languages can still obtain valuable information through natural conversation. This democratization of data access improves organisational decision-making by allowing a broader range of stakeholders to explore and analyse data directly, without dependency on technical teams. As a result, insights can be generated faster and integrated more effectively into operational and strategic decisions.

### 3. AI Processing Pipeline for Voice-Based Analytics

#### 3.1 Speech-to-Text Conversion Using Whisper

- The first stage of the AI processing pipeline is responsible for converting the user's spoken input into textual form. This task is performed using a speech-to-text model based on the Whisper architecture. The model processes the uploaded audio file and produces a high-quality textual transcription that represents the spoken question. This textual output serves as the foundational input for all subsequent processing stages.
- Accurate transcription is critical, as any errors at this stage may propagate through the pipeline and negatively affect intent detection and query generation. Therefore, a robust speech recognition model is essential to ensure reliable interpretation of user requests, particularly in environments where accents, background noise, or domain-specific terminology may be present.

#### 3.2 Determining Whether the Question Requires Analytical Query Execution

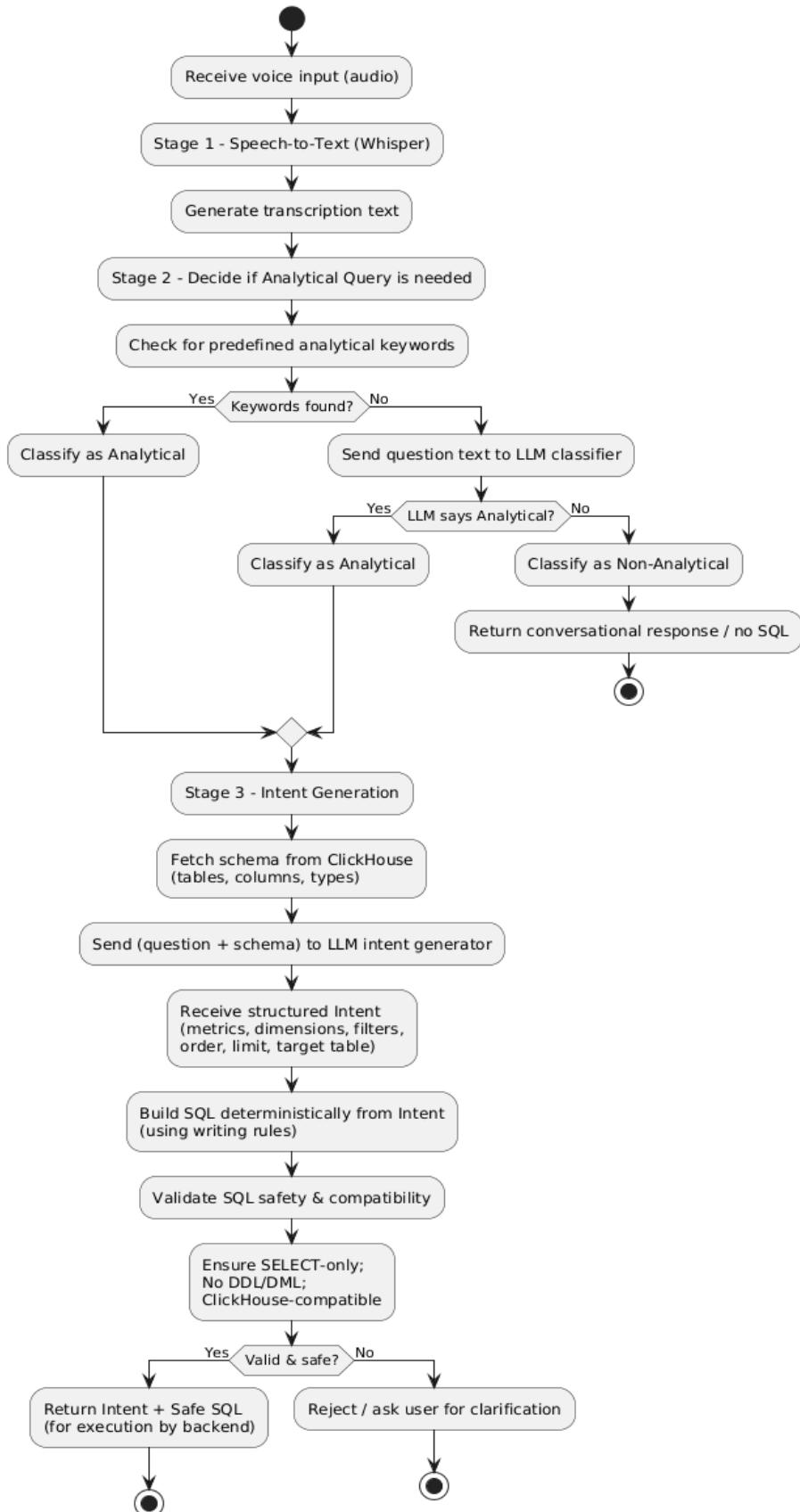
- The second stage determines whether the transcribed question requires analytical processing and database query execution. This decision is essential to avoid unnecessary query generation for questions that are conversational, informational, or unrelated to data analysis. The system employs a two-step strategy to make this determination.
- In the first step, the system checks the transcribed text against a predefined set of analytical keywords commonly associated with data analysis, such as aggregation terms, temporal expressions, and metric-related phrases. If such keywords are detected, the question is directly classified as analytical.
- If no analytical keywords are found, the second step is activated. In this step, the question is passed to a language model, which evaluates the semantic structure and intent of the question to determine whether it represents an analytical request. The model classifies the question as either analytical or non-analytical based on its meaning rather than explicit keywords. This hybrid approach combines rule-based

efficiency with model-based semantic understanding to achieve reliable classification.

### 3.3 Intent Generation and Safe Analytical Query Construction

- In the third stage, the system transforms the analytical question into a structured intent representation. The transcribed question is sent, along with the database schema retrieved from the ClickHouse system, to a language model responsible for intent generation. The schema includes available tables, columns, and data types, ensuring that the generated intent is grounded in the actual structure of the database.
- The resulting intent contains all information required to manually construct an analytical query using deterministic writing rules. This includes selected tables, metrics with aggregation functions, grouping dimensions, filters, ordering conditions, and result limits. Instead of generating SQL directly, the system relies on this structured intent as an intermediate representation, allowing for controlled and transparent query construction.
- After intent generation, the system performs strict validation to ensure that the resulting query will be safe and compatible with ClickHouse. This validation verifies that the query is a read-only SELECT statement, conforms to ClickHouse syntax, and does not include any destructive or unsupported operations. Only after passing these checks is the intent considered valid, and the stage is completed. This ensures that generated queries are both semantically correct and operationally safe.

### AI Processing Pipeline (Voice -> Intent -> Safe Query)



*Figure 36 : AI Processing Pipeline*

## 4. AI Models and Their Roles in the BI Voice Agent System

### 4.1 Speech-to-Text Model (Whisper – Large v3)

#### a) Model Overview

The speech-to-text component of the BI Voice Agent system relies on the Whisper large v3 model. This model is responsible for converting raw audio input into accurate textual representations. It serves as the entry point of the AI pipeline, enabling the system to process spoken language as structured text suitable for further analysis. The choice of the large v3 variant reflects the system's requirement for high transcription accuracy across diverse accents, speaking styles, and acoustic conditions.

#### b) Input and Output

The input to the Whisper model consists of an audio file containing the user's spoken question. The output is a textual transcription that accurately reflects the spoken content. This text is produced in a normalized and machine-readable format, making it suitable for subsequent natural language processing stages. The transcription output does not include any analytical interpretation; it strictly represents the spoken words.

#### c) Internal Functioning

Internally, the Whisper model applies deep learning techniques to analyse audio signals and map them to linguistic units. The model processes acoustic features extracted from the audio and decodes them into text using a sequence-to-sequence architecture. The large v3 variant provides improved robustness and accuracy, particularly in challenging scenarios such as background noise or mixed-language speech, which are common in real-world business environments.

#### d) Role in the System

Within the overall system, the Whisper model acts as a foundational component. All subsequent AI operations depend on the correctness of its output. By providing reliable textual input, the model enables accurate classification of the question and effective intent extraction. The model operates independently of business logic and database context, ensuring a clear separation between speech processing and analytical reasoning.

### 4.2 Analytical Question Classification Model

#### a) Model Overview

The second artificial intelligence model used in the system is a lightweight large language model deployed locally through the Ollama framework, based on the Gemma 3 architecture with a 1B parameter configuration. This model is dedicated to classifying user questions and determining whether a given transcribed input requires analytical processing and database query execution. Its primary role is decision-making rather than content generation, enabling efficient routing of requests within the AI pipeline.

The choice of a compact model reflects a design trade-off between performance and resource efficiency. By using a smaller model hosted locally, the system can perform fast classification without incurring external API latency or cost, making it suitable for real-time interaction.

**b) Input and Output**

The input to the classification model is the transcribed text produced by the speech-to-text stage. The model analyses this text and produces a binary or categorical output indicating whether the question is analytical or non-analytical. The output does not include any SQL or structured query elements; instead, it provides a routing decision that determines whether the request should proceed to the intent generation stage or be handled as a conversational response.

**c) Internal Functioning**

Internally, the model evaluates the semantic structure of the input text rather than relying solely on explicit keywords. It considers contextual cues, intent-related phrasing, and implicit analytical patterns that may not be captured by rule-based checks. This allows the system to correctly classify questions that lack obvious analytical keywords but still require data-driven responses. The model complements the initial keyword-based detection by providing semantic validation when ambiguity exists.

**d) Key Characteristics**

Key characteristics of this model include low latency, local execution, and deterministic behaviour suitable for classification tasks. Its compact size enables fast inference and predictable performance, which are critical for maintaining a responsive user experience. While the model is not designed for complex reasoning or long text generation, it excels at its designated role of intent classification within the system.

**e) Role in the System Workflow**

Within the system workflow, the classification model acts as a gatekeeper that prevents unnecessary analytical processing. Only questions classified as analytical are forwarded to the intent generation stage, while non-analytical questions are handled separately. This design improves system efficiency, reduces load on downstream models, and ensures that database queries are generated only when truly required.

## 4.3 Intent Generation and Schema-Aware Language Model

**a) Model Overview**

The third artificial intelligence model used in the system is a large language model accessed through the OpenRouter service, based on the Gemma 3n architecture. This model is responsible for generating structured analytical intent from user questions that have been classified as analytical. Its primary function is to translate natural language queries into a formal representation that ensures compatibility with the underlying analytical database.

Unlike the classification model, which performs lightweight decision-making, this model is used for complex semantic understanding and structured output generation. The use of

a remotely hosted model allows the system to leverage stronger reasoning capabilities and broader contextual understanding, which are essential for accurate intent construction in analytical scenarios.

**b) Input and Output**

The input to the intent generation model consists of the analytical question text combined with schema information retrieved from the ClickHouse database. This schema information includes available tables, columns, and data types, providing essential context that constrains the model's output. The output is a structured intent representation, typically expressed in a machine-readable format, containing all elements required to construct an analytical query.

The generated intent includes selected tables, metrics with aggregation functions, grouping dimensions, filtering conditions, sorting preferences, and result limits. This structured output acts as an intermediate layer between natural language and SQL, enabling controlled and transparent query construction.

**c) Schema-Aware Reasoning and Hallucination Prevention**

A critical feature of this model's usage is schema-aware reasoning. By explicitly providing database schema information, the system constrains the model to reference only existing tables and columns. This significantly reduces the risk of hallucination, a common issue in large language models where non-existent entities may be generated. Schema awareness ensures that all generated intents are grounded in the actual data structure of the system.

Additionally, the model is instructed to adhere to a predefined intent format, which further limits ambiguity and enforces consistency. Any intent that references invalid schema elements or violates structural constraints is rejected during subsequent validation stages.

**d) Role in Safe Analytical Query Construction**

The intent generated by this model is not executed directly as SQL. Instead, it serves as a controlled blueprint for deterministic query construction. This design choice allows the system to apply strict validation rules before execution, ensuring that the resulting query is safe, read-only, and compatible with ClickHouse. By separating semantic understanding from query execution, the system minimizes the risk of incorrect or unsafe database operations.

This model therefore plays a central role in balancing flexibility and safety: it provides rich semantic interpretation while allowing the system to maintain full control over the final query generation process.

**e) Integration within the AI Pipeline**

Within the AI pipeline, this model represents the final and most semantically intensive stage. It is invoked only after the question has been classified as analytical and prepared for intent extraction. Its output directly influences the structure of the analytical query and the subsequent visualization. As such, the correctness and clarity of the generated intent are essential for the overall reliability of the BI Voice Agent system.

## **5. Summary**

This chapter described the artificial intelligence component of the BI Voice Agent system and its role in enabling voice-based analytical interaction. It explained how spoken user input is processed through several AI stages, starting from speech-to-text conversion, followed by question classification, and ending with structured intent generation.

The chapter also presented the three AI models used in the system. The first model converts voice input into text, the second model determines whether the question requires analytical processing, and the third model generates a structured intent that can be safely translated into an analytical query. Together, these models form a clear and efficient AI workflow that allows users to interact with data using natural language.

# **Chapter 7**

## **Data science Module**

## 1. Introduction

### 1.1 Purpose of the Data Science Component

The Data Science component in the BI Voice Agent project applies the ETL principle to prepare data for analytical querying. It starts by uploading external databases or files, then extracting, cleaning, and loading the data into the ClickHouse analytical database. Once loaded, this data can be queried later through voice interaction, where spoken questions are converted into SQL queries.

The main purpose of this component is to ensure that the data stored in ClickHouse is clean, structured, and ready for analysis, enabling accurate and reliable voice-based queries.

### 1.2 Relationship Between ETL and Voice-Based Querying

The ETL process prepares data for use by the voice-based querying system. Clean and well-structured data allows the AI component to retrieve correct schema information from ClickHouse and generate valid SQL queries from user voice input. Any issues in data preparation may lead to incorrect or failed queries.

### 1.3 Scope of the ETL

This chapter focuses on the practical application of ETL for data preparation. It explains how data is uploaded, extracted, cleaned, and loaded into ClickHouse to support voice-based analytical queries. Predictive modeling and machine learning training are not covered.

## 2. Applied ETL Workflow for Data Preparation

### 2.1 Data Source Submission (User Input)

The ETL workflow starts when the user submits a data source to the system. This source can be a file uploaded manually, such as CSV or Excel, or an online database connection. At this stage, the data is still external to the analytical system and has not yet been processed or validated.

### 2.2 Connection Registration (connection\_topic)

Once the data source is submitted, its connection information is published to a Kafka topic dedicated to connection registration. This step signals the ETL system that a new data source is available and ready for extraction. The published message contains essential metadata describing the source type and access details.

## **2.3 Schema Extraction (schema\_topic)**

After receiving the connection information, the system extracts the schema of the data source. This includes identifying available tables, columns, and data types.

The extracted schema is published to a dedicated Kafka topic and serves as a structural description of the data. This schema information is later used to guide data transformation and to support analytical query generation

## **2.4 Raw Data Extraction (extracted\_rows\_topic)**

Once the schema is identified, the ETL system begins extracting the raw data rows from the source. Each row is published as a message to a Kafka topic dedicated to raw data. At this stage, the data remains uncleaned and unmodified, preserving its original values for further processing.

## **2.5 Data Transformation (Transformer Service)**

The transformer service consumes raw data rows and applies data preparation operations. These operations include data cleaning, type casting, and handling null or invalid values. The goal of this stage is to improve data quality and ensure consistency with the extracted schema. Cleaned rows are then forwarded to the next stage of the pipeline.

## **2.6 Clean Data Publishing (clean\_rows\_topic)**

After transformation, the cleaned and validated data rows are published to a Kafka topic dedicated to clean data. This topic represents data that is ready to be loaded into the analytical database. Only rows that pass cleaning and validation rules reach this stage.

## **2.7 Data Loading into ClickHouse (Loader Service)**

The loader service consumes clean data rows and inserts them into the ClickHouse analytical database. Data is loaded into tables that can later be queried efficiently. This step finalizes the ETL process and makes the data available for analytical querying.

## **2.8 Metadata and Logging (metadata\_topic)**

Throughout all ETL stages, execution metadata and logs are published to a dedicated Kafka topic. This metadata includes information about processed rows, errors, and execution status. It provides visibility into the ETL workflow and supports monitoring, auditing, and troubleshooting.

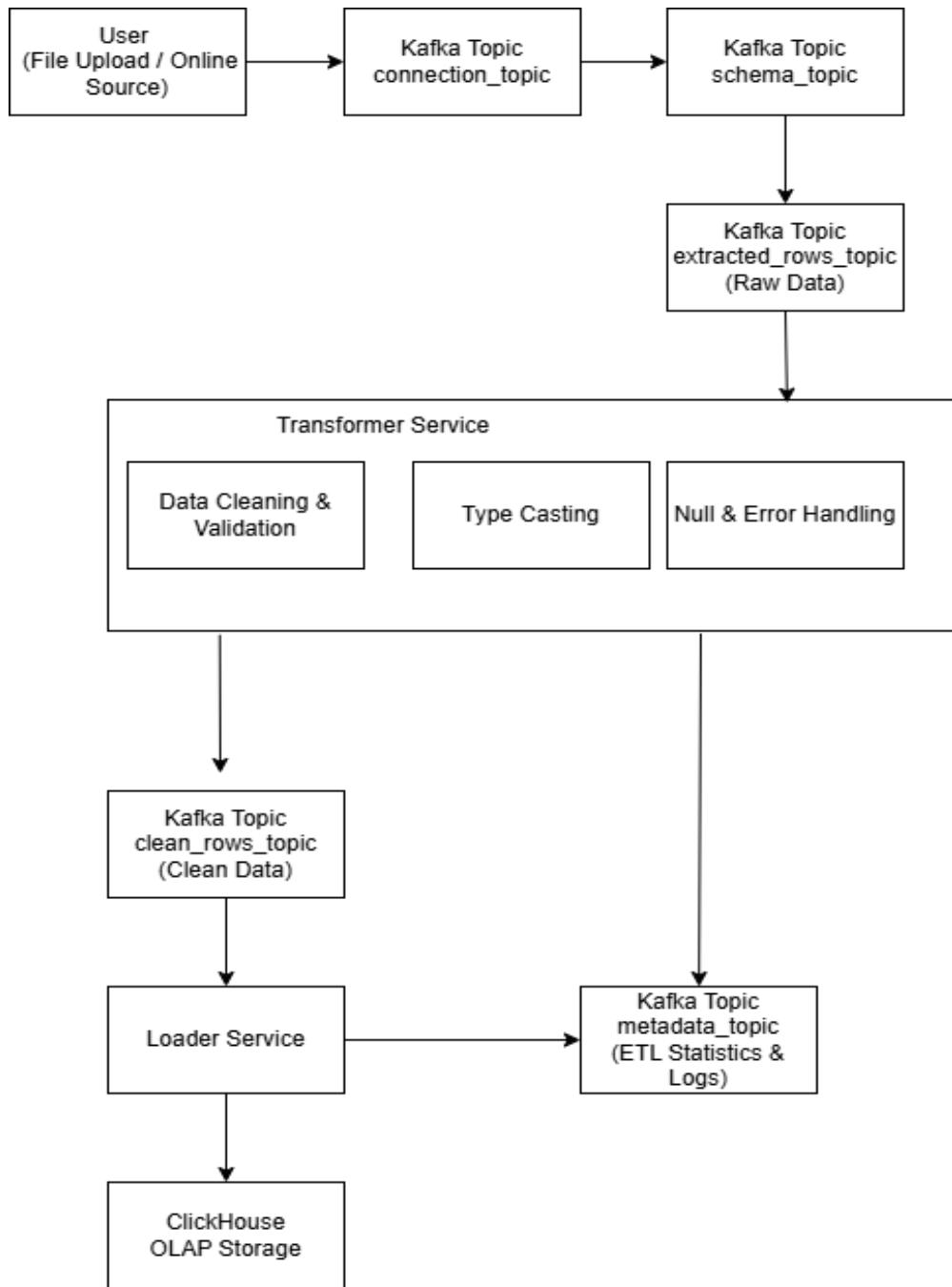


Figure 37 : ETL Pipeline

### **3. Data Readiness for Voice-Based Querying**

#### **3.1 3.1 Structured Data Availability in ClickHouse**

After the ETL workflow completes, the processed data is stored in ClickHouse in a structured and query-ready form. Tables, columns, and data types are clearly defined, allowing the analytical database to efficiently execute aggregation and filtering operations. This structured availability is essential for enabling accurate analytical queries generated from voice input.

#### **3.2 Schema Accessibility for AI Query Generation**

The AI component relies on the availability of database schema information to generate valid SQL queries. Since the ETL pipeline publishes and maintains structured schemas in ClickHouse, the AI module can retrieve up-to-date information about tables and columns before constructing queries. This schema accessibility ensures that voice-generated queries reference existing data structures and avoid invalid or non-existent fields.

#### **3.3 Impact of Clean Data on Query Accuracy**

Clean and validated data directly affects the accuracy of analytical query results. Data cleaning and type consistency performed during the ETL process reduce the risk of incorrect aggregations, failed queries, or misleading outputs. When voice-generated SQL queries are executed on well-prepared data, the results are more reliable and easier to interpret.

#### **3.4 Enabling Reliable Voice-Based Analytics**

By combining structured data storage in ClickHouse with schema-aware AI query generation, the system enables reliable voice-based analytics. The ETL pipeline ensures that data is ready for querying, while the AI component translates user voice input into executable SQL. This integration allows users to interact with data naturally through voice while maintaining analytical correctness.

## **4. Summary**

This chapter presented the applied data science workflow used to prepare data for voice-based analytical querying. It described how data is uploaded, extracted, cleaned, and loaded into ClickHouse through an event-driven ETL pipeline. The chapter also explained how prepared data supports schema-aware AI query generation and improves the accuracy of analytical results. Together, these processes ensure that voice-driven queries operate on reliable and well-structured data.

# **Chapter 8**

## **Practical Implementation**

## ***8.1 Introduction***

In this chapter, we present the practical implementation of the proposed system, highlighting the technologies, tools, and frameworks used during development. This chapter focuses on how the system was built in practice, covering backend and frontend implementation, database management, artificial intelligence components, and infrastructure tools. In addition, system interfaces are demonstrated, and the chapter concludes with an overview of testing procedures used to verify system functionality across different scenarios.

## ***8.2 Used Tools***

### **8.2.1 Django & Django REST Framework**

Django is a high-level Python web framework that enables rapid development and clean, pragmatic design. It provides built-in features such as authentication, ORM, and administrative interfaces, which significantly reduce development complexity.

In this project, Django is used as the main backend framework for implementing the system's core logic, user management, workspace management, database handling, and voice report services.

Additionally, Django REST Framework (DRF) is used to build RESTful APIs. DRF integrates seamlessly with Django's models, views, and URL routing, making it ideal for developing scalable and secure APIs. It provides serializers, authentication mechanisms, permission control, and standardized API responses, which are essential for frontend-backend communication.

### **8.2.2 React**

React is a popular JavaScript library for building user interfaces, developed by Facebook. It enables the creation of reusable UI components and efficient rendering through its virtual DOM mechanism.

In this project, React is used to implement the frontend application, providing a dynamic and interactive user interface. React facilitates smooth navigation between pages, real-time UI updates, and modular component-based design. Tools such as React Router are used for client-side routing, while state management is handled using lightweight libraries to maintain authentication and workspace states.

### **8.2.3 PostgreSQL Database**

PostgreSQL is an open-source relational database management system known for its robustness, reliability, and advanced features.

In this system, PostgreSQL is used as the primary relational database, storing core application data such as users, workspaces, voice reports, database metadata, and permissions. The Django ORM is used to interact with PostgreSQL, providing an abstraction layer that simplifies database operations while maintaining data integrity and consistency.

### **8.2.4 ClickHouse**

ClickHouse is a high-performance, column-oriented database designed for analytical workloads and large-scale data processing.

In this project, ClickHouse is used as the analytical database engine. It stores processed data generated by the ETL pipeline and serves as the execution engine for analytical SQL queries generated from voice inputs. ClickHouse is accessed using both HTTP and native protocols, depending on the use case, ensuring efficient query execution and batch data loading.

### **8.2.5 Visual Studio Code (VS Code)**

Visual Studio Code is a lightweight yet powerful source code editor that provides features such as syntax highlighting, IntelliSense, debugging tools, and Git integration.

VS Code is used as the primary development environment for the entire project, including frontend, backend, AI services, and ETL components. Its extensibility and rich plugin ecosystem enhance productivity and code quality.

### **8.2.6 Bitbucket**

Bitbucket is a Git-based source code repository hosting platform that supports version control and collaborative development.

In this project, Bitbucket is used to manage the source code repository, track changes, and maintain development history. It facilitates collaboration between team members and ensures proper versioning of the system throughout the development lifecycle.

## ***8.3 AI Used Technologies and Tools***

### **8.3.1 OpenAI Whisper**

OpenAI Whisper is an automatic speech recognition (ASR) model capable of transcribing speech into text with high accuracy.

In this system, Whisper is used as the speech-to-text component, converting voice inputs submitted by users into textual form. The transcribed text serves as the initial input for subsequent natural language processing and intent extraction stages.

### **8.3.2 Large Language Models (LLMs) via OpenRouter**

Large Language Models are used to extract analytical intent and generate structured SQL queries from natural language input.

The system integrates LLMs through the OpenRouter API, enabling flexible model selection and scalable inference. These models are responsible for understanding user questions, identifying metrics and filters, and producing SQL queries suitable for analytical execution.

### **8.3.3 LangChain and LangGraph**

LangChain is a framework designed for building applications powered by large language models. It provides abstractions for prompt management, chaining logic, and model interaction.

LangGraph extends this approach by enabling graph-based workflows for reasoning and decision-making. In this project, LangChain and LangGraph are used to implement the reasoning pipeline, allowing structured processing of user queries, classification of question types, and routing between analytical and conversational flows.

### **8.3.4 Pydantic**

Pydantic is a data validation library that uses Python type annotations to enforce data correctness.

In this system, Pydantic is used to validate intent schemas, ensuring that extracted intents, metrics, dimensions, and filters conform to predefined structures before SQL generation and execution. This validation step improves system reliability and reduces runtime errors.

### **8.3.5 Ollama and Local Language Models**

Ollama is a local inference platform used to run large language models on-premise without relying on external cloud services. In this project, Ollama is utilized to host and execute local language models for intent extraction and SQL generation.

Using local models provides several advantages, including improved data privacy, reduced latency, and full control over model behavior. This approach ensures that sensitive analytical queries and business data are processed locally without being sent to third-party services.

## **8.4 ETL Pipeline Technologies**

To support large-scale data ingestion and processing, the system includes an ETL pipeline built using modern distributed tools.

Apache Kafka is used as a message broker to enable asynchronous communication between ETL services.

Pandas and OpenPyXL are used for data extraction, transformation, and file processing.

SurrealDB is used to store metadata, logs, and audit information related to ETL operations.

ClickHouse serves as the final destination for processed analytical data.

This architecture ensures scalability, fault tolerance, and efficient data processing.

### **8.4.1 Apache Kafka**

Apache Kafka is a distributed event streaming platform used as the backbone of the ETL pipeline. In this system, Kafka enables asynchronous and decoupled communication between ETL services, allowing data to flow efficiently through extraction, transformation, and loading stages.

Kafka topics are used to transfer structured messages between services, ensuring scalability, fault tolerance, and reliable data processing across the ETL pipeline.

### **8.4.2 SurrealDB**

SurrealDB is a modern, cloud-native database used for storing ETL metadata, logs, and audit information. In this project, SurrealDB records pipeline execution details, transformation metadata, and processing status.

This separation between analytical data (stored in ClickHouse) and metadata (stored in SurrealDB) improves system organization, traceability, and monitoring capabilities.

## ***8.5 Infrastructure and DevOps Tools***

The system uses Docker and Docker Compose to containerize and orchestrate backend services, ETL components, Kafka, ClickHouse, and SurrealDB. Environment variables are managed using .env files to ensure secure and flexible configuration across environments.

This setup simplifies deployment, improves reproducibility, and enables local and distributed development environments.

## **8.6 Testing**

Testing is conducted using pytest and pytest-django, which provide a robust testing framework for Django applications. Test cases are designed to validate API endpoints, authentication flows, database operations, and AI processing logic.

These tests ensure that the system behaves correctly under different scenarios and that core functionalities operate as expected.

## **8.7 Data Visualization and Reporting**

### **8.7.1 Metabase**

Metabase is an open-source business intelligence and data visualization platform used to present analytical results generated by the system. In this project, Metabase is integrated to create interactive dashboards and visual reports based on SQL queries generated from voice input.

The system programmatically creates questions and dashboards in Metabase and embeds them securely into the application using JWT-based embedding.

This integration enables users to view analytical insights in a clear and interactive manner without directly accessing the Metabase interface.

## 6.3 System interfaces

- Home page



Figure 38 : Home Page Interface

- Log in

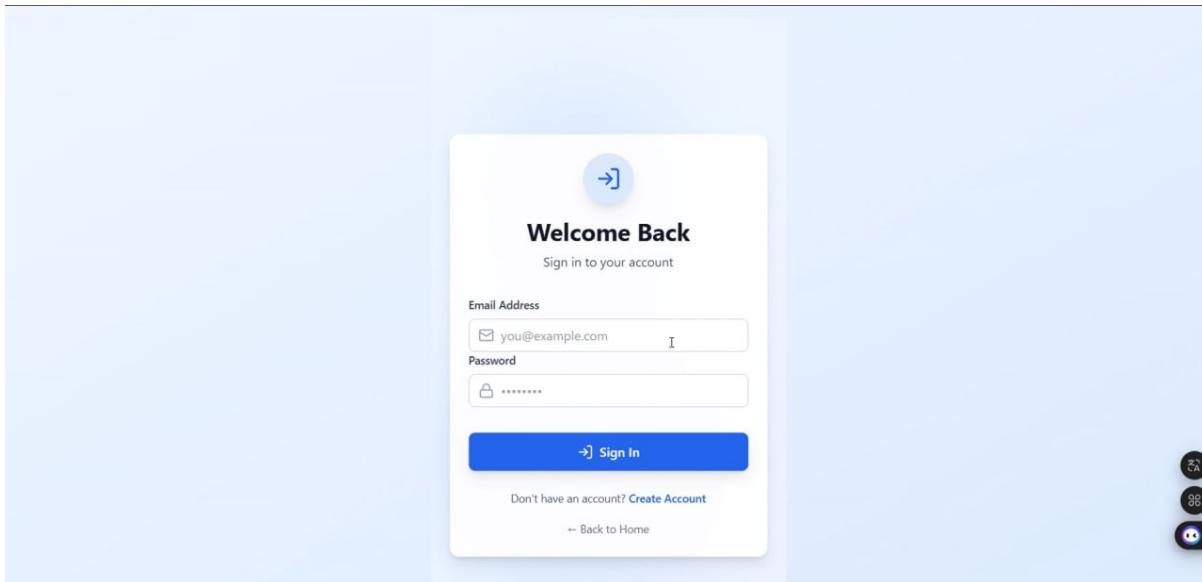


Figure 39 : Login interface

- Sign up

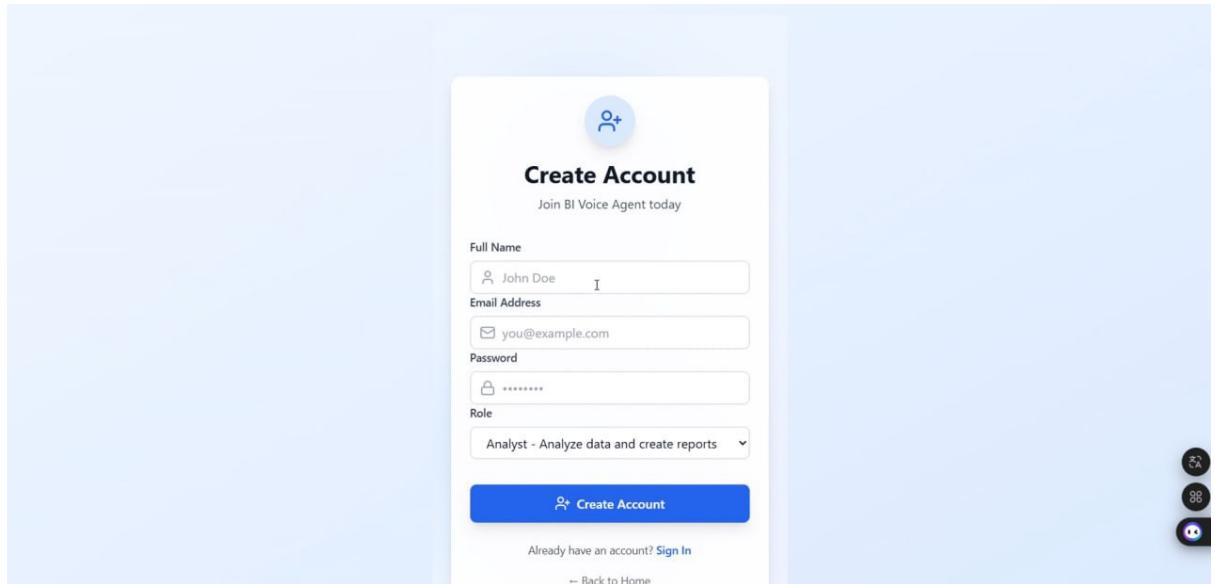


Figure 40 : sign up interface

- Link for verification email

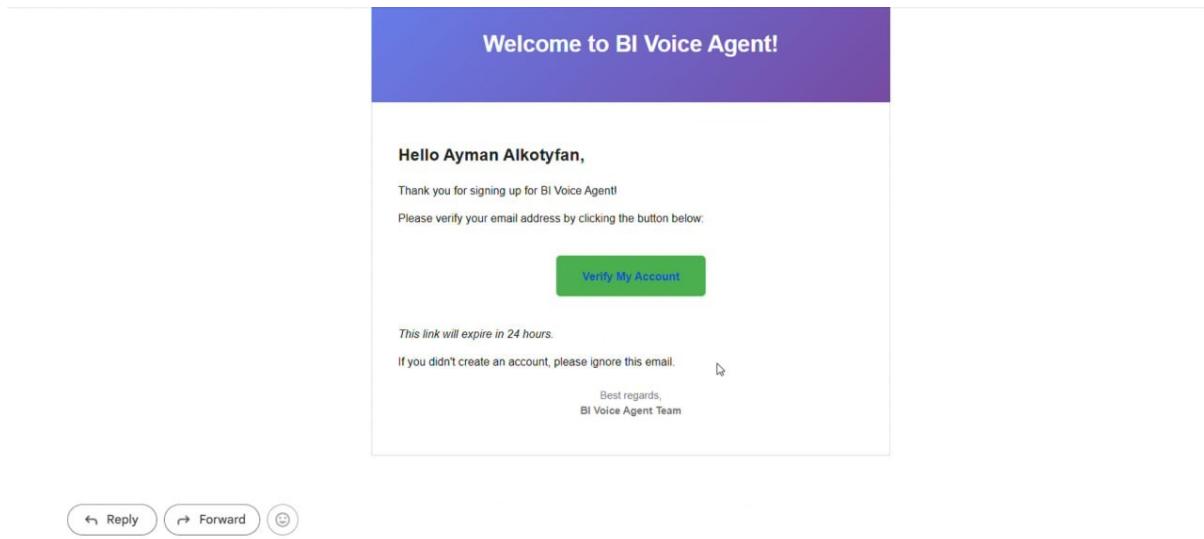


Figure 41 : Email verification in gmail

- Dashboard manager

The screenshot shows the BI Voice Dashboard Manager interface with the following sections:

- Header:** BI Voice - AI-Powered Analytics, Welcome: Ayman Alkotyfan, MANAGER, Welcome back, Ayman Alkotyfan!, manager
- Sidebar:** Dashboard, Voice Reports, Database, Members, Invite Member, Workspace, Profile
- Main Content:**
  - Voice-Driven Analytics:** Upload audio and get instant insights with AI-powered charts.
  - Create New Voice Report:** Upload audio to generate SQL queries and visualizations automatically.
  - Metrics:** Total Reports: 0, Completed: 0, Total Rows: 0.
  - No Reports Yet:** Upload your first audio file to generate insights, Create First Report button.
- User Profile:** Ayman Alkotyfan, manager, Logout

Figure 42 : Dashboard Manager

## • Workspace settings

The screenshot shows the 'Workspace Settings' page of the BI Voice application. At the top, it displays 'Welcome, Ayman Alkotyfan' and 'MANAGER'. On the left sidebar, there are several navigation items: Dashboard, Voice Reports, Database, Members, Invite Member, Workspace (selected), and Profile. The main content area is titled 'Workspace Settings' with the subtitle 'Manage your workspace configuration'. It contains two sections: 'Workspace Information' and 'Workspace Owner'. In the 'Workspace Information' section, there is a field for 'Workspace Name' containing 'My Awesome Workspace' and a larger 'Description (Optional)' field with placeholder text 'Describe your workspace and its purpose...'. Below these fields is a note: 'This workspace is owned by you. Only workspace owners can update these settings, invite members, and manage roles.' At the bottom right of this section is a blue 'Save Changes' button. To the right of the main content area, there are three small circular icons with icons inside: a gear, a person, and a user.

Figure 43 : Workspace Settings

## • Profile settings

The screenshot shows the 'Profile Settings' page of the BI Voice application. At the top, it displays 'Welcome, Ayman Alkotyfan' and 'MANAGER'. On the left sidebar, there are several navigation items: Dashboard, Voice Reports, Database, Members, Invite Member, Workspace, and Profile (selected). The main content area is titled 'Profile Settings' with the subtitle 'Manage your account information'. It contains two sections: 'Profile Information' and 'Account Information'. In the 'Profile Information' section, there are fields for 'Full Name' (containing 'John Doe') and 'Email Address' (containing 'you@example.com'). At the bottom right of this section is a blue 'Save Changes' button. In the 'Account Information' section, there are three items: 'Role' (set to 'manager'), 'Email Status' (set to 'Verified'), and 'Account Status' (set to 'Active'). To the right of the main content area, there are three small circular icons with icons inside: a gear, a person, and a user.

Figure 44 : Profile settings

## • Detective account

The screenshot shows the 'Account Information' section with fields for Role (set to 'manager'), Email Status (set to 'Verified'), and Account Status (set to 'Active'). Below this is the 'Danger Zone' section, which contains a warning about deactivating the account. A red button labeled 'Deactivate Account' is prominently displayed.

Figure 45 : Detective account interface

## • invitation member

The screenshot shows the 'Invite Team Member' form. It includes fields for 'Email Address' (containing 'colleague@example.com') and 'Role' (set to 'Analyst - A'). A tooltip provides details about the Analyst role. Below the form is an 'Invitation Process' section with four steps: sending an email, a link expiring in 48 hours, users needing to sign up if they don't have an account, and automatic workspace joining upon acceptance.

Figure 46 : invitation member interface

## • Join workspace in gmail

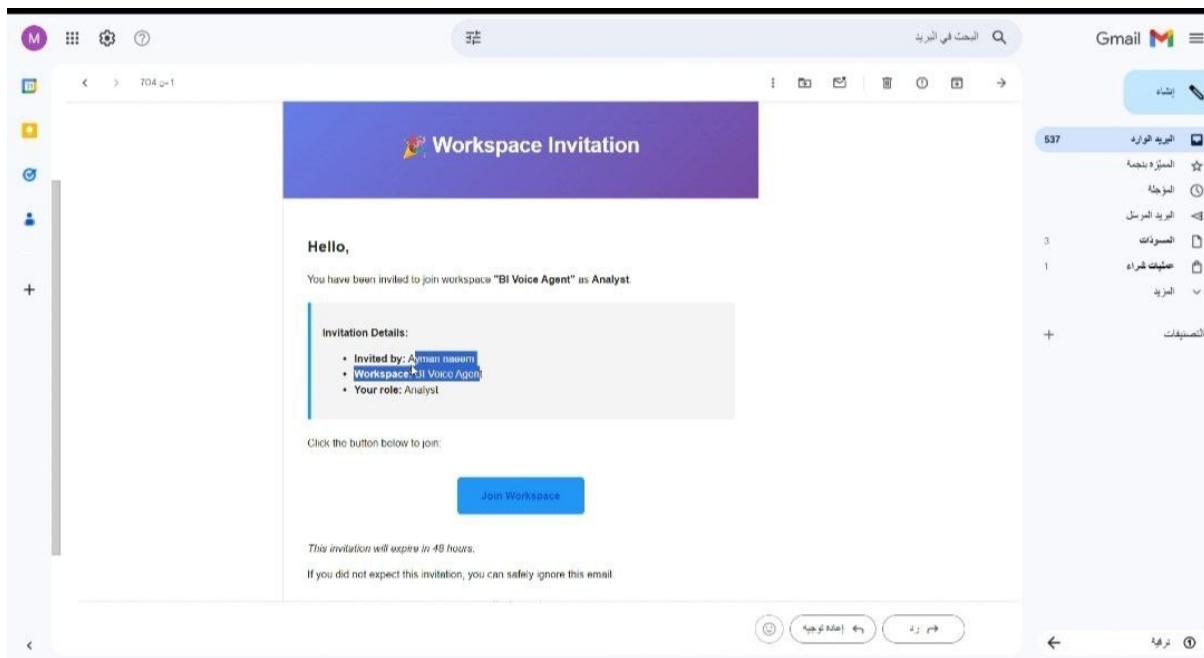


Figure 47 : join workspace in gmail

## • Dashboard analysis

The dashboard has a sidebar with the following navigation options:

- Dashboard (selected)
- SQL Editor
- Members
- Profile

The main content area is titled 'SQL Analysis Hub' and displays the following information:

Welcome back, Massa nasri ANALYST

**SQL Analysis Hub**  
Review and optimize voice-generated SQL queries

**Open SQL Editor**  
Edit, optimize, and execute SQL queries for all workspace reports

**Total Reports: 0**

**Avg. Query Time: 0ms**

**Total Rows: 0**

No Reports Available  
Waiting for managers to create voice reports

User profile information on the left sidebar:

Massa nasri  
analyst

Logout

Figure 48 : dashboard Analysis

## • Member settings

The screenshot shows the 'Workspace Members' section of the BI Voice application. The left sidebar includes links for Dashboard, Voice Reports, Database, Members (selected), Invite Member, Workspace, and Profile. The main area displays two members: Ayman naeem (You) with the role Manager and status Active, and Massa nasri with the role Analyst and status Suspended. A modal window titled 'Invite Member' is visible in the top right corner.

Member	Role	Status	Actions
A Ayman naeem (You) aymanik331@gmail.com	Manager	Active	
M Massa nasri massa.nasri03@gmail.com	Analyst	Suspended	

Figure 49 : Member Settings

## • Suspend member

The screenshot shows the 'Workspace Members' section with a modal dialog titled 'Unsuspend Member'. The dialog asks, 'Are you sure you want to unsuspend Massa nasri? They will regain access to the workspace.' It contains 'Cancel' and 'Unsuspend' buttons. The background workspace members list shows Ayman naeem (You) as Active and Massa nasri as Suspended.

Figure 50 : Suspend Member interface

- **Change member role**

The screenshot shows the BI Voice platform's workspace members section. A modal window titled "Change Member Role" is open, prompting the user to change the role for "Massa nasri". The "New Role" dropdown menu is set to "Analyst". Below the modal, there are "Cancel" and "Update Role" buttons. The background shows a list of members: Ayman naem (You) with status "Active" and Massa nasri with status "Active". The sidebar includes links for Dashboard, Voice Reports, Database, Members (selected), Invite Member, Workspace, Profile, and Logout. The top navigation bar shows "Welcome, Ayman naem" and "MANAGER".

Figure 51 : change member role

- **Dashboard Executive**

The screenshot shows the BI Voice platform's executive dashboard. The main title is "Executive Dashboard" with the subtitle "Comprehensive analytics and insights at a glance". It features three metrics: "Total Reports 0", "Completed 0", and "Total Rows 0". Below these metrics, a large yellow exclamation mark icon is displayed with the text "Dashboard Not Available" and the message "No dashboard available yet. Reports need to be created first.". A green button labeled "View Analytics Page" is present. The sidebar includes links for Dashboard (selected), Analytics, Members, and Profile. The top navigation bar shows "Welcome, Massa nasri" and "EXECUTIVE". The bottom right corner displays the URL "localhost:5173/dashboard/analytics".

Figure 52 : Dashboard Executive

## • Upload database

The screenshot shows the BI Voice AI-Powered Analytics platform. The top navigation bar includes 'BI Voice' logo, 'Welcome, Ayman naeem', 'MANAGER' status, and a success message: 'Database uploaded successfully and ETL processing started'. The left sidebar has links for 'Dashboard', 'Voice Reports', 'Database \*' (selected), 'Members', 'Invite Member', 'Workspace', and 'Profile'. The main content area is titled 'Database Management' with the sub-section 'Database Information'. It displays details: 'Filename: states\_all.csv', 'File Size: 287.47 KB', 'Rows: -', 'Columns: -', 'Upload Date: 29-11-29:40 2026/1/29', and 'Status: Processing'. Below this is a 'Processing Your Data' section with a sunburst icon and the text: 'Your database is being processed through the ETL pipeline. This may take a few moments.' A vertical sidebar on the right contains icons for user management.

Figure 53 : Upload database

## • Upload voice

This screenshot is identical to Figure 53, showing the BI Voice platform's Database Management interface. It displays the same successful upload message, sidebar menu, and processing status for the 'states\_all.csv' file. The 'Processing Your Data' section also indicates the database is being processed through the ETL pipeline.

Figure 54 : Upload Voice

- **SQL editor**

The screenshot shows the BI Voice AI-Powered Analytics platform. On the left, there's a sidebar with 'BI Voice' logo, 'Dashboard', 'SQL Editor' (selected), 'Members', and 'Profile'. The main area has a 'Welcome, Massa nasri ANALYST' message. The 'SQL Editor' section title is 'SQL Editor' with a subtitle 'Edit and optimize SQL queries for voice reports'. It shows 'All Reports' with a card for 'Report #4 completed' (Show average total revenue by year). The 'Report #4' card contains the SQL query:

```

SELECT * FROM (SELECT YEAR, if(isNull(avgIf(toFloat64OrNull(TOTAL_REVENU), toFloat64OrNull(TOTAL_REVENUE) IS NOT NULL)), 0, avgIf(toFloat64OrNull(TOTAL_REVENU), toFloat64OrNull(TOTAL_REVENUE) IS NOT NULL)) AS avg_total_revenue FROM etl.states_all_csv WHERE toFloat64OrNull(TOTAL_REVENU) IS NOT NULL GROUP BY YEAR) WHERE avg_total_revenue != 0;

```

Below the query are 'Save Changes' and 'Execute' buttons. The 'Execution Results' section shows 12 rows and 236ms time. There are also 'Chart' and 'Line' options.

Figure 55 : Edit SQL

## 6.4 Summary

This chapter presented the practical implementation of the BI Voice Agent system, detailing the technologies and tools used across all layers of the application. The system combines modern web technologies, advanced AI models, distributed data processing, and scalable infrastructure to deliver an intelligent voice-based business intelligence platform.

# **Chapter 9**

## **Report Overview**

## ***9.1 Introduction***

This chapter presents an overview of the entire report and explains the purpose and content of each chapter. The main goal of this chapter is to guide the reader through the logical organization of the report and clarify how each chapter contributes to the development, analysis, and implementation of the proposed AI-based BI Voice Agent system. The chapter ensures a clear understanding of the report flow, starting from problem identification and theoretical background, moving through system analysis and design, and ending with implementation and evaluation.

## ***9.2 Report Structure and Purposes***

- Chapter 1: Introduction

This chapter introduces the project background and motivation, defines the problem statement addressed by the BI Voice Agent system, and outlines the project objectives. It also provides a general overview of the proposed solution, highlighting the role of artificial intelligence in enabling voice-based business intelligence analysis, and presents the structure of the report.

- Chapter 2: Fundamental Concepts and Literature Review

This chapter discusses the fundamental concepts related to the project, including Business Intelligence (BI), voice processing systems, speech-to-text technologies, natural language processing (NLP), and data analytics. It also reviews related studies and existing systems that combine AI, voice interfaces, and BI tools, providing a comparative analysis and identifying gaps that the proposed system aims to address.

- Chapter 3: Project Management

This chapter focuses on the project management aspects of the BI Voice Agent. It includes the project charter, scope of work (SOW), project timeline illustrated through a Gantt chart, and risk management analysis. This chapter ensures that the project is planned, monitored, and executed in a structured and controlled manner.

- Chapter 4: System Analysis

This chapter presents the system analysis phase, starting with the overall project timeline and followed by the Software Requirements Specification (SRS). It details functional and non-functional requirements, use case descriptions, initial test cases, and the initial Requirement Traceability Matrix (RTM), ensuring a clear and comprehensive understanding of system requirements.

- Chapter 5: System Design

This chapter describes the system design of the BI Voice Agent in detail. It includes the overall system architecture, data flow between components, and the design of core modules such as voice input processing, AI reasoning, database interaction, and visualization integration. This chapter serves as a blueprint for implementing the system.

- Chapter 6: Practical Implementation

This chapter covers the practical implementation of the system, including the tools, frameworks, and technologies used. It explains the implementation of AI components (such as speech-to-text, NLP processing, and SQL generation), system interfaces, and integration with databases and visualization tools. It also presents test execution results and the final Requirement Traceability Matrix (RTM),

demonstrating the consistency between requirements and implementation.

### ***8.3 Summary***

This chapter provides a clear guide to understanding the organization of the report and the role of each chapter in documenting the development of the BI Voice Agent system. By following this structured approach, the report ensures a logical progression from conceptual foundations and system analysis to design, implementation, and evaluation, resulting in a comprehensive and well-documented project.

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