Contents

1 Informal Description

1.1 Context

Urban green areas such as parks, public gardens, tree-lined streets, and small urban forests play a crucial role in improving the quality of life of citizens. They contribute to reducing air and noise pollution, mitigating urban heat islands, supporting biodiversity, and providing spaces for social interaction and well-being.

Despite their importance, many municipalities struggle to manage and maintain these green areas effectively. Maintenance activities are often reactive rather than preventive, relying on manual inspections, citizen complaints, or sporadic interventions. As a result, green areas may become degraded, unsafe, or underutilized, while public administrations face increasing costs and limited resources.

1.2 Stakeholders' Needs

The primary stakeholders involved in the management of urban green areas include:

- **Local Administration:** Municipalities need effective tools to monitor the condition of green areas, prioritize maintenance interventions, and allocate resources efficiently. They also need to justify decisions to citizens and policymakers, ensuring transparency and compliance with environmental regulations.
- **Citizens:** Citizens expect clean, safe, and accessible green spaces that enhance their quality of life. They want to be informed about the state of public spaces, to report issues easily, and to see timely responses from the administration.
- **Environmental Experts:** Botanists, environmental consultants, and maintenance staff need accurate and up-to-date data about vegetation health, soil conditions, and environmental stress factors to plan appropriate interventions.

1.3 Problem Description

The current management of urban green areas is often fragmented and inefficient. Data related to vegetation health, maintenance history, environmental conditions, and citizen feedback are scattered across different systems or not collected at all. This leads to delayed interventions, higher long-term costs, and dissatisfaction among citizens.

Moreover, the lack of predictive capabilities prevents administrations from anticipating issues such as plant diseases, drought stress, or degradation of public spaces. Decisions are frequently based on limited information and subjective judgment rather than on comprehensive and continuously updated data.

1.4 Why a Computer-based System?

A computer-based system enhanced with AI techniques represents a suitable solution to address these challenges. Such a system can integrate heterogeneous data sources, from environmental sensors to citizen reports, analyze them and provide actionable insights to decision-makers.

Artificial intelligence can support:

- Continuous monitoring of urban green areas.
- Early detection of potential problems.
- Prioritization of interventions based on risk, impact, and available resources.
- Improved communication between citizens and local administrations.
- Data-driven decision-making to optimize maintenance strategies and resource allocation.

1.5 Expected Features of the System

The proposed system should include the following key features:

1. **Urban Green Areas Dashboard:** A centralized interface providing an overview of all green areas, including their location, condition, and maintenance status.
2. **Data Collection and Integration:** The system should collect and integrate data from multiple sources, such as environmental sensors, external datasets, and citizen reports.
3. **AI-based Analysis and Prediction:** AI models should analyze historical and real-time data to detect anomalies, predict future issues, and support maintenance planning.
4. **Citizen Interaction and Reporting:** Citizens should be able to report issues and receive feedback on planned or completed interventions.
5. **Decision Support for Administrations:** The system should support local administrations in prioritizing actions, estimating costs, and evaluating the impact of different strategies.

1.6 Conclusion

The proposed system addresses a relevant and timely problem faced by many public administrations. By leveraging artificial intelligence within a well-defined public-sector context, the system aims to improve environmental sustainability, operational efficiency, and citizens' quality of life.

2 Goal-oriented Analysis

2.1 Requirements Elicitation

The elicitation process has been conducted by identifying the main stakeholders involved in the context of urban green area management and by analyzing their needs, expectations, and constraints.

2.1.1 Citizens' Requirements

Their requirements include:

- **Access to Information:** Citizens should be able to access clear and updated information about the condition of public green areas, including ongoing or planned maintenance activities.
- **Issue Reporting:** Citizens should be able to report problems related to urban green areas through a simple and accessible interface.
- **Feedback and Transparency:** Citizens should receive feedback about the status of their reports and be informed when an intervention is planned or completed.
- **Usability and Accessibility:** The system should be easy to use and accessible to citizens with different levels of digital literacy.

2.1.2 Local Administration Requirements

Their requirements include:

- **Centralized Monitoring:** Administrations should be able to monitor all urban green areas through a centralized dashboard.
- **Prioritization of Interventions:** Administrations should be supported in prioritizing maintenance actions based on urgency, environmental impact, and available resources.
- **Decision Support:** The system should provide decision-support functionalities to assist administrators in planning short-term and long-term maintenance strategies.
- **Accountability and Reporting:** Administrations should be able to generate reports to justify decisions and resource allocation to policymakers and funding bodies.

2.1.3 Environmental Experts Requirements

Their requirements include:

- **Accurate Environmental Data:** Experts should have access to reliable data regarding vegetation health, soil conditions, and environmental stress factors.

- **Predictive Insights:** The system should support experts by identifying early signs of degradation, diseases, or other risks affecting green areas.
- **Operational Support:** Maintenance staff should be supported in scheduling and coordinating interventions efficiently.

2.1.4 System Requirements

From a system perspective, the following requirements emerge:

- **Data Integration:** The system should integrate heterogeneous data sources, including sensor data, external datasets, historical maintenance records, and citizen reports.
- **AI-based Analysis:** The system should employ AI techniques to analyze collected data and generate insights useful for monitoring and prediction.
- **Scalability:** The system should be able to scale to support different city sizes and increasing volumes of data.
- **Interoperability:** The system should be able to interoperate with existing information systems used by public administrations.

2.1.5 Non-functional Requirements

Several non-functional requirements have been identified:

- **Security and Privacy:** Sensitive data, especially citizen-related data, should be protected according to applicable data protection regulations.
- **Reliability:** The system should provide accurate and reliable information to avoid incorrect or misleading decisions.
- **Explainability:** AI-generated insights should be understandable by human decision-makers to support trust and accountability.

2.2 Goal Modeling Overview

The goal-oriented analysis is conducted using the *KAOS Approach*, which allows modeling stakeholder intentions and systematically refining them into requirements.

2.3 Abstract Goals

The following high-level strategic goals have been identified:

1. **(G1) Improve Urban Green Areas Quality:** Urban green areas should be maintained in a healthy, safe, and accessible condition.
2. **(G2) Support Sustainable Urban Development:** Green areas should contribute to environmental sustainability and citizens' well-being.
3. **(G3) Improve Decision-making in Public Administration:** Local administrations should make informed and timely decisions regarding maintenance and planning.

2.4 Goal Refinements

For each abstract goal, refinements have been made to break them down into more specific sub-goals.

2.4.1 Refinement of G1: Improve Urban Green Areas Quality

G1 can be refined into the following sub-goals:

1. **(G1.1) Monitor the Condition of Urban Green Areas:** The condition of green areas should be continuously monitored.
2. **(G1.2) Detect Degradation and Risks Early:** Potential issues should be identified before they lead to serious degradation.

2.4.2 Refinement of G2: Support Sustainable Urban Development

G2 can be refined into the following sub-goals:

1. **(G2.1) Reduce Environmental Impact:** Maintenance strategies should minimize negative environmental effects.
2. **(G2.2) Increase Citizens' Quality of Life:** Green areas should promote social interaction, safety, and well-being.

2.4.3 Refinement of G3: Improve Decision-making in Public Administration

G3 can be refined into the following sub-goals:

1. **(G3.1) Provide Data-driven Insights:** Decisions should be supported by data analysis rather than intuition alone.
2. **(G3.2) Optimize Resource Allocation:** Financial and human resources should be used efficiently.

2.4.4 Requirements

Some refined goals are assigned to the software system and thus become requirements, such as:

1. **(R1) Provide a Monitoring Dashboard:** The system shall provide a dashboard displaying the condition of urban green areas.
2. **(R2) Analyze Data Using AI Techniques:** The system shall analyze integrated data to detect anomalies and predict risks.
3. **(R3) Support Intervention Prioritization:** The system shall support the prioritization of maintenance interventions.
4. **(R4) Enable Citizen Reporting:** The system shall allow citizens to submit reports regarding green area issues.

2.4.5 Obstacles

Several potential obstacles emerge during goal analysis:

- **Low Data Quality:** Incomplete, outdated, or inaccurate data can compromise the effectiveness of AI models, reducing the reliability of monitoring activities, risk detection, and data-driven insights.
- **Privacy Constraints:** The need to protect citizens' personal data may limit data availability and sharing, affecting the system's ability to provide detailed analytics and support evidence-based decision-making.

2.5 KAOS Diagram

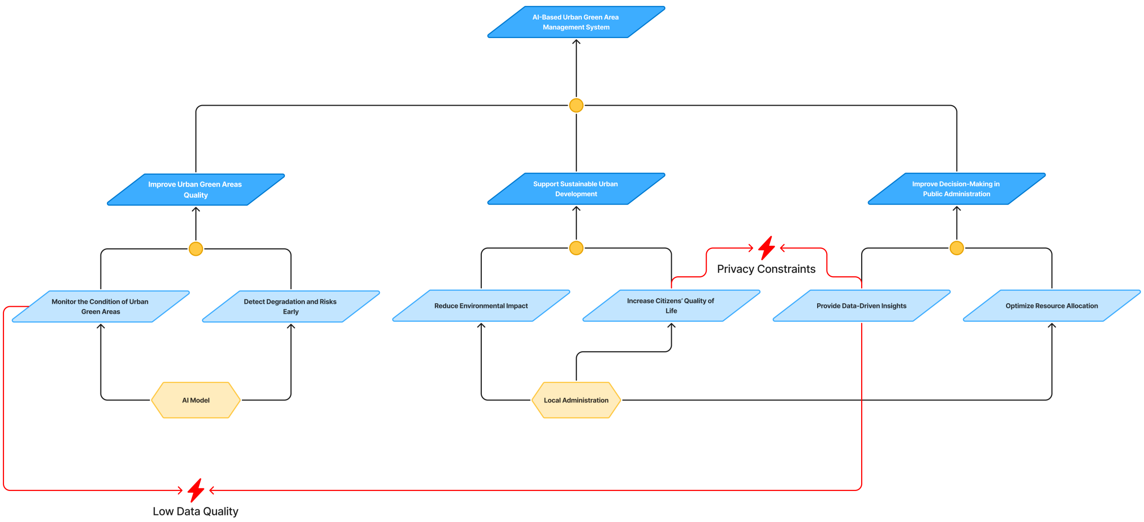

Figure 1: KAOS Diagram

3 Problem Frames

3.1 Context

The context of the system includes multiple interacting domains:

- **Citizens:** Who interact with the system to access information and report issues.
- **Local Administration:** Responsible for decision-making and coordination.
- **Environmental Experts and Maintenance Staff:** Who rely on system outputs to plan and execute interventions.
- **Urban Environment:** Representing the physical green areas being monitored.
- **External Data Sources:** Such as environmental sensors or datasets.
- **AI-based Urban Green Areas Management System:** Which acts as the machine.

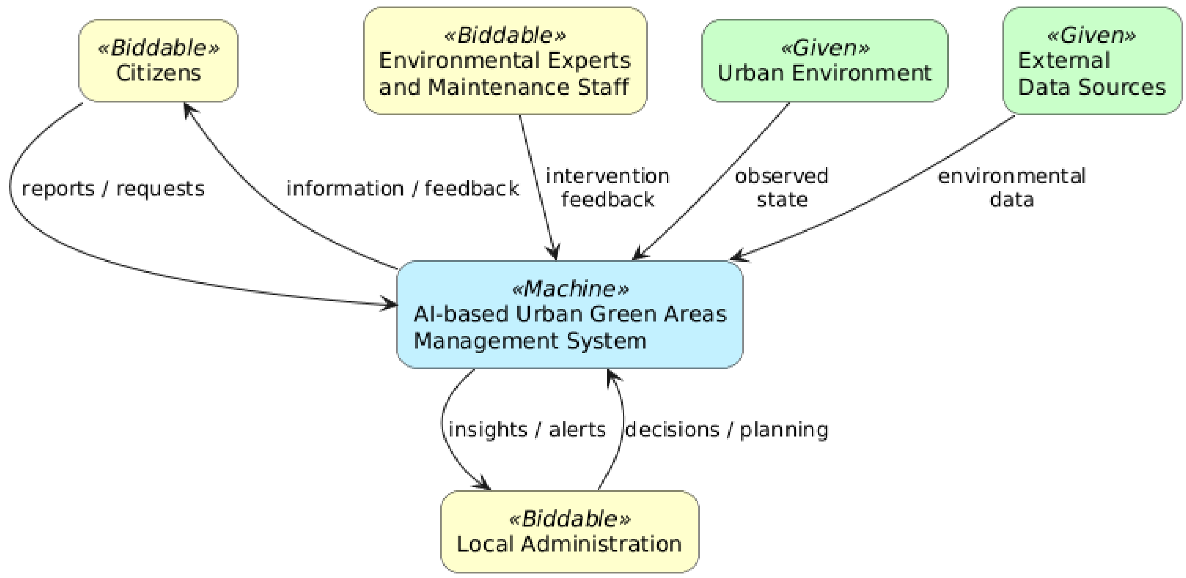

Figure 2: Context Diagram

3.2 Problem Frame

The main problem addressed by the system is the inefficient and fragmented management of urban green areas:

- The *Urban Environment* evolves independently and may degrade over time.
- *Citizens* observe issues but lack structured communication channels.
- The *Local Administration* needs reliable and timely information to intervene.
- The system observes data from the environment and stakeholders, processes it, and provides actionable information.

The shared phenomena include:

- Reports submitted by citizens.
- Environmental data collected from sensors or datasets.
- Maintenance decisions issued by the administration.
- Notifications and feedback provided by the system.

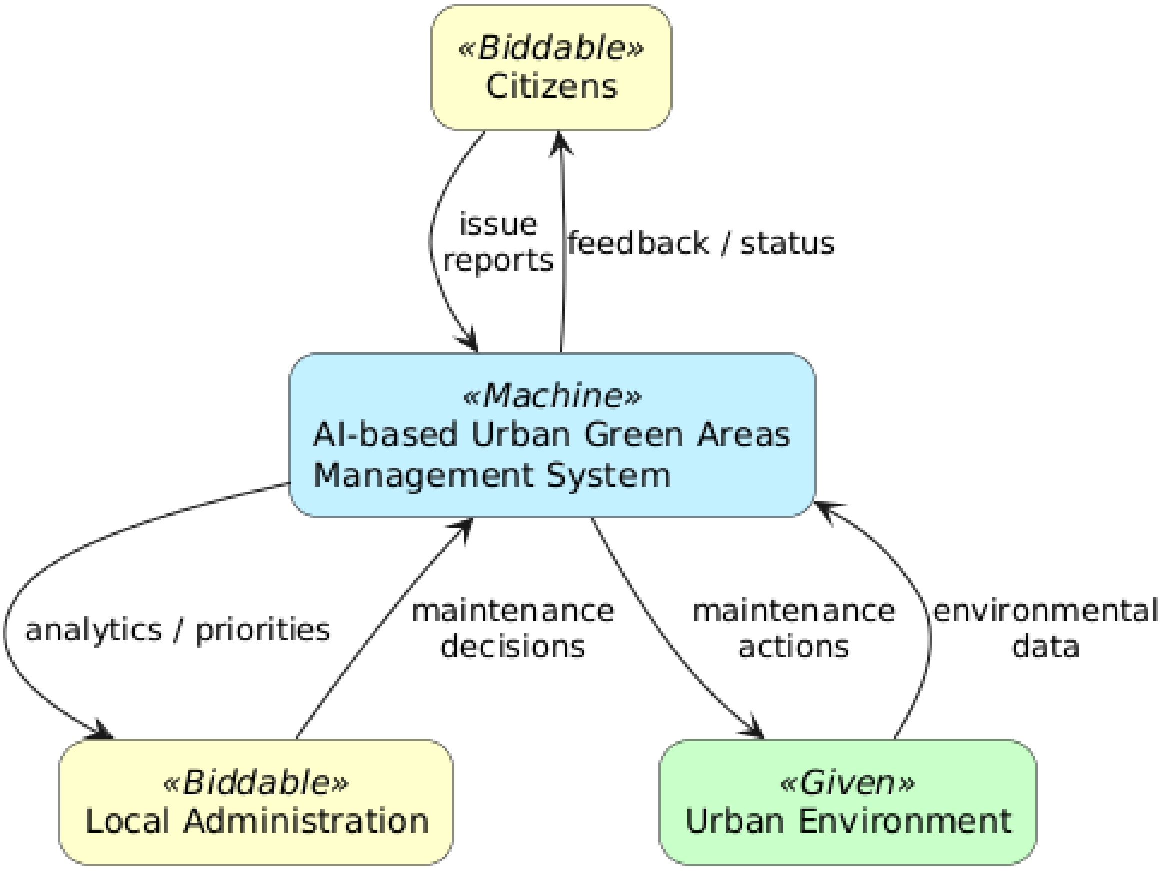

Figure 3: Problem Frame Diagram

3.2.1 Citizen Problem Frame

This problem frame focuses on the interaction between *Citizens* and the system. Citizens want to:

- Access information about the condition of urban green areas;
- Report issues related to safety or maintenance;
- Receive feedback about reported problems.

> **Domains:**
>
> - *Management System* (machine)
> - *Citizen* (biddable)

Correctness Argument:

- *Citizens* can successfully submit reports through the system.
- Submitted reports are correctly recorded and associated with the corresponding green area.
- *Citizens* can access updated information and receive feedback on the status of interventions.

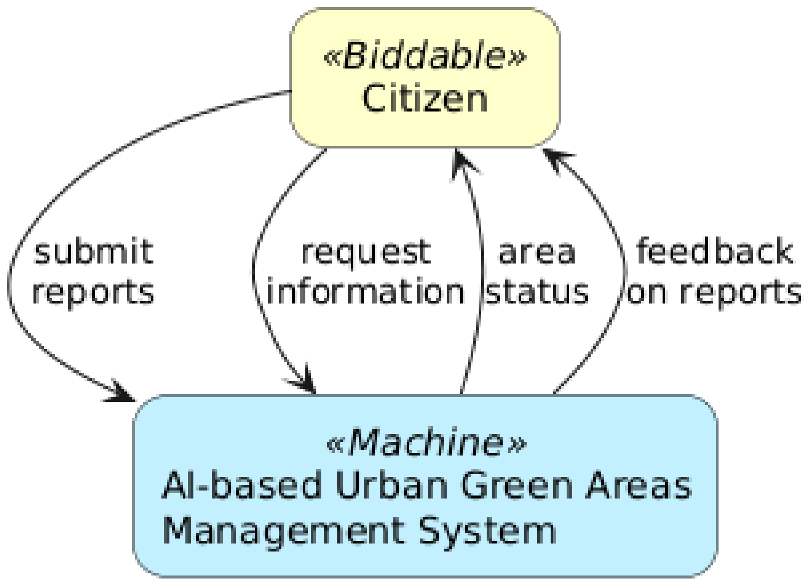

Figure 4: Citizen Problem Frame Diagram

3.2.2 Local Administration Problem Frame

This problem frame addresses the needs of the *Local Administration*, which must plan and prioritize maintenance activities.

> **Domains:**
>
> - *Management System* (machine)
> - *Urban Environment* (given)
> - *Local Administration* (biddable)

Correctness Argument:

- *Administrators* can access a comprehensive overview of urban green areas.
- The system supports prioritization of interventions based on data and identified risks.
- Decisions taken using the system are traceable and justifiable.

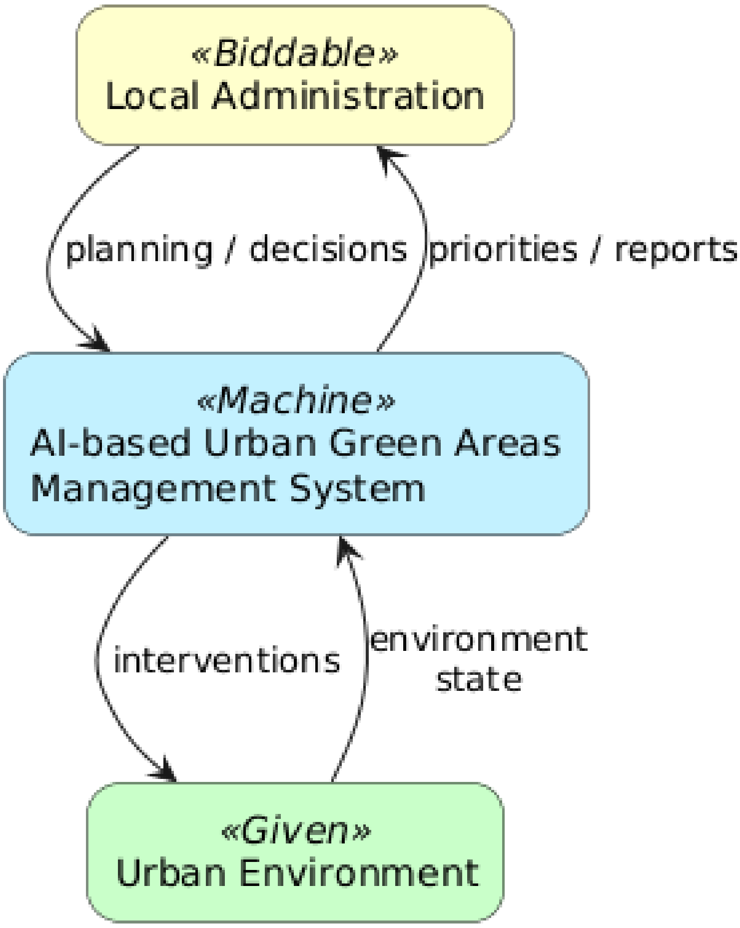

Figure 5: Local Administration Problem Frame Diagram

3.3 Environmental Data Management Problem Frame

This frame focuses on the collection, storage, and management of environmental data related to urban green areas.

> **Domains:**
>
> - *Management System* (machine)
> - *Urban Environment* (given)
> - *External Data Sources* (given)

Correctness Argument:

- Environmental data are accurately collected from various sources.
- Data accurately reflect the state of the *Urban Environment*.
- Data are made available to other system components in a reliable manner.

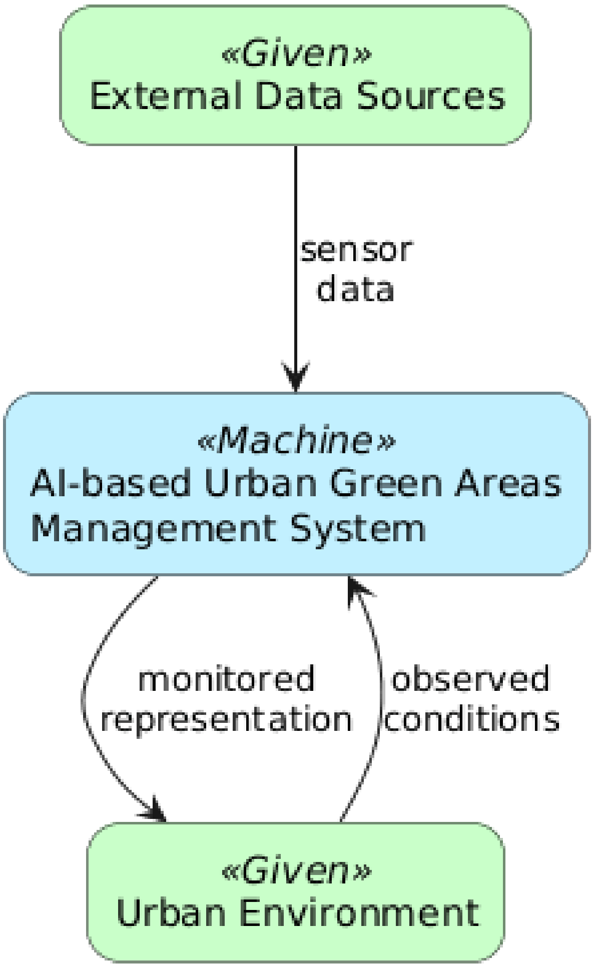

Figure 6: Environmental Data Management Problem Frame Diagram

3.3.1 AI Analysis Problem Frame

This problem frame describes the AI-based analysis of collected data to generate insights for decision-making.

> **Domains:**
>
> - *Management System* (machine)
> - *Environmental Data* (given)

Correctness Argument:

- It analyzes available data to identify anomalies and potential risks.
- Predictions and insights are consistent with observed data.
- The system presents AI outputs in a way understandable by human decision-makers.

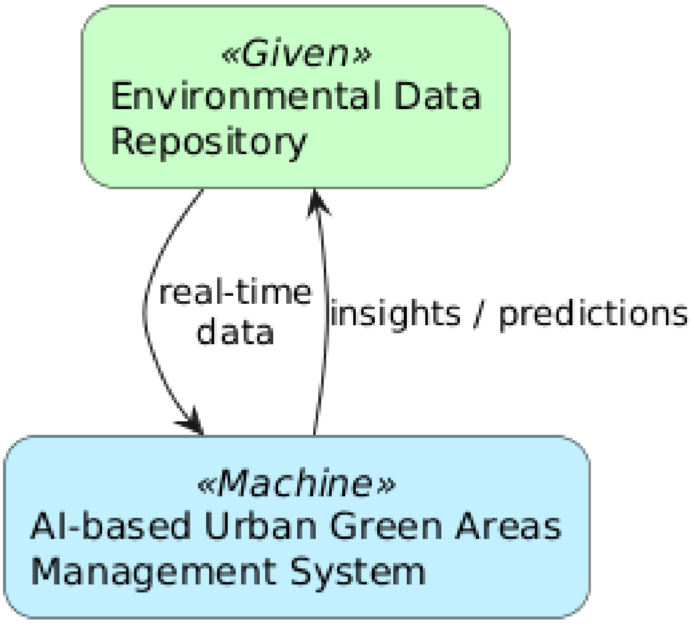

Figure 7: AI Analysis Problem Frame Diagram

3.4 Notification and Feedback Problem Frame

This frame addresses the notification mechanism to inform stakeholders about reported issues and planned interventions.

> **Domains:**
>
> - *Management System* (machine)

> - *Citizens* (biddable)
> - *Local Administration* (biddable)

Correctness Argument:

- Stakeholders receive timely updates regarding reported issues and interventions.
- Notifications cease when no longer relevant.
- Information provided is accurate and consistent with system data.

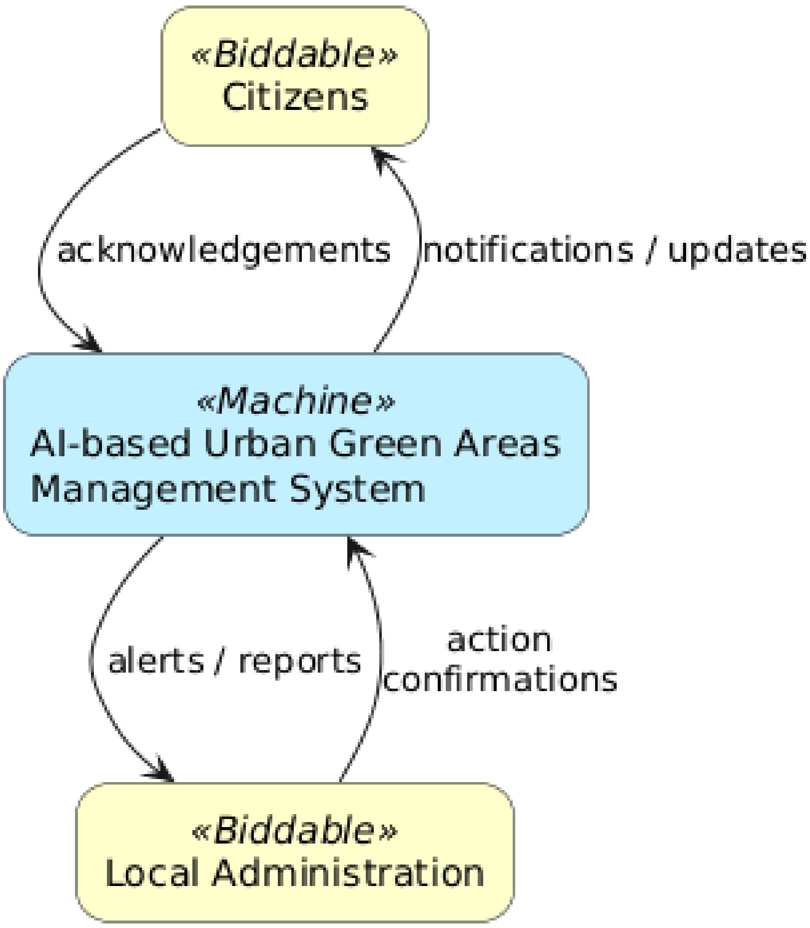

Figure 8: Notification and Feedback Problem Frame Diagram

3.5 UML Diagrams

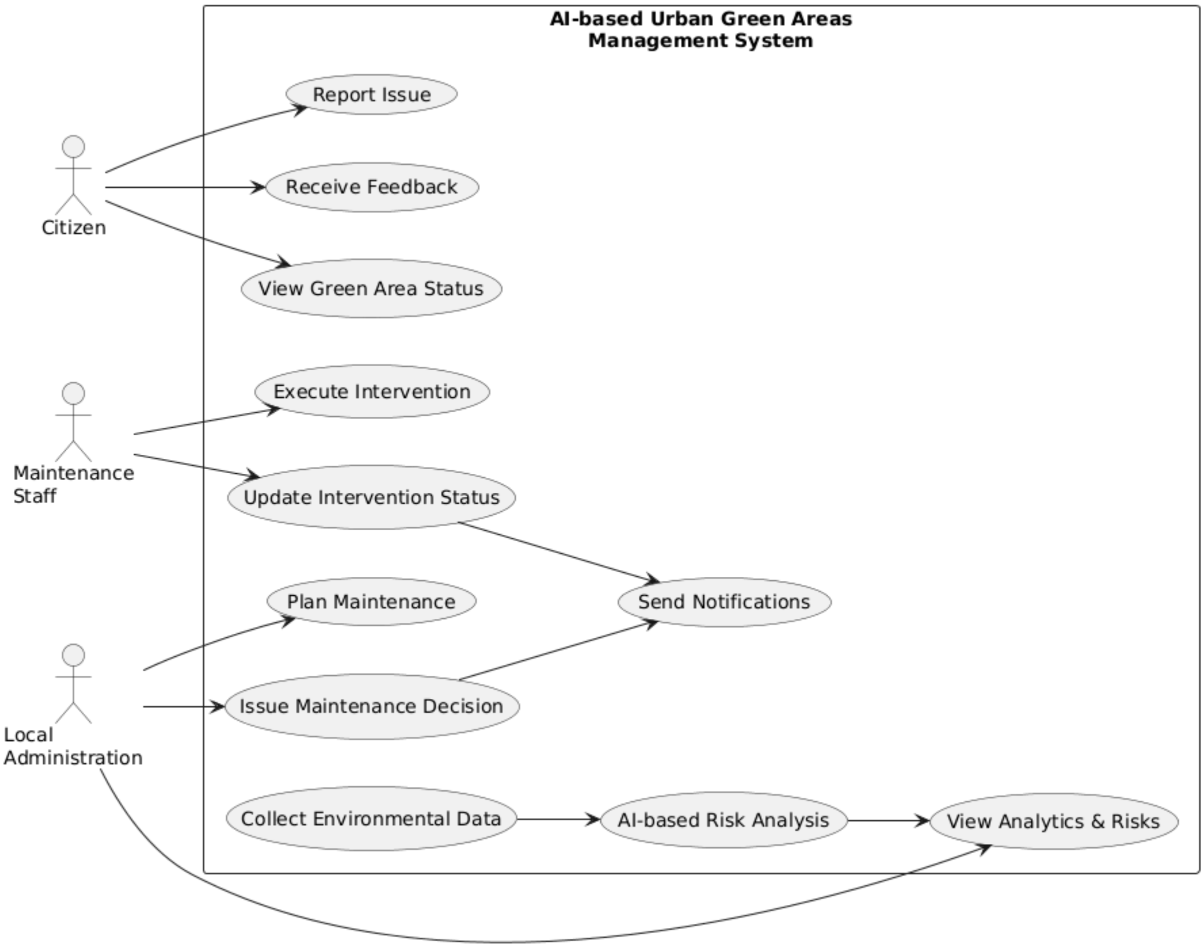

Figure 9: Use-case Diagram

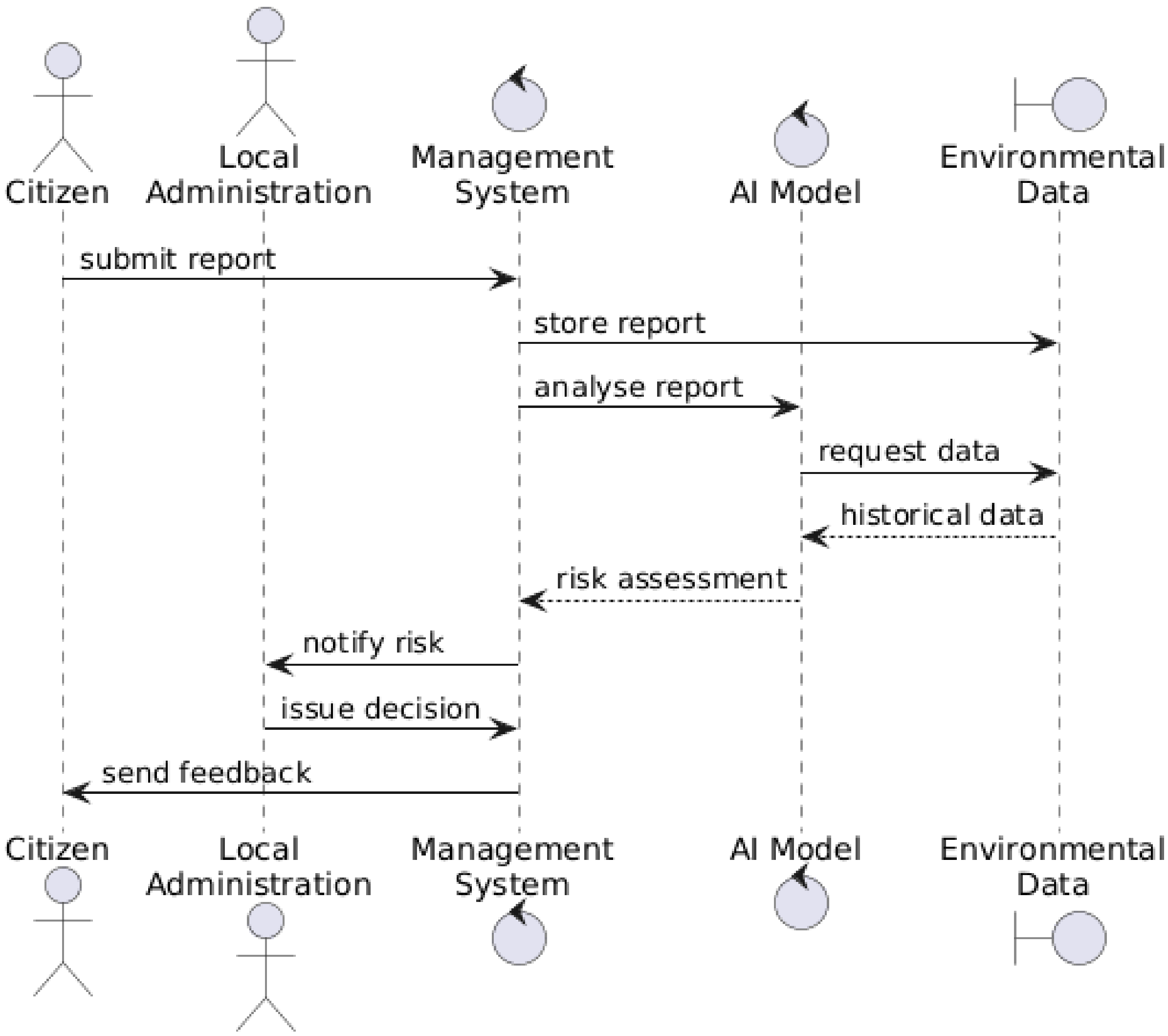

Figure 10: Sequence Diagram

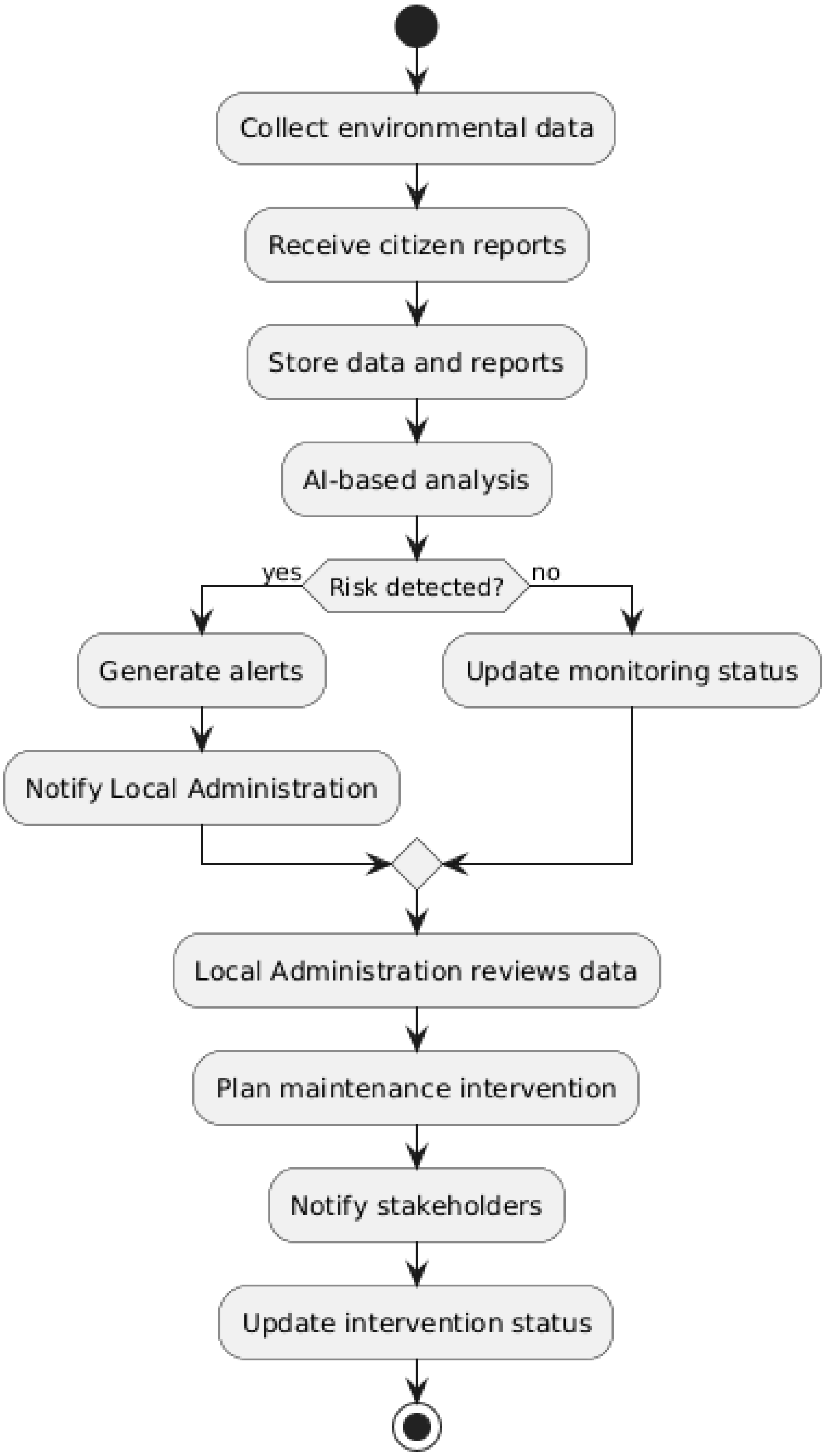

Figure 11: Activity Diagram

4 Feasibility Analysis

4.1 Technical Feasibility

The technical feasibility analysis evaluates whether the proposed system can be implemented using existing technologies and within the constraints of the public-sector environment.

4.1.1 Data Collection

From a technical perspective, the collection and management of data related to urban green areas are feasible:

- Environmental data can be obtained from existing sources such as environmental sensors, public datasets, satellite imagery, and historical maintenance records.
- Citizen-generated data can be collected through web or mobile interfaces.
- Relational or hybrid databases can be used to store structured information about green areas, reports, and interventions.

4.1.2 AI-based Analysis

The use of AI techniques for monitoring and prediction is technically feasible:

- Machine learning models can be employed to detect anomalies, trends, or risks based on historical and real-time data.
- Predictive models can support early detection of degradation or maintenance needs.
- The system does not require fully autonomous decision-making; AI outputs are used as decision-support tools for human administrators.

4.1.3 Core Management System

The core system responsible for data integration, analysis, and interaction with stakeholders is technically feasible:

- Standard web-based architectures can support dashboards, reporting tools, and administrative interfaces.
- Modular design allows separation between data management, AI analysis, and user interaction components.
- The system can be deployed incrementally, starting with basic monitoring features and gradually introducing advanced AI functionalities.

4.1.4 User Accessibility

The development of user interfaces for citizens and administrators is feasible using standard technologies:

- Web-based interfaces ensure accessibility without requiring specialized hardware.
- Mobile-friendly designs support citizen participation and reporting.
- Accessibility guidelines can be applied to ensure inclusiveness.

4.1.5 Security and Privacy Considerations

From a technical standpoint, security and privacy requirements can be addressed using existing solutions:

- Authentication and authorization mechanisms can restrict access to sensitive functionalities.
- Data protection measures can be implemented to comply with relevant regulations.

4.1.6 Risk Analysis

Potential risks include:

- **Data Quality Issues:** Inaccurate or incomplete data could affect AI outputs.
- **Resistance to Adoption:** Stakeholders may be reluctant to trust AI-based recommendations.

4.2 Economic Feasibility

The economic feasibility analysis evaluates costs, benefits, and overall sustainability of the proposed system.

4.2.1 Costs

The main cost categories include:

- **Development Costs:** Costs related to software development, data integration, and AI model training.
- **Infrastructure Costs:** Expenses for servers, cloud services, or data storage.
- **Maintenance Costs:** Ongoing costs for system updates, model retraining, and technical support.
- **Training Costs:** Training public administration staff to use and interpret system outputs.

4.2.2 Economic Assumptions

These values represent total company costs, not net salaries, based on average daily company costs in the Italian market:

- **Senior Project Manager:** 500 € / day
- **Senior MLOps Engineer:** 700 € / day
- **Junior Software Engineer:** 300 € / day

The project is designed to involve resources for a duration of 165 working days (8 months, 33 weeks). Developers should work full-time with a workload of 5 days a week, while management roles are part-time, with a workload of 2 days a week (40%):

- **1 Senior Project Manager:** 500 $\times$ 165 $\times$ 0,4 = 33.000 €
- **1 Senior MLOps Engineer:** 700 $\times$ 165 = 115.500 €
- **1 Junior Software Engineer:** 300 $\times$ 165 = 49.500 €

Other costs was distributed in a timeline of 5 years, this horizon was set to be the payback period for the investment.

4.2.3 Cost Summary Table

Description	**Cost Type**	**Estimated Cost (€)**
System Design and Software Development	One-time	198.000
AI Model Development and Training	One-time	15.000
Data Integration and Migration	One-time	10.000
Staff Training	One-time	20.000
Infrastructure	Annual	10.000
System Maintenance and Updates	Annual	20.000
AI Model Maintenance and Retraining	Annual	5.000
Total Cost Estimation (5-year Horizon)	**Total**	**418.000**

4.2.4 Benefits

The system provides several tangible and intangible benefits:

- **Cost Reduction:** Reduced emergency maintenance interventions, and lower repair costs due to preventive actions.
- **Operational Efficiency:** Reduced administrative workload, and better allocation of maintenance staff.
- **Avoided Long-term Degradation:** Increased lifespan of green infrastructure, and reduced replacement costs.

4.2.5 Benefits Summary Table

Description	Estimated Benefit (€)
Cost Reduction	50.000
Operational Efficiency	100.000
Avoided Long-term Degradation	25.000
Total Benefit Estimation (Every Year)	**175.000**

4.2.6 Return on Investment (ROI)

The ROI is not immediate but accumulates in a 5-year period:

- **Total Costs:** 418.000 €
- **Total Benefits:** 175.000 $\times$ 5 = 875.000 €
- **Net Benefit:** 875.000 − 418.000 = 457.000 €
- **Final Estimation:**

$$\text{ROI} = \frac{\text{Net Benefit}}{\text{Total Costs}} \times 100$$

$$\text{ROI} = \frac{457.000}{418.000} \times 100 \approx 109\%$$

Interpretation:

- The system reaches break-even between the 4th and 5th year.
- After 5 years, the investment yields a positive ROI of approximately 115%.
- Long-term benefits are expected to further increase as the system matures and scales.