Integrative Project Assignment

PI-Sem2-2023-24 - version 3.1

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Abstract

This document comprises the Integrative Project Assignment detailed description of the practical work to be developed within ESOFT, MATCP, MDISC, PPROG, and LAPR2 courses. The work consists of developing an IT solution to support some of the critical tasks of an organization responsible for planning and maintaining green spaces for collective use. This document briefly introduces the business' domain and sub-areas, the functional and non-functional requirements of the solution to be developed, the Integrative Project technical details, and the operating mode, i.e., the work approach.

Table 1: Version register

Version	Description
1.0	First version
1.1	Added Sprint1 and Acceptance Criteria
1.12	Typos and minor errors corrected
1.13	Minor grammar/language errors corrected in US03-AC1; US05-AC1; US06; US08
2.0	Added Sprint2: US09; US10; US11; US12; US13; US14, and Acceptance Criteria
2.1	Updates on US09-US11
2.12	Non-functional requirements concerning data persistence and graphical interfaces were suppressed in current sprint
2.2	Added AC2-AC3 in US13 and US14
3.0	Added Sprint3 USs
3.01 3.02	Typos and minor errors corrected US28 updated with interval and AC2
3.03	Typos and minor errors corrected
3.1	Data structure in US17 corrected, and clarification of Assembly Point vs Signal Point in Section 3.3.2 (US17 and US18)

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1 Integrative Project

In this project, students should analyze, design and implement a computer solution to support the activity of an organization responsible for managing green spaces for collective use in predominantly urban contexts. Students must be organized in teams, and the proof-of-concept to be developed covers several critical aspects concerning the planning and maintenance of green spaces (such as gardens or parks), namely: multidisciplinary team management; allocation of teams to green spaces; fleet, machines and other equipment management; optimization of irrigation and/or lighting systems; production of statistical indicators that allow measuring the performance of the activity.

Following the good practices learned throughout the degree, and in particular in Software Engineering (ESOFT), Programming Paradigms (PPROG), Computational Mathematics (MATCP), Discrete Mathematics (MDISC) and Laboratory-Project II (LAPR2) courses, this project implies applying an iterative and incremental development process. Therefore, an agile methodology based on SCRUM should be used to manage teamwork in each four-week SPRINT.

The software solution to be developed must be composed of a set of applications in Java that must accomplish the requirements. In order to increase the solution maintainability, and respect good software development practices, the implementation must follow a TDD (Test-Driven Development) approach.

2 Problem Statement: Description

The green spaces for collective use, often called "gardens" and "parks", are fundamental for people's quality of life, especially in urban or semi-urban contexts. Currently, their need, location, and dimensions are stipulated in the general law and are an integral part of Municipal Master Plans. Contact with nature is an essential element for the well-being of the population in general. This contact was natural and obvious until the Industrial Revolution, after which a significant migration of populations from rural to urban areas occurred. According to a 2022 UN report, at the current rate, it is expected that the concentration of the world's population in urban areas will increase from 56% to 68% by the year 2050, which in urban contexts translates into an increase of 2.2 thousand million people. The Portuguese reality does not differ much from the global context.

In democratic and liberal systems, such as the Portuguese, citizens naturally demand the existence of green spaces in both quantity and quality suitable for the size of the population. Therefore, the proper management of these spaces is of great importance.

Green spaces for collective use can vary significantly in dimensions and available amenities. They may range from small landscaped areas, parks with trees and some amenities like benches or playgrounds, to parks with multiple hectares (e.g., in Porto, there are the *Parque da Cidade* - City Park - the *Parque Oriental* - the Oriental Park), wooded areas, lakes, and various facilities and installations.

MusgoSublime (MS) is an organization dedicated to the planning, construction and maintenance of green spaces for collective use in their multiple dimensions, namely: plant material (e.g. flowers, shrubs, trees); urban furniture (e.g. benches, tables, gymnastics equipment); irrigation systems and drinking fountains; lighting systems and the respective power supply; rainwater conduction and drainage systems. In the context of the current project MS will provide the requirements for the proof-of-concept to be developed.

2.1 Green Spaces for Collective Use

The green spaces for collective use managed by MS can significantly vary in size and installed equipment:

- Garden - garden space with or without trees with little or no equipment (may have a basic irrigation system or/and benches);
- Medium-sized park - green space with a few hundred or thousands of square meters with a wooded garden area, it includes some infrastructures such as toilets, drinking fountains, irrigation system, lighting, children's playground (for example, *Quinta do Covelo*, *Jardim d'Arca de Água*);
- Large-sized park - multi-function space with diverse garden spaces, and woods, including varied equipment and services (for example, *Parque da Cidade*).

2.2 Collaborators, tasks, and teams

MS has a wide range of employees who carry out numerous tasks regarding the design and management of green spaces. Some job examples are designer, budget manager, gardener, electrician or bricklayer. Thus, an employee has a main occupation (job) and a set of skills that enables him to take on certain tasks and responsibilities, for example, driving different types of vehicles (e.g. light, or heavy), operating machines such as backhoes or tractors, tree pruning, application of agriculture phytopharmaceuticals.

Tasks are carried out on an occasional or regular basis, in one or more green spaces, for example: tree pruning, installation of an irrigation system, and installation of a lighting system.

Teams are temporary associations of employees who will carry out a determined set of tasks in one or more green spaces. When creating multipurpose teams, the number of members and the set of skills that must be covered are crucial.

2.3 Vehicles, machines, and equipment

Vehicles are needed to carry out the tasks assigned to the teams and to transport machines and equipment. This type of vehicle may be only for passengers or mixed, light or heavy, open box or closed vans or trucks.

As for machines, MS has tractors, backhoe loaders, and rotating machines, lawnmowers, among others. The equipment can be greatly diverse, such as sprayers, lifting platforms, chainsaws, brush cutters, blowers, ladders, cisterns and the various elements that can be attached to tractors, such as disc harrows, weeders, aerators and scarifiers.

2.4 Agenda

The Agenda is a crucial mechanism for planning the week's work. Each entry in the Agenda defines a task (that was previously included in the to-do list). A team will carry out that task in a green space at a certain time interval on a specific date. Comparatively analyzing the Agenda entries and the pending tasks (to-do list) allows you to evaluate the work still to be done, the busyness of the week, and the work performed by a team in a green space at a determined time interval and on a specific date.

2.5 Green Spaces User Portal

The green spaces management aims (within the available budget) to design, build and maintain parks and gardens that meet the requirements of the common citizen who wants to be informed. With this in mind, the objective is to develop a Portal in which parks and garden users can post comments, and report faults and malfunctions of equipment.

2.6 System Users

This system may potentially be used by multiple users, namely:

- Human Resources Manager (HRM) - a person who manages human resources and defines teams based on the needs of ongoing projects and on the employees' skills.
- Vehicle and Equipment Fleet Manager (VFM) – a person who manages the fleet park, the machines, equipment and vehicles, ensuring their good condition and assigning them to the tasks to be carried out.
- Collaborator – a person who is an employee in the organization and carries out design, construction and/or maintenance tasks for green areas, depending on their skills.
- Green Spaces Manager (GSM) - the person responsible for managing the green spaces in charge of the organization.
- Green Spaces User (GSU) - a person who uses the green spaces managed by the organization and who can, through the Portal, make comments or report faults in parks and gardens on the Portal.
- Software Quality Assessment Team Manager (QAM) - a person who manage the Software Quality Assessment Team and its process.

3 Minimal Viable Product (MVP)

The purpose of this project is to develop a Minimal Viable Product iteratively and incrementally; therefore the work is divided into three Sprints:

- Sprint 1 – Weeks 3 to 6 – from 4/March to 7/April
- Sprint 2 – Weeks 7 to 10 – from 8/April to 12/May

- Sprint 3 – Weeks 11 to 14 – from 13/May to 9/June

A description of the PVM is provided for each sprint. Teams must follow the user stories (US) provided and consider their interconnections and respective dependencies and, at the end of each Sprint, each team must be able to meet the specified requirements. Teams must be able to add USs to the backlog, size them appropriately, and distribute them across team members.

3.1 Sprint 1

3.1.1 Teams and Vehicle Fleet Management

This Sprint targets developing the following US (Requirement Engineering and Analysis):

- US01 - As a Human Resources Manager (HRM), I want to register skills that a collaborator may have.
  - AC1: A skill name can't have special characters or digits.
- US02 - As an HRM, I want to register a job that a collaborator needs to have.
  - AC1: A job name can't have special characters or digits.
- US03 - As an HRM, I want to register a collaborator with a job and fundamental characteristics.
  - AC1: name, birth date, admission date, address, contact info (mobile and email), taxpayer number, ID doc type, and respective number should be provided by the HRM. The taxpayer identification number and the citizen card number should be valid.
- US04 - As an HRM, I want to assign one or more skills to a collaborator.
- US05 - As an HRM, I want to generate a team proposal automatically.
  - AC1: The max and minimum team size and the set of skills must be supplied by the HRM, like in the following example:

    `4; 3; <tree pruner; tree pruner; tree pruner; light vehicle licence>`

- US06 - As a VFM, I wish to register a vehicle including Brand, Model, Type, Tare Weight, Gross Weight, Current Km, Register Date, Acquisition Date, and Maintenance/Check-up Frequency (in km).
- US07 - As a VFM, I wish to register a vehicle's maintenance.
- US08 - As a VFM, I want the system to produce a list (report) of vehicles needing maintenance.
  - AC1: The report should have the data concerning the vehicle description (Plate, Brand, Model and Current Kms) and the Checkup related data, like the following example:

Plate	Brand	Model	Curr.Kms	Freq	Last	Next
10-10-QR	Ford	Focus	43124	15000	41152	56152

For Sprint 1 (aka Sprint A), regarding the Requirements Engineering activity:

- teams with 4 or more students enrolled in ESOFT must elaborate all user stories;
- teams with 3 or fewer students enrolled in ESOFT must only elaborate user stories related to "Collaborators, tasks and teams" (i.e. US01 to US05).

3.2 Sprint 2

3.2.1 Teams and Vehicle Fleet Management

The user stories elaborated in Sprint 1, should now follow the Software Engineering process and proceed to Design and Implementation phases.

3.2.2 KPIs and Statistical Analysis

Managing public green spaces efficiently implies considering some KPI (key performance indicator) like: water or energy consumption, most used pieces of equipment, and park users' profile by age, for instance. The best practices concerning Statistical Analysis should be considered in the elaboration of US09 to US11.

- US09 - As a GSM, I want to know the exact costs referring to water consumption of specific green space so that I may manage these expenses efficiently. Therefore, within this US, the aim is to carry out a statistical analysis concerning the water consumption costs in all parks. The "water_consumption.csv" file provide the necessary data to carry out the study. This file records daily water consumption (in m^3) since the day each park opened. The amount paid for water is 0.7 €/m^3, up to a consumption of $1000m^3$/month, with a fee of 15% added for higher consumption levels.

The data file contains records of the following information: "Park Identification", "Year", "Month", "Day", "Consumption". Consider this data in order to obtain the following outcomes:

- Barplot representing monthly water consumption, as a result of the following specifications given by the user: year, time period (StartMonth, EndMonth) and park identification.
- Average of monthly costs related to water consumption, for each park, as a result of the following specifications given by the user: number of parks to be analyzed, and park identification.
- Consider the water consumption of every day that is recorded. The aim is to analyze and compare statistical indicators between the park with the highest and lowest (not null) water consumption. For these two parks, perform the following tasks and compare results:
  - Calculate the mean, median, standard deviation, and the coefficient of skewness;
  - Build relative and absolute frequency tables (classified data), considering 5 classes;
  - For each park, check if the data has outliers, using the outlier definition as values that deviate from the median by more than 1.5 times the interquartile range;
  - Graphically represent data through histograms with 10 and 100 classes.

- US10 - As a GSM, I want to know which piece(s) of equipment is/are used in each day so that I can understand the users' preferences. Consider that the park has several equipment like, for instance, walking trails, picnic area and exercise gymnastics equipment. At the park exit there is an electronic device with a list of all the equipment, in which the user(s) must indicate the equipment they used that day.

  In the file "EquipmentUsed.csv" the choices of 1000 users are recorded. Make a pie chart representing, in percentage, the use of each piece of equipment.

- US11 - As a GSM, I want to be able to collect data from the user portal about the use of the park, so that I may understand the use of the park by different age groups. To analyse the use of the park by age groups, a three-question survey was inserted in the user portal:

Question	**Answer type**
Age range	1 - Child (up to 15 years old) 2 - Adult (between 16 and 65 years old) 3 - Senior (over 65 years old)
Would you recommend the park to others?	Y/N
How many times do you visit the park per month?	Numeric

  The obtained responses are recorded in the "Inquiry.csv" file.

  - Indicate the type of each of the three variables.
  - Indicate the proportion of users from each age group who would recommend the park to others.
  - Create a boxplot for each age group, regarding the monthly frequency of use of the park, and draw the main conclusions obtained from this type of graph.

In the elaboration of the US09 to US11 the following acceptance criteria will be considered:

- Programming Language: Python
- Development environment: Jupyter Notebook
- Work delivery format: A single Jupyter Notebook file, which contains all the work carried out.
- Each US must be composed of: (1) introduction (succinct and objective); (2) code and results, and (3) analysis and interpretation of the results.
- Formulas must be written in LaTeX.
- At the end of the file, you must indicate the contribution (in %) of each member of the group to the development of the work (the sum of all percentages must be 100%).

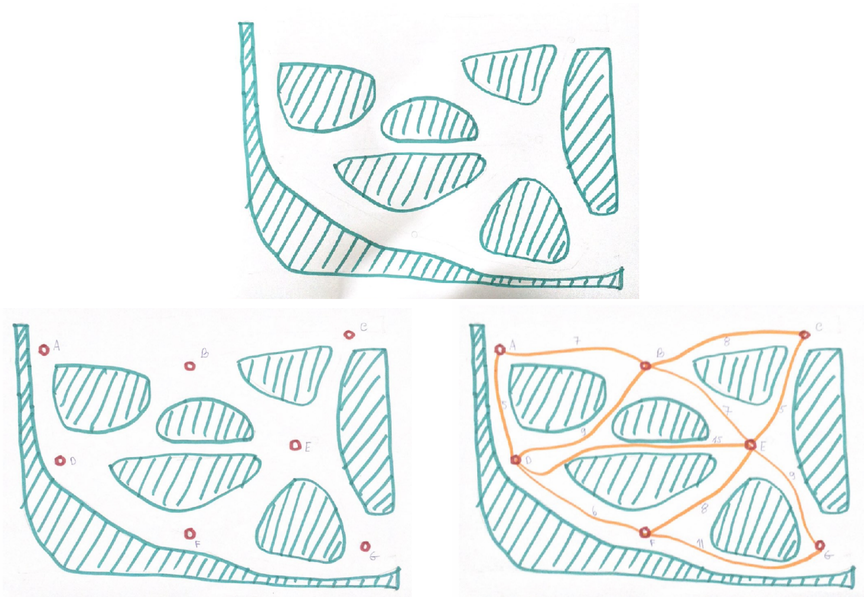

Figure 1: (i) Green Area Survey; (ii) Water Supply Points Forecast; (iii) Route Forecast and Measurement.

3.2.3 Planning and Building Irrigation Systems

Planning and building irrigation systems in green parks are expensive and time consuming tasks. The use of computer systems and namely powerful algorithms can save materials like pipes, reduce the time required for the planning and installation, and allow to create more efficient irrigation systems. This becomes even more relevant when considering the installation of irrigation systems in parks that are already in operation, because periods of construction prevent their normal operation.

In the first phase, a topographic survey is carried out to identify the garden/wooded areas and existing paths in the park. A basic sketch of the result of this phase is shown in Figure 1.i. In the next phase, based on the survey previously carried out, a collaborator specialized in irrigation systems defines the necessary water supply points. As the example shown in the Figure 1.ii. Finally, the routes between each pair of water supply points are identified and measured according to Figure 1.iii.

- US12 - As a GSM, I want to import a .csv file containing lines with:

  ```
  Water Point X; Water Point Y; Distance
  ```

  into a unique data structure.

The set of imported lines describes all possible routes that can be opened to lay pipes between each pair of water points, and their respective installation costs (these could simply refer to the length, or to any other cost parameter).

- US13 - As a GSM, I want to apply an algorithm that returns the routes to be opened and pipes needed to be laid with a minimum accumulated cost, ensuring that all points are adequately supplied.
  - AC1: All implemented procedures must only use primitive operations, and not existing functions in JAVA libraries.
  - AC2: The procedure should return a .csv file with the output subgraph, format (vertice, vertice, edge cost), and the respective total cost. It should also present the visualization of the drawing (using, for example, Graphviz or GraphStream packages) of a given input graph, and the output subgraph.
  - AC3: Work delivery format: a folder with (i) the drawing of the input and output graphs, respectively, for the two garden examples, (ii) the .csv file with the output graph and the respective total cost, and (iii) a .pdf print with only the procedure(s) implemented for solve this problem.

- US14 - As a QAM, I want to run tests for inputs of variable size, to observe the asymptotic behavior of the execution time of the US13 algorithm.
  - AC1: The graphic referring to the asymptotic behavior of the execution running time tests should be presented in a time unit that allows to distinguish the running times of all tested examples.
  - AC2: The procedure should run for 30 given files, and return (i) a .csv file with (input size, execution time) of the algorithm, and (ii) an image file with the execution time graphic, as a function of the input size, for the .csv data (use any package, for example, Gnuplot).
  - AC3: Work delivery format: a folder with (i) the .csv file for the 30 examples available, and (ii) an image file with the graphic of the execution time as a function of the input size, for this .csv data.

3.3 Sprint 3

3.3.1 Data Analysis

- US15 - The monthly cost associated with water consumption in each park is related to its size. Consider the file "water_consumption_updated.csv" adapted from the file used in US09, in which the daily water consumption of more parks were inserted. The file "Area.csv" has the area (in hectares) of each park. Consider that the cost of water consumed follows the rules defined in US09.

  The park management company is considering starting to manage a new 55-hectare park. Predict the average monthly cost that will be paid for water consumption in this new park. Apply the linear regression model, considering the park area as the independent variable and the average monthly cost spent on water consumption as the response variable. Start by studying the feasibility of linear adjustment.

- US16 - Consider the data and results associated with US14. Applying polynomial regression, determine the best line that fits the data. Students who did not take US14 must use the data contained in the file "solution_us14.csv".

In the elaboration of the US15 to US16 the following acceptance criteria will be considered:

- Programming Language: Python
- Development environment: Jupyter Notebook
- Work delivery format: A single Jupyter Notebook file, which contains all the work carried out.
- Each US must be composed of: (1) introduction (succinct and objective); (2) code and results, and (3) analysis and interpretation of the results.
- Formulas must be written in LaTeX.
- At the end of the file, you must indicate the contribution (in %) of each team member to the development of the work (the sum of all percentages must be 100%).

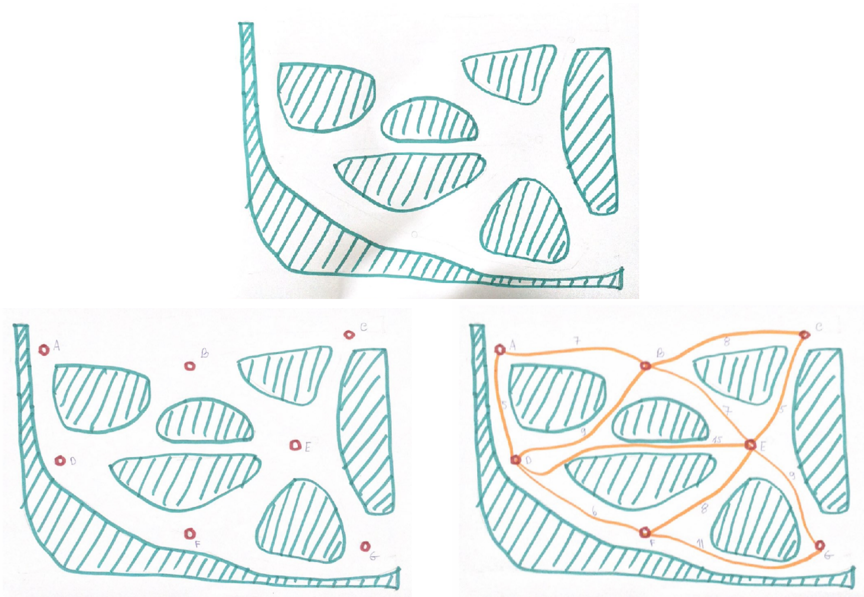

Figure 2: (i) Green Area Survey; (ii) Places to Apply Emergency Signs; (iii) Route Forecast and Measurement.

3.3.2 Emergency plans

When managing green spaces for collective use, it is necessary to define an emergency plan that includes Assembly Points and Evacuation Routes. Assembly Points are locations previously determined and known by all employees, where people must meet in the event of an evacuation or emergency. These Assembly Points are strategically located, visible and easily accessible to ensure everyone knows where to go in dangerous situations. Evacuation Routes indicate the path that users must follow from multiple locations in the park, named Signal Points, to an Assembly Point from which an organized evacuation of the park will take place.

Like in the planning of irrigation systems, in the first phase, if it doesn't exist yet, a topographic survey is carried out to identify the garden/wooded areas and existing paths in the park. A basic sketch of the result of this phase is shown in Figure 2.i.

In the next phase, based on the survey previously carried out, a collaborator specialized in Emergency Planning defines the necessary Places to Apply Emergency Signs, designated by Signal Points (e.g. like Toilets, Cafés, Playgrounds and other popular places), and also the Assembly Point(s), as the example shown in Figure 2.ii. Finally, the routes between each pair of these Points (Signal and Assembly) are identified and measured according to

Figure 2.iii.

- US17 - As a GSM, I want to place signs to evacuate (in case of emergency) park users to an Assembly Point so that these signs give a shortest route from these different points (where the signs will be placed) to the Assembly Point.

  - AC1: The data to be used in this US should be imported from a .csv file containing a weighted matrix W, where each entry w_{ij} is a positive number, containing the cost between Point i and j, or 0, which means that there are no edge between these two points. The structure is the following:

    ```
    0 ; 3 ; 9 ; 1
    3 ; 0 ; 0 ; 2
    9 ; 0 ; 0 ; 5
    1 ; 2 ; 5 ; 0
    ```

    A .csv file will also be provided consisting of a line with the name of the points, in the same order as in the matrix, and where Assembly Point(s) will be identified as AP (APk, with $k = 1, \ldots, \#(AP)$).
  - AC2: The developed algorithm must use only primitive operations, and not existing functions in JAVA libraries. It should return a shortest route from any sign to the Assembly Point (passing by the necessary locals also signaled).
  - AC3: The procedure should return a .csv file with the output paths, line format "(vertice sign a, vertice sign b, ..., vertice Assembly Point); path cost". It should also present the visualization of the drawing of a given input graph, and the output path from one sign asked for the GSM to the Assembly Point.
  - AC4: Work delivery format: a folder including (i) the drawing of the input graph, and the drawings of a shortest route from any sign to the Assembly Point, respectively, for the garden examples that will be available, (ii) the .csv file with the output paths and the respective path cost, and (iii) a .pdf print with only the procedure(s) implemented for solving this problem.

- US18 - As a GSM, I want to place signs to evacuate (in case of emergency) park users to one of the several Assembly Points, so that these paths give a shortest routes to the closest Assembly Point.

- AC1: Algorithm development, output information, and work delivery format are analogues to US17.

- US19 - As a QAM, I want to conclude about the worst-case time complexity of the procedures developed in US13, US17, and US18.

  - AC1: Work delivery format: a .pdf containing the theoretical framework and analysis of the worst-case time complexity of the procedures developed in the respective user stories. All the algorithms should be presented in pseudo-code, where the complexity analysis should be made.

3.3.3 Task management

The management of green areas for public use requires the timely management and completion of multiple tasks throughout the year. In the daily management, the GSM uses two essential tools: the Agenda and the Task List (aka To-Do List). The To-Do List comprises all the tasks required to be done in order to assure the proper functioning of the parks. These tasks can be regular (e.g. pruning trees) or occasional (e.g. repairing a broken equipment). They may also require a multi-disciplinary team and the length of the task can vary from a few minutes (e.g. replacing a light bulb) to weeks (e.g. installing an irrigation system).

The To-Do List comprises all pending tasks for all parks. The entries in this list describe the required task, the degree of urgency (High, Medium, and Low), and the approximate expected duration. The Agenda is made up of entries that relate to a task (which was previously in the To-Do List), the team that will carry out the task, the vehicles/equipment assigned to the task, expected duration, and the status (Planned, Postponed, Canceled, Done).

- US20 - As a Green Space Manager (GSM), I want to register a green space (garden, medium-sized park or large-sized park) and its respective area.

- US21 - As a GSM, I want to add a new entry to the To-Do List.

  - AC1: The new entry must be associated with a green space managed by the GSM.
  - AC2: The green space for the new entry should be chosen from a list presented to the GSM.

- US22 - As a GSM, I want to add a new entry in the Agenda.
  - AC1: The new entry must be associated with a green space managed by the GSM.
  - AC2: The new entry must exist in the To-Do list.
- US23 - As a GSM, I want to assign a Team to an entry in the Agenda.
  - AC1: A message must be sent to all team members informing them about the assignment.
  - AC2: Different email services can send the message. These services must be defined through a configuration file to allow the use of different platforms (e.g. Gmail, DEI's email service, etc.).
- US24 - As a GSM, I want to Postpone an entry in the Agenda to a specific future date.
- US25 - As a GSM, I want to Cancel an entry in the Agenda.
  - AC1: A canceled task should not be deleted but rather change its state.
- US26 - As a GSM, I want to assign one or more vehicles to an entry in the Agenda.
- US27 - As a GSM, I need to list all green spaces managed by me.
  - AC1: The list of green spaces must be sorted by size in descending order (area in hectares should be used). The sorting algorithm to be used by the application must be defined through a configuration file. At least two sorting algorithms should be available.
- US28 - As a Collaborator, I wish to consult the tasks assigned to me between two dates.
  - AC1: The list of tasks spaces must be sorted by date.
  - AC2: The Collaborator should be able to filter the results by the status of the task.
- US29 - As a Collaborator, I want to record the completion of a task.

NOTE: Teams with 3 or fewer students enrolled in ESOFT and PPROG, don't need to deliver the user stories: US24, US25, US26 and US29.

3.4 Non-functional requirements

This section describes some non-functional requirements which must be considered when implementing the project.

- Business rules validation must be respected when recording and updating data.
- The class structure must be designed to allow easy maintenance and the addition of new features, following the best Object-Oriented (OO) practices.
- The application must be developed in Java Language.
- The application's graphical interface is to be developed in JavaFX 11. All those who wish to use the application must be authenticated with a password of seven alphanumeric characters, including three capital letters and two digits.
- The application documentation must be in English language.
- During the system development, the team must: (i) adopt best practices for identifying requirements, and for OO software analysis and design; (ii) adopt recognized coding standards (e.g., CamelCase); (iii) use Javadoc to generate useful documentation for Java code.
- The development team must implement unit tests for all methods, except for the methods that implement Input/Output operations. The unit tests should be implemented using the JUnit 5 framework. The JaCoCo plugin should be used to generate the coverage report.
- All the images/figures produced during the software development process should be recorded in SVG format.
- The application ought to employ object serialization to guarantee the data persistence across two successive runs.