Integrative Project – Project Assignment
LEI - 2021/2022 – 1st Semester, 2nd Year
v4.0, January 2nd

Abstract

A cargo shipping company requires a software system to handle their logistics. This company operates through land and sea, across different continents and has several warehouses spread along the world.

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1 Integrative Project's Goals and Context

In this project, students should be able to apply concepts of analysis, modelling and object-oriented programming to develop a system that supports the management of a logistics company.

In compliance with good practices learned and applied during the first part of the semester, namely on the course units of Applied Physics (FSIAP), Computer Architecture (ARQCP), Data Structures (ESINF) and Databases (BDDAD), and Laboratory/Project III (LAPR3) an iterative and incremental development process is used. An agile methodology based on Scrum must be applied to manage each team's work during each three-week sprint.

For teams where students are enrolled in all subjects, the system will be composed by two applications, one developed in Java, and another developed in C/Assembly.

To increase software's maintainability and best practices, Object-Oriented (OO) software design must be adopted, and implementation should follow a Test-Driven Development (TDD) approach.

Technical documentation must be produced during the project by using Javadoc documentation and the Readme.md file in your repository.

All BDDAD user stories are to be implemented using SQL or PL/SQL.

2 Problem Description

A Cargo shipping company requires a software system to handle their logistics. This company operates through land and sea, across different continents and has several warehouses spread along the world.

2.1 Containers

Due to the number of containers being transported, the company now requires some software that allows them to track the fastest routes from one point in the world to another.

Containers can be transported by land or sea. Every ship has the containers according to a three-axis displacement (as shown in Figure 1), always starting on the same corner of the ship, the corner between Port and Stern. This is point (0,0,0) for coordinates (x,y,z). For example, on Figure 1 container 1) is positioned at (0, 2, 2); container 2) is positioned at (1,0,6) and container 3) is positioned at (1,1,7). Ships may have containers below that axis using a negative number for the "z" axis.

Figure 1 – Three-axis displacement on a ship[1]

As shown in Figure 2 containers have certain characteristics[2] such as:

- Container Identification.
- Container Payload, Tare and Gross.
- Container dimensions (width, height, length) by using the ISO Code[3].

[1] https://lineragency.greencarrier.com/wp-content/uploads/2016/06/strictcontrols.jpg
[2] https://container-xchange.com/blog/container-markings-what-do-they-mean/
[3] https://www.containercontainer.com/iso6346/

- For the time being let us assume that all containers share the same length.

- Let's assume two types of containers.
  - One type, will be containers to keep at refrigeration temperatures, that is, to keep at maximum interior temperatures of 7ºC.
  - The other type, will be to maintain interior temperatures of - 5ºC.

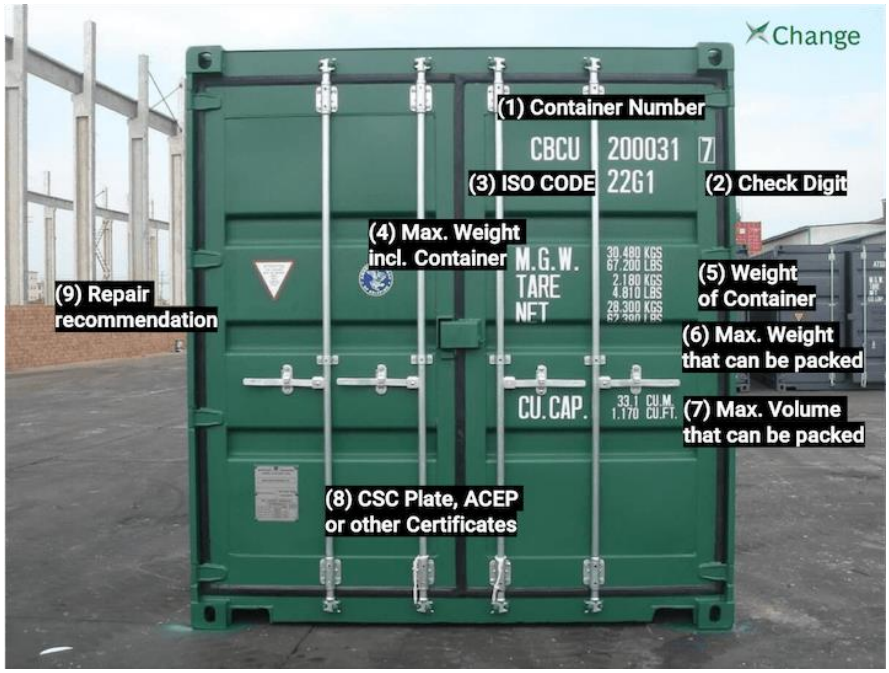

Figure 2 - Container characteristics[4]

2.2 Cargo Manifest

Each time a ship docks at a port or a truck arrives at a location, an Unloading Cargo Manifest is delivered to the operations team at the port or warehouse and at the end of operations a Loading Cargo Manifest is delivered to the ship crew. The same is true for trucks. The Cargo Manifest only has the necessary information about the containers that are being loaded and unloaded.

Each Cargo Manifest has at least the following information:

- Container identification.
- Container position in the transport vehicle.
  - We will be assuming that truck transport can only carry one container at a time.
- Container gross weight.

[4] https://container-xchange.com/wp-content/uploads/2019/01/container-markings-xchange-2.png

Furthermore, some containers can be refrigerated and rely on an outside energy source to work. Ships can fire up energy producing units to supply the energy for those containers. Yet, to preserve fuel those are set to reduce the energy producing units to a bare minimal by default.

2.3 Ships

Ships are characterized by:

- MMSI: unique 9-digit ship identification code.
- Ship name.
- Ship identification according to the IMO identification number[5].
    - IMO: unique 7-digit international identification number, which remains unchanged after transferring the ship's registration to another country.
- Numbers of energy generators.
- Generator's power output.
    - Let us assume that all generators provide the same power output.
- Call sign: ship's unique callsign.
- Vessel type: ship type, numerically coded.
- Length: ship length, in meters.
- Width: ship width, in meters.
- Capacity: ship load capacity in m3.
    - Ship maximum capacity according to a container mapping (using a three-axis displacement).
- Draft: Vertical distance between the waterline and the bottom of the ship's hull, in meters. Varies with ship load and water density

Dynamic data fields relating to a ship's positioning data:

- Base Date Time: date/time of AIS message.
- Latitude: ship latitude (in degrees: [-90; 90], negative value represents South, 91 indicates 'not available').
- Longitude: ship longitude (in degrees: [-180; 180], negative value represents West, 181 indicates 'not available').
- Speed over ground (SOG).
- Course over ground (COG): direction relative to absolute North (in degrees: [0; 359]).
- Heading: ship heading (in degrees: [0; 359], 511 indicates 'not available').
- Position: ship code in tow.

[5] https://www.imo.org/en/OurWork/MSAS/Pages/IMO-identification-number-scheme.aspx

- Transceiver Class: class to transceiver used when sending data.

2.4 Ports and Warehouses

Every Port and

Warehouse should have at least the following information:

- Identification.
- Name.
- Continent.
- Country.
- Location: latitude and longitude.

2.5 Roles

The system is to be used by the following people:

- Client – someone who wants to get a quote for a shipment from one place to another.
- Fleet manager – someone who controls the fleet.
- Traffic manager – someone who controls the shipping/truck position.
- Warehouse staff – someone who loads and unloads cargo from warehouses.
- Warehouse manager – someone who manages the existing warehouses.
- Port staff – someone who loads and unloads cargo from ships.
- Port manager – someone who manages the list of ports.
- Ship captain – someone who oversees ship operations.
- Ship chief electrical engineer – someone who controls the electrical part of a ship.
- Truck driver – someone who oversees truck operations.

2.6 Non-Functional Requirements

This section describes some of the non-functional requirements that must be taken into consideration when implementing your project.

All users must be registered in the system.

Business logic validation should take place when registering or updating data. The database is the main repository for the application and should always reflect an integrity state. All data should be persisted on a remote SGBD. Failure to comply with this will penalize the project grading.

To maximize interoperability with other existing and/or developing systems, the software main core should be written in Java. Some other software used for quick notifications should be developed in C/Assembly.

The class structure must be designed to allow easy application maintenance and addition of new features and following good OO design practices.

3 Minimum Viable Product

The goal of this assignment is to achieve a Minimum Viable Product in incremental steps. For this purpose, the work will be divided in three Sprints:

- Sprint 1 – October 25th to November 14th ~~12th~~.
- Sprint 2 – November 15th to December 5th ~~3rd~~.
- Sprint 3 – December 6th to January 3rd ~~December 22nd~~.
- Sprint 4 – January 3rd to January 23rd ~~21st~~.

For each Sprint, a description for a minimum viable product is provided to students. Students should follow the user stories and perform story mapping. At the end of each sprint, each team should be able to have all the requirements fulfilled.

Teams should be able to add the User Stories to their backlog, size them and assign them over to each team member.

3.1 Sprint 1

The maritime transport is provided by different ships. Ships send messages during voyages to the US Coast Guard. These messages contain the positional and displacement information of each ship at a given time. The file (ships.csv) contains static information about the ship details and dynamic data regarding the voyage [6].

- [US101] As a traffic manager, I which to import ships from a text file into a BST.
  - Acceptance criteria [ESINF]:
    - no data lost.
- [US102] As a traffic manager I which to search the details of a ship using any of its codes: MMSI, IMO or Call Sign.
  - Acceptance criteria [ESINF]:
    - correct use of OOP concepts.
- [US103] As a traffic manager I which to have the positional messages temporally organized and associated with each of the ships
  - Acceptance criteria [ESINF]:
    - efficient access of any position value(s) of a ship on a period or date.
- [US104] As a traffic manager I which to make a Summary of a ship's movements.
  - Acceptance criteria [ESINF]:

[6] https://www.youtube.com/watch?v=3M7mxBimT70

        - For a given ship return in an appropriate structure one of its codes (MMSI, IMO or Call Sign), Vessel Name, Start Base Date Time, End Base Date Time, Total Movement Time, Total Number of Movements, Max SOG, Mean SOG, Max COG, Mean COG, Departure Latitude, Departure Longitude, Arrival Latitude, Arrival Longitude, Travelled Distance (incremental sum of the distance between each positioning message) and Delta Distance (linear distance between the coordinates of the first and last move)[7].
- [US105] As a traffic manager I which to list for all ships the MMSI, the total number of movements, Travelled Distance and Delta Distance.
    - Acceptance criteria [ESINF]:
        - ordered by Travelled Distance and total number of movements (descending/ascending).
- [US106] Get the top-N ships with the most kilometres travelled and their average speed (MeanSOG).
    - Acceptance criteria [ESINF]:
        - in a period (initial/final Base Date Time) grouped by Vessel Type.
- [US107] Return pairs of ships with routes with close departure/arrival coordinates (no more than 5 Kms away) and with different Travelled Distance.
    - Acceptance criteria [ESINF]:
        - Sorted by the MMSI code of the 1st ship and in descending order of the Travelled Distance difference.
        - Do not consider ships with ~~the number of movements greater than 1000 and~~ Travelled Distance less than 10 kms.
- [US108] As Project Manager, I want the team to develop the data model required to support all the functionality and to fulfill the purpose of the system to develop. This data model is to be designed following a systematic data modeling methodology.
    - Acceptance Criteria [BDDAD]:
        - The result should include (1) the conceptual data model, (2) the logical data model according to the database technology to use, (3) the physical data model to be implemented at the selected DBMS, (4) a data dictionary describing the relevant details of the database elements and (5) a clear and concise justification supporting the selected database technology.

[7] http://www.movable-type.co.uk/scripts/latlong.html

        - It is possible to run a SQL script to create the database schema in a complete and consistent way without errors.
        - The data models generated at each one of the three abstraction levels (conceptual, logical, and physical) map only the meaningful concepts and characteristics in compliance with the corresponding level.
        - Each one of the data models respects the former one, i.e., the logical data model respects the conceptual data model, and the physical data model respects the logical data model. The conceptual data model is a valid view/representation of the UoD.
        - The notation used for each one of the data models is adequate, consistent, and following the specifications.
- [US109] As Project Manager, I want the team to draft an SQL script to test whether the database verifies all the data integrity restrictions that are required to fulfil the purpose of the system and the business constraints of the UoD.
    - Acceptance Criteria [BDDAD]:
        - There is a catalogue of data integrity restrictions grouped by type (Domain, Identity, Referential, Application) clearly stated.
        - For each data integrity restriction in the catalogue there is a set of SQL instructions that verify the restriction.
        - All SQL instruction in the data integrity verification script are accompanied by a comment that describes the expected result (Pass or Fail; in the latter a justification is given).
- [US110] As Project Manager, I want the team to define the naming conventions to apply when defining identifiers or writing SQL or PL/SQL code. The naming conventions may evolve as new database and programming objects are known. The naming conventions guide should be organized in a way to facilitate its maintenance.
    - Acceptance Criteria [BDDAD]:
        - There are naming conventions clearly stated to create databases and database objects. The minimum set includes tables, attributes, constraints, primary and foreign keys.
        - The naming conventions are available in a way that makes them easy to understand and complete in a continuous way.
- [US111] As Project Manager, I want the team to create a SQL script to load the database with a minimum set of data sufficient to carry out data integrity verification and functional testing. This script shall produce a bootstrap report providing the number of tuples/rows in each relation/table.

- Acceptance Criteria [BDDAD]:
  - The bootstrap SQL script runs and loads the database as expected with no errors
  - The bootstrap report is generated and correct, i.e., all tables are mentioned, and their cardinality is correct.

3.1.1 Non-Functional Requirements

To assure data integrity in the database there are restrictions that apply generally, regardless of any other considerations. Many of these arise naturally, such as, length, width, weight, and volume cannot be negative. Others, such as latitude and longitude, although being also natural, might not be so well known to non-experts in the field.

Besides these general restrictions, the UoD imposes a few others, such as, "IMO: unique 7-digit international identification number" or "ship latitude …91 indicates 'not available'". All the data integrity restrictions from the UoD should be considered and described when designing the database; some of these may be imposed at the data model, others require coding.

3.2 Sprint 2

- [US201] As a Port manager, I which to import ports from a text file and create a 2D-tree with port locations.
    - Acceptance criteria [ESINF]:
        - 2D-tree balanced.
- [US202] As a Traffic manager, I which to find the closest port of a ship given its CallSign, on a certain DateTime.
    - Acceptance criteria [ESINF]:
        - using 2D-tree to find closest port.
- [US203] As Project Manager, I want the team to review the relational data model in view of the new user stories so it can support all the requirements to fulfil the purpose of the system being developed.
    - Acceptance Criteria [BDDAD]:
        - The following deliverables are expected: (1) revised relational data model in 3NF, (2) revised SQL script to create the database schema in Oracle (physical data model) and (3) database bootstrap script.
        - It is possible to run a SQL script to create the database schema in a complete and consistent way without errors.
        - It is possible to run a script to load the database with enough data to explore the database and run the user stories (database bootstrap script).
- [US204] As Client, I want to know the current situation of a specific container being used to transport my goods.
    - Acceptance Criteria [BDDAD]:
        - Clients provide the container identifier and get the type and the concrete instance of its current location, e.g., PORT, Leixões or SHIP, WeFly.
- [US205] As Ship Captain, I want the list of containers to be offloaded in the next port, including container identifier, type, position, and load.
    - Acceptance Criteria [BDDAD]:
        - "next port" is properly identified.
        - The containers being offloaded are properly identified.
        - Output is in accordance with the specification wrt the information about each container.
- [US206] As Ship Captain, I want the list of containers to be loaded in the next port, including container identifier, type, and load.
    - Acceptance Criteria [BDDAD]:

        - "next port" is properly identified.
        - The containers being loaded are properly identified.
        - Output is in accordance with the specification wrt the information about each container.
- [US207] As Ship Captain, I want to know how many cargo manifests I have transported during a given year and the average number of containers per manifest.
    - Acceptance Criteria [BDDAD]:
        - Only the cargo manifests of the specified year are considered.
        - Average containers per cargo manifest are properly computed.
- [US208] As Ship Captain, I want to know the occupancy rate (percentage) of a given ship for a given cargo manifest. Occupancy rate is the ratio between total number of containers in the ship coming from a given manifest and the total capacity of the ship, i.e., the maximum number of containers the ship can load.
    - Acceptance Criteria [BDDAD]:
        - Ship and cargo manifest are correctly identified.
        - Occupancy rate is properly computed.
- [US209] As Ship Captain, I want to know the occupancy rate of a given ship at a given moment.
    - Acceptance Criteria [BDDAD]:
        - Ship is properly identified.
        - Reuses US208.
        - Occupancy rate is properly computed.
- [US210] As Traffic manager, I need to know which ships will be available on Monday next week and their location.
    - Acceptance Criteria [BDDAD]:
        - Monday next week is properly identified.
        - Only available ships are returned.
        - All available ships are returned.

3.3 Sprint 3

- [US301] As a Traffic manager, I which to import data from countries, ports, borders and seadists ~~files~~ from the database to build a freight network.
    - Acceptance criteria [ESINF]:
        - The capital of a country has a direct connection with the capitals of the countries with which it borders. The ports of a country, besides

connecting with all the ports of the same country, the port closest to the capital of the country connects with it; and finally, each port of a country connects with the n closest ports of any other country.
        - The calculation of distances in Kms between capitals, and ports and capitals must be done using the GPS coordinates.
        - The graph must be implemented using the adjacency matrix representation and ensuring the indistinct manipulation of capitals and seaports.
- [US302] As a Traffic manager I wish to colour the map using as few colours as possible.
    - Acceptance criteria [ESINF]:
        - Neighbouring countries must not share the same colour.
- [US303] As a Traffic manager I wish to know which places (cities or ports) are closest to all other places (closeness places).
    - Acceptance criteria [ESINF]:
        - Return the n closeness locals by continent.
        - The measure of proximity is calculated as the average of the shortest path length from the local to all other locals in the network.
- [US304] As Ship Captain, I want to have access to audit trails for a given container of a given cargo manifest, that is, I want to have access to a list of all operations performed on a given container of a given manifest, in chronological order. For each operation I want to know: the user/login that performed it, the date and time the operation was performed, the type of operation (INSERT, UPDATE, DELETE), the container identifier and the cargo manifest identifier.
    - Acceptance Criteria [BDDAD]:
        - There is a table for recording audit trails, i.e., record all write-operations involving containers of a cargo manifest.
        - Proper mechanisms for recording write-operations involving containers of a cargo manifest are implemented (INSERT, UPDATE, DELETE).
        - A simple and effective audit trail consultation process is implemented.
- [US305] As Client, I want to know the route of a specific container I am leasing.
    - Acceptance Criteria [BDDAD]:
        - Users provide their registration code, the container identifier and get its path, from source to current location indicating time of arrival and departure at each location and mean of transport (ship or truck) between each pair of locations.

        - When the provided identifier is not valid or, being valid, is not leased by the client, a warning is returned.
- [US306] As Port manager, I want to know the occupancy rate of each warehouse and an estimate of the containers leaving the warehouse during the next 30 days.
    - Acceptance Criteria [BDDAD]:
        - For each warehouse the required output is available.
        - The 30 days period is properly considered.
- [US307] As Port manager, I intend to get a warning whenever I issue a cargo manifest destined for a warehouse whose available capacity is insufficient to accommodate the new manifest.
    - Acceptance Criteria [BDDAD]:
        - Destination warehouse is properly identified.
        - Warehouse available capacity is properly computed.
        - The warning is triggered when required.
- [US308] As Traffic manager, I want to have a system that ensures that the number of containers in a manifest does not exceed the ship's available capacity.
    - Acceptance Criteria [BDDAD]:
        - The destination ship is properly identified.
        - Ship's available capacity is properly computed.
        - The warning is triggered when required.
- [US309] As Traffic manager, I do not allow a cargo manifest for a particular ship to be registered in the system on a date when the ship is already occupied.
    - Acceptance Criteria [BDDAD]:
        - The ship is properly identified.
        - Ship's availability is properly computed.
        - A warning or an exception is triggered when required.
- [US310] As Port manager, I intend to have a map of the occupation of the existing resources in the port during a given month.
    - Acceptance Criteria [BDDAD]:
        - Occupation of resources is restricted to the month provided.
        - The reported occupation respects actual port capacity.
- [US311] As Ship Captain, I want to provide a database access account, with login "crew" and password "bd7wd5aF", which gives access exclusively to the information of the containers that are loaded on my ship. The information about each container to be made available is: identifier, type, position and load.
    - Acceptance Criteria [BDDAD]:

        - The user account is created.
        - Only the required permissions are granted.
        - Only the containers loaded at the Captain's ship are available for consultation.
        - Only the described data is publicly available through this "crew" account.
- [US312] As Client, I want to know the current situation of a specific container being used to transport my goods – US204.
    - Acceptance Criteria [BDDAD]:
        - When the provided identifier is not valid or, being valid, is not leased by the client, a warning is returned. This warning has two elements, the error code and the identifier of the container. The error code will be: 10 – invalid container id or 11 – container is not leased by client.
- [US313] As a Port staff, given a Cargo Manifest, I wish to fill a statically reserved matrix in memory with each container's ID in its respective place.
    - Acceptance criteria [ARQCP]:
        - The matrix should be statically reserved in C, considering the maximum. capacity of the ship, with all positions set to zero.
        - The function should be developed in C.
- [US314] As a Port staff, I wish to know the total number of free/occupied slots in the transport vehicle.
    - Acceptance criteria [ARQCP]:
        - The number of free/occupied slots should be determined by an Assembly function that traverses the matrix filled with the containers' IDs.
        - The function should return an eight-byte value, where the number of free slots is placed in the four most significant bytes and the number of occupied slots in the four least significant bytes.
- [US315] As a Port staff, given a position in the transport vehicle, I wish to know if a container is there or not.
    - Acceptance criteria [ARQCP]:
        - The free/occupied position should be determined by an Assembly function that verifies the matrix filled with the containers' IDs.
        - The function should return 1 if a container is there or 0, otherwise.
- [US316] As a Port staff, given a set of positions, I wish to know the total number of occupied slots.
    - Acceptance criteria [ARQCP]:

        - Using the Assembly function developed in the previous US, develop another Assembly function that traverses an array of positions and determines the total number of occupied slots.
- [US317] As Ship Chief Electrical Engineer I want to know what set of materials to use in a container, to operate at temperatures of 7°C.
    - Acceptance criteria [FSIAP]:
        - What types of materials should I use to make up the outer walls.
        - What kind of materials should I use for the middle layers.
        - What types of materials should I use for the interior walls.
- [US318] As Ship Chief Electrical Engineer I want to know what set of materials to use in a container, to operate at temperatures of -5 °C.
    - Acceptance criteria [FSIAP]:
        - What types of materials should I use to make up the outer walls.
        - What kind of materials should I use for the middle layers.
        - What types of materials should I use for the interior walls.
- [US319] As Ship Chief Electrical Engineer I want to know the thermal resistance, for each operating temperature, of each container that must contain at least three different materials in its walls. One for the outer wall, one for the intermediate material, and one for the inner wall.
    - Acceptance criteria [FSIAP]:
        - For each container, working at a temperature of 7ºC, determine the thermal resistance it offers, according to the choice of materials made.
        - For each container working at a temperature of -5ºC, determine the thermal resistance it offers according to the choice of materials.
- [US320] As Ship Chief Electrical Engineer I intend to present in a summary document, the choice of materials considered for the two types of containers considered, and their thermal resistances.
    - Acceptance criteria [FSIAP]:
        - Present in a document (summary)(pdf), the choices considered for each type of container, as well as the respective thermal resistances.

3.4 Sprint 4

- [US401] As a Traffic manager I wish to know which ports are more critical (have greater centrality) in this freight network.
    - Acceptance criteria [ESINF]:

        - Return the n ports with greater centrality.
        - The centrality of a port is defined by the number of shortest paths that pass through it.
- [US402] As a Traffic manager I wish to know the shortest path between two locals (city and/or port).
    - Acceptance criteria [ESINF]:
        - Land path (only includes land routes, may start/end in port/city).
        - Maritime path (only includes ports).
        - Land or sea path (may include cities and ports).
        - Obligatorily passing through n indicated places.
- [US403] As a Traffic manager I wish to know the most efficient circuit that starts from a source location and visits the greatest number of other locations once, returning to the starting location and with the shortest total distance.
    - Acceptance criteria [ESINF]:
        - Implement one of the heuristics used for this type of circuit.
- [US404] As Fleet Manager, I want to know the number of days each ship has been idle since the beginning of the current year.
    - Acceptance Criteria [BDDAD]:
        - Current year is properly identified.
        - Idle time is correctly computed per ship.
        - Ships with no idle time are also reported.
- [US405] As Fleet Manager, I want to know the average occupancy rate per manifest of a given ship during a given period.
    - Acceptance Criteria [BDDAD]:
        - Ship is properly identified and considered.
        - Period is properly identified and considered.
        - Average occupancy rate per manifest and ship is correctly computed.
- [US406] As Fleet Manager, I want to know which ship voyages – place and date of origin and destination – had an occupancy rate below a certain threshold; by default, consider an occupancy rate threshold of 66%. Only the trips already concluded are to be considered.
    - Acceptance Criteria [BDDAD]:
        - Reuses US405.
        - Average occupancy rate is properly computed.
        - Trips still ongoing are not considered for the occupancy rate calculations.
- [US407] As Port manager, I intend to generate, a week in advance, the loading and unloading map based on ships and trucks load manifests and corresponding travel plans,

to anticipate the level of sufficient and necessary resources (loading and unloading staff, warehouse staff, ...).

    - Acceptance Criteria [BDDAD]:
        - Week in advance is properly identified.
        - Loading and unloading map is comprehensive.
        - Loading and unloading map is clear with respect to the sufficient and necessary resources for loading and unloading tasks.

- [US408] As Port manager, I intend to develop a data model to build a Data Warehouse to analyse the volume of maritime traffic between any two ports. The fact to be analysed is the traffic volume measured by the indicators "number of containers", "accumulated number of containers" and "target number of containers". These indicators refer to the number of containers that are in transit between two ports/locations on the first day of each month. The dimensions to consider are Time, Port of origin and Port of destination. The Time dimension has a hierarchy with the following levels: Year, Month. The location/Port is subject to the following hierarchy: Continent, Country, Port. An estimate of the upper cardinality of the dimension and fact tables must be indicated.
    - Acceptance Criteria [BDDAD]:
        - Fact tables are properly identified and described.
        - Dimension tables are properly identified and described.
        - The star/snowflake model is consistent with the purpose of the specified data warehouse app as well as the fact and dimension tables previously identified.
        - The estimate of the cardinalities is coherent with the data model and properly justified.
        - A SQL script to load and query the data warehouse to support a proof of concept is available and runs with no errors.
- [US409] As a Port staff given a Cargo Manifest, I wish to fill a dynamically reserved ~~matrix~~ array in memory with all the container's information in its respective place.
    - Acceptance criteria [ARQCP]:
        - The ~~matrix~~ array should be dynamically reserved in C, adjusting the size of the ~~matrix~~ array to the amount of handled data.
        - All the details of a container can be present in more than one file. As such, define a struct that represents a container. Therefore, in the end, you should have a matrix of structs.
        - The data types chosen for each field of the struct should be adjusted to the types of values they store. Memory usage should be kept to the

minimum required. Also consider the order of fields that minimizes memory consumption.

        - The function should be developed in C.
- [US410] As a Ship Chief Electrical Engineer, given the position of a container, I want to know the amount of needed energy to keep the container at its required temperature.
    - Acceptance criteria [ARQCP]:
        - Develop an Assembly function, that given a position of a container, determines if that container is refrigerated or not, considering the information stored in the array of containers.
        - The function should return 1 if a container is refrigerated or 0, otherwise.
        - Develop a C function that, using the previous function developed in Assembly to know if a container is refrigerated, determines the amount of needed energy to keep the container at its required temperature.
- [US411] As a Ship Chief Electrical Engineer, I want to receive an alert when the current energy generation units are not enough to provide energy to all refrigerated containers at once.
    - Acceptance criteria [ARQCP]:
        - The needed calculations should be done in C.
- [US412] As Ship Chief Electrical Engineer, we intend to know how much energy to supply, for each container, in a determined trip, with an exterior temperature of 20 ºC, and a travel time of 2h30.
    - Acceptance criteria [FSIAP]:
        - The total energy to be delivered to a container with an operating temperature of 7 °C.
        - The total energy to be delivered to a container with an operating temperature of - 5 °C.
- [US413] As Ship Chief Electrical Engineer, the objective is to know the total energy to be supplied to the set of containers in a certain established trip, assuming that all the containers have the same behaviour.
    - Acceptance criteria [FSIAP]:
        - Know the journey time.
        - Know the temperature of the trip, or sections of the trip.
        - Determine the total energy to be supplied to the set of containers with an operating temperature of 7 °C.
        - Determine the total energy to be supplied to the set of containers with an operating temperature of - 5 °C.

- [US414] As Ship Chief Electrical Engineer, you want to know how much energy to supply to the container cargo, in a voyage (or route), depending on the position of the containers on the ship. Admitting that the interior containers, or the sides not exposed directly to the "sun", maintain the initial temperature, or of departure. However, the exposed sides may present temperature variations during the trip.
    - Acceptance criteria [FSIAP]:
        - Know the journey time.
        - Know the temperatures of the travel sections.
        - Know how many sides of each container are subject to temperature variation.
        - Determine the energy required for one trip of the containers at a temperature of 7 ºC, depending on their position in the load.
        - Determine the energy required for one trip of the containers at a temperature of -5 ºC, depending on their position in the cargo.
- [US415] As the ship's captain I need to know how many auxiliary power equipment are needed for the voyage, knowing that each one supplies a maximum of 75 KW.
    - Acceptance criteria [FSIAP]:
        - Know the amount of energy required per type of container for a trip.
        - Determine the total energy required to load containers on a given voyage (or route) as a function of their position in the load.
        - Determine how many generators of the stated power are required for the trip.
- [US416] As ship's master I intend to submit a summary document, with the following items.
    - Acceptance criteria [FSIAP]:
        - Present in a document (summary)(pdf), the necessary energy of each container, of each type (internal temperatures), with an external temperature of 20 ºC, and a travel time of 2h30.
        - Present in a summary document, pdf, the total energy to supply, to the set of containers, in a established trip, assuming that all containers have the same behaviour.
        - Present in a summary document, pdf, the energy to supply to the container load, in one trip (or route), as a function of the position of the containers on the vessel, and of the interior temperature of the two types of containers considered.

        - Present in a summary document, pdf, the number of generators required for the voyage, or sectors of the trip.
- [US417] As the Ship Captain I want the technical team to search for at least three types of ship/vessels that are better suited to the task (e.g., depending on the type of cargo), in which the "control" bridge can assume three positions, one in the bow, one in the stern, and finally in the midship.
    - Acceptance Criteria [LAPR3]:
        - Search the different types of vessels for transporting different types of cargo. Containers, or solids in bulk.
        - Identify the differentiating characteristics.
- [US418] As the Ship Captain I want the determine the unladen center of mass for each vessel (if different) according to its characteristics. For calculation purposes, consider known geometric figures.
    - Acceptance Criteria [LAPR3]:
        - Make a sketch of the vessel's geometric figure.
        - Identify/choose a reference for the calculation.
        - Determine the center of mass for the different vessels (consider that the vessel is all made of the same material).
- [US419] As the Ship Captain I want to know where to position, for example, one hundred (100) containers on the vessel, such that the center of mass remains at xx and yy, determined in the previous point.
    - Acceptance Criteria [LAPR3]:
        - Identify the area/volume of a container and its center of mass. The distribution of the mass inside the container will be considered uniform.
        - Make a sketch of the distribution and loading on the vessel.
        - Calculate the center of mass of the sketch performed.
- [US420] As the Ship Captain I want to know for a specific vessel, how much did the vessel sink, assuming that each container has half a ton of mass.
    - Acceptance Criteria [LAPR3]:
        - Determine the total mass placed on the vessel and the pressure exerted by it on the water.
        - Determine the difference in height that the vessel has suffered, above water level.

4 Technical Details

The following project development requirements must be met:

- JUnit Code Coverage should be above 80%.
- PIT Mutation Testing Coverage should be above 75%.

Software products that do not compile on Jenkins, have an automatic grading of 0 (zero).

Software products that show up as "Failed" on SonarQube, have an automatic grading of 0 (zero).

4.1 ARQCP

In Sprint 3, all needed data structures should be statically reserved in memory, considering the worst-case scenario. Functions developed in Assembly have no parameters. As such, all needed input should be given as global variables, either defined in C or Assembly.

In Sprint 4, all needed data structures should be **dynamically reserved** in memory, adapting the amount of reserved memory to the amount of data being processed. Functions developed in Assembly should **have parameters**. As such, global variables are no longer needed and **cannot not be used**.

4.2 BDDAD

Students should create one database according to the tutorial that will be provided on Moodle. These databases have the following name "LAPR3-GXXX" where XXX should be replaced by your team number.

All the scripts for creating/updating your database schema should be exported to your project's git repository.

4.3 ESINF

For each sprint a report must be made where it is presented and explained the class diagram and made the complexity analysis of the requested functionalities.

4.4 FSIAP

More information on this component can be found in the technical guide.

4.5 LAPR3

More information is available on LAPR3 Moodle's web page[8].

For a safe voyage to be carried out by a given ship or vessel, cargo distribution must be as balanced as possible, that is, the ship's center of mass must always be correctly positioned, regardless of the number of containers at each time/section of the voyage. Please check user Sprint 4 user stories regarding this matter.

[8] https://moodle.isep.ipp.pt/course/view.php?id=1681

5 Revision History

V0.5	Work in progress.
V1.0	Initial Release.
V1.1	Correction to Acceptance Criteria on US107.
V2.0	Update to sections 1, 2.1 and 4.1. Added sections 3.2, 3.3, and 3.4. Added project requirements to section 4.
V2.1	Update to section 4.3.
V3.0	Update to section 3.3.
V3.1	Update sprint duration on section 3.
V4.0	Update section 3.4 and 4.5.

Notes: new changes are underlined while removed content are strikethrough.