H2020-MSCA-RISE-2016

ProSFeT Project

Promoting Sustainable Freight Transport in Urban Contexts: Policy and Decision-Making Approaches

D2.3

Specification and feasibility study for the software implementation of a Decision Support System for Urban Freight Transport planners

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under the Marie Sklodowska-Curie grant agreement No 734909

Project Information

Acronym: ProSFeT Project
Title: Promoting Sustainable Freight Transport in Urban Contexts: Policy and Decision-Making Approaches
Coordinator: The University of Sheffield
Reference: 734909
Program: H2020-MSCA-RISE-2016
Start: 1st January 2017
Duration: 36 months
Website: http://prosfet.eu/PROSFET/

Consortium:

- The University of Sheffield (USFD)
- Consiglio Nazionale delle Ricerche (CNR)
- Universidad de Extremadura
- South East European Research Centre (SEERC)
- Sheffield City Council
- City of Bradford Metropolitan District Council
- Stockholms Stad
- Softeco
- Shaping Cloud

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Research and Innovation programme under the Marie Sklodowska-Curie grant agreement No 734909

Deliverable

Number: **D2.3**
Title: Specification and feasibility study for the software implementation of a Decision Support System for Urban Freight Transport planners
Lead beneficiary: USFD/CNR
Work package: WP2
Dissemination level: Public
Nature: Report
Due date: 31.12.2019
Submission date: 30.12.2019
Authors: Project Coordinator
Contributors: Beneficiaries

Cite as:

Barisone, A., Genovese, A., Gorini, M., Jing., L., Luo, S., Sgalambro, A., Stella, L. (2019). Specification and feasibility study for the software implementation of a Decision Support System for Urban Freight Transport planners. Technical Report for the *ProSFeT Project*, D2.3.

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1. Introduction

Logistical activities contribute about 10% to 30% of the total volume of traffic in urban areas; Such freight traffic activities generate approximately 25% of CO_2, 30% of NO_x and 50% of on-road issues (e.g. noise and traffic accident) (Dablanc, 2011). Besides the environmental and social nuisance, evidence from research shows that urban distribution generates about 28% of the total goods movement cost in the supply chain (Butrina et al., 2017). Aiming at solving the above external and internal issues, since 2004, European Commission proposed to build the sustainable urban transportation system to improve the performance of urban mobility from the perspectives of economy, environment and society (Behrends, 2016). As part of this strategy, sustainable urban logistics (SUL) should *"meet economic, environmental and social needs efficiently and equitably, while minimising avoidable or unnecessary adverse impacts and their associated costs, over relevant space and timescales*" (Anderson et al., 2005).

Within this context, pooling solutions have proven to be an efficient way for alleviating environmental and congestion problems in urban areas. The most significant feature of this method is the promotion and implementation of consolidation approaches within city areas. In this, different organisations (e.g. shippers, carriers, customers) collaborate in the common use of logistics resources regarding materials, equipment, and human resources (Morana et al., 2014). As a pivotal type of facility within such models, Urban Consolidation Centres (UCCs) have received increasing interests from both the academic community and practitioners. An UCC is *a facility involving the trans-shipment of goods directed to urban areas, aiming to consolidate deliveries, and thus provide greater efficiency (and effectiveness) in the distribution process by increasing the truck load factor and decreasing the number of trucks used, which can help mitigate urban congestion and air pollution* (Tario et al., 2011*).* Normally, an UCC delivery network (Figure 3.1.) is composed of different participants such as operators, shippers, carriers, UCC administrators. Furthermore, two more kinds of stakeholders (goods suppliers and consumers) are involved in this delivery system (Wang et al., 2015). Physically, goods from different origins should be gathered at the UCC before they are moved into urban areas. After this intermediate step, goods will be sorted depending on their destination and due date; finally, goods will be allocated for final deliveries in the city centre through the usage of smaller vehicles. The key objective of UCC facilities is to achieve a higher truck loading rate, along with a lower number of utilised trucks (Allen et al., 2014).

Unfortunately, as also reported in the previous phases of the ProSFeT project, most of these initiatives were developed on the basis of very limited understanding and partial data about urban logistics. Indeed, most of the focus has been about distribution to retail stores and similar establishments; however, this just constitutes a fraction of the logistical flows happening within

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urban areas, often already involving some form of consolidation from the shipper. Traditionally, other forms of flows (such as the ones related to construction materials, waste management, materials needed in the facilities management cycle, catering industry) remained out of the picture. Previous research from the ProSFeT project reported that:

- Facilities related to Urban Logistics Operations (such as Urban Consolidation Centres, UCCs) have traditionally failed to attract stable and significant revenue models that could be attractive for the whole set of stakeholders involved; for instance, delivery operations involving the usage of an UCC might end up being significantly more expensive for shippers, failing to create a convincing economic case.
- Not much research has been devoted to cost, risk and revenue sharing models that could lead to the implementation of successful Urban Logistics initiatives (including, for instance, UCCs).
- The implementation of urban logistics initiatives can be significantly affected by political decisions; often, in the European context, local political situations might be uncertain and volatile, producing significant changes in the administrative landscape. This is not ideal for the stability and certainty requested for the success of most of the urban logistics initiatives.

Empirical evidence suggests that the design and implementation of Urban Logistics solutions should be guided by a careful assessment of their estimated impacts; furthermore, an early involvement of stakeholders from both public and private sectors should be sought, in order to evaluate the long-term sustainability of potential solutions.

For this reason, the availability of adequate tools, capable of addressing, from a multi-stakeholder perspective, also strategic issues (for instance, related to the investment planning phase) rather than just operational ones (concerned with the day-to-day functioning of already established logistical platforms) could be of interest to stakeholders involved in the policy- and decision-making process.

Within this context, this report constitutes deliverable D2.3 for work package 2 of the ProSFeT project. The report illustrates the fundamentals of a Decision Support System (DSS), which was developed within the framework of the project. A major contribution for the development of the DSS is thanks to a number of secondments, which involved staff from multiple beneficiaries (USFD, SOFTECO, Shaping Cloud, CNR).

It is worth to mention that, during the ProSFeT project, there have been several opportunities to demonstrate the practical usability of the current version of the DSS and its potential usefulness to a variety of stakeholders. Three local authorities have participated in co-creation activities which

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have resulted in the presented DSS (with practical engagement sessions happening during the mid-term review meeting and the final event). Also, during the secondment periods involving Softeco Sismat both as hosting and sending organisation, interactions between company staff, researchers, and stakeholders from the urban freight transport sector have been organised. This has resulted in a good understanding of stakeholders' needs, which has been translated in the current version of the DSS.

2. The need for Scenario Planning tools for UCC strategic design

Scenario planning examines sensitivity to changes in the environment, using a range of models to explore how different scenarios may affect current and planned initiatives. It allows the opportunity to incorporate some resilience planning into the SUL framework. While in the market several operational tools aimed at optimising the functioning of Urban Consolidation Centres can be retrieved, the ProSFeT project highlighted the lack of strategic decision support systems (that could be utilised also by other stakeholders in the industry) aimed at providing some sort of *scenario planning* functionality which could be very useful in the phase of strategic design of an UCC. In this specific functionality, a decision-maker (who, for instance, could be a transport planner in a city council) could just insert some hypothetical demand for the last-mile delivery services (in terms of typical incoming trucks per day and number of customers that need to be served, with their operating time windows). The tool could then provide an indication about some issues that need to be considered in the planning stage for the design of an UCC, such as:

- The location and recommended number of UCCs to be located in the urban area under investigation;
- The required fleet size to be operational at the UCCs (and, consequently, the number of charging stations needed for them, in case of electric vehicles);
- The number of incoming and outgoing doors that are needed for the UCCs, and, consequently, the overall area required for the warehouse;
- Workforce planning issues (required drivers, warehouse operatives and other workers required for the functioning of the warehouse);
- A measure of the savings (in terms of cost, of overall travel distances and of environmental impacts) that the implementation of the UCC could imply.

Assessing all these dimensions, the tool could:

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- Facilitate better informed decision-making in the planning stage (for instance, by providing useful elements for identifying a suitable area for the site);
- Provide a rough but helpful estimate about the investment required for setting up an UCC facility (in many cases these estimates are produced by utilising very unreliable models that are completely detached from the way in which such platforms will work in the reality);
- Provide an initial estimate about financing and cost-sharing options in the long run, in order to ensure the sustainability of such facilities.

2.1 DSS Requirements

Taking into account the above-mentioned needs, the DSS should have the following characteristics.

Capability of handling planning in an autonomous way. The requirement that motivates the development of a DSS is the willingness to provide stakeholders and/or end users with access to a tool for tailored support dealing with planning activities, instead of doing it manually or outsourcing support as an external service.

A DSS should include the chance for the users to: add logistic points that are part of the planning; include a UCC at a given point; add vehicles and logistic orders to start the planning; obtain the planning results out of the given data.

Capability of handling geo-points. A fundamental requirement is to handle the geospatial data on a map. This should include the longitude and latitude of a given point on map, e.g. the coordinates of a UCC or logistic point, and the links representing streets, namely the directed edges containing information on one-way and two-way streets.

This requirement involves the development of the following features: by adding a new logistic point or base, the corresponding demand point or base must be visible on map and the planner should be able to interact with it, namely business listing; the logistic points and bases present in the database should be shown on map and should be editable or removable; streets should be highlighted in the map alongside the information about one-way or two-way streets.

Handling logistic trips. The Decision Tool should include an internal trip planner, that can optimize on a set of measures, which can be useful for stakeholders and/or end users. The trip planner

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should consider the one-way and two-way streets, the constraints on the operating hours both of the UCCs and of the logistic points, and the constraints on the size of vehicles.
Therefore, the users should be able to: run the planning with a given set of data; choose to optimize for distance travelled, time elapsed or for a custom optimization. The resulting plan should rely on up-to-date geospatial data, which can be replaced in the tool if needed.

Handling different types of orders. The stakeholders and/or users should be able to include different kinds of logistic orders in the planning. More specifically, the types to be included are: first mile, last mile and point-to-point. First mile orders refer to the movement of products from a UCC to a courier service who take them to the final users. Last mile orders refer to the final movement to the end users. Finally, point-to-point orders refer to the delivery of products from one logistic point to another logistic point.
The most basic requirement should include the creation at random of a number of a certain kind of orders specified by the user. More elaborate requirements could involve the creation of orders by specifying a UCC or a set of logistic points, or even an exact vehicle.

3. The General Specification of the Decision Support System

The main feature of the Decision Support System is to allow the user to generate planning results from:

- A set of UCCs (at least 1), representing Urban Consolidation Centres;
- A set of demand points (representing demand points and retail establishments in a urban area), characterised by their location and their availability times (time windows);
- A set of logistic orders (linking the UCC to the demand points);
- A set of vehicles composing the fleet of the UCC, characterised by fuel consumption and capacity.

Planning results can be optimised for a given objective function, usually distance or time. As such, the problem to be solved can be represented as a Vehicle Routing Planning problems, with time windows and capacitated vehicles. The solution to this problem can be provided through a proprietary algorithm developed by Softeco Sismat, based on a Branch-and-Bound algorithmic scheme. This software includes five modules (Figure 1): (i) Geographic Information System (GIS);

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(ii) Facility Planning; (iii) Location Routing Planning; (iv) Financial Evaluation Tool; (v) Output. The following sub-sections will present an overview of such sections.

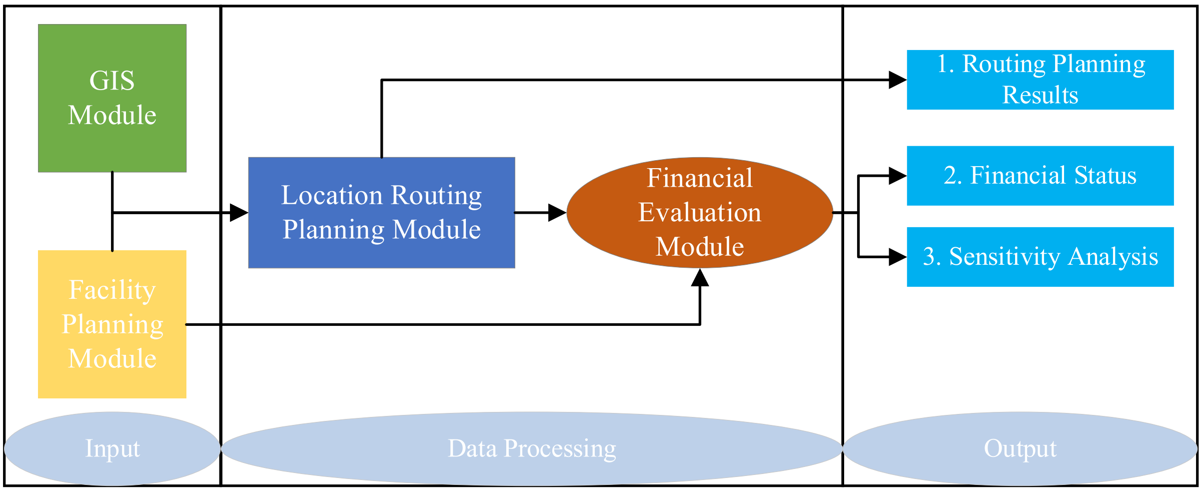

Figure 1 – Framework of the proposed DSS

3.1 GIS Module

Through a Graphical Use Interface, the user can specify the data to be used to customise the planning results. The integration of a Geographic Information System (GIS) within the Decision Support System is instrumental for the acquisition of some fundamental data input. The real city information in terms of street network, morphology of the city, buildings, properties can be acquired through the access to some pre-saved data, or by preprocessing external sources (OpenStreetmap data) (see Figure 2 below). As such, the interface has a high versatility, which can be used to deal with the UCC planning problems in different cities.

The second step is to define the location of the UCC. This can be simply done by clicking on the map, as shown in Figure 1. This can reflect the area which has been identified by the planner as a candidate location. The location of the UCC is determined by the planner according to the need to evaluate the potential of a given site.

The third step (see Figure 2) is the configuration of the demand points (consignee/consignor locations), which can be performed by two means, i.e. by importing an external file or restoring an existing plan scenario from a file. Also, the fleet of vehicles can be specified, and assigned to the UCC.

Fourth, the user can specify the amount of logistic orders to be created, which can be of three kinds: last mile, i.e. delivery from the UCC to the final user; first mile, i.e. pickup from a customer in town and consolidation in the the UCC (usually in view of a long range shipment with a courier service), and point-to-point, i.e. for pickup and deliveries both internal to the covered city. An

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important feature of the tool is the capability of randomly generating orders; this is a crucial need, as, in the planning stage, the decision-maker may not yet have an estimation of the demand for the UCC service. As such, the tool can generate orders according to different uptake scenarios; this can help the planner assessing the required uptake in order to have a financially viable service. If required to elaborate new hypothetic scenarios, UCCs and demand points can be moved or deleted (see Figure 3). The user can click on a UCC and edit the name of the base and the coordinates. The same can be done to a demand point. Alternatively, the UCC can be removed, by clicking on the base, and placed again later by clicking on the map where the new base should be placed. The demand points can be removed in case they are no longer needed.

3.2 Facility Planning Module

After all the GIS-related information has been acquired, the planners can also input some information related to the functioning of the UCC, through the associated Facility Planning Module. The following Table 1 shows the required parameters. Table 2 recaps all the actions required in the graphical user interface, along with pre-requisites and outcomes.

Data Categories
Hourly wage of UCC Operatives
Hourly wage of UCC drivers
Fuel Cost per Litre (per KWh in case of Electric Vehicles)
Fuel efficiency of the vehicle
Number of UCC Operatives
Working Days
Numbers of Vehicles used per day
Number of drivers

Table 1 – Parameters required for the Facility Planning Module.

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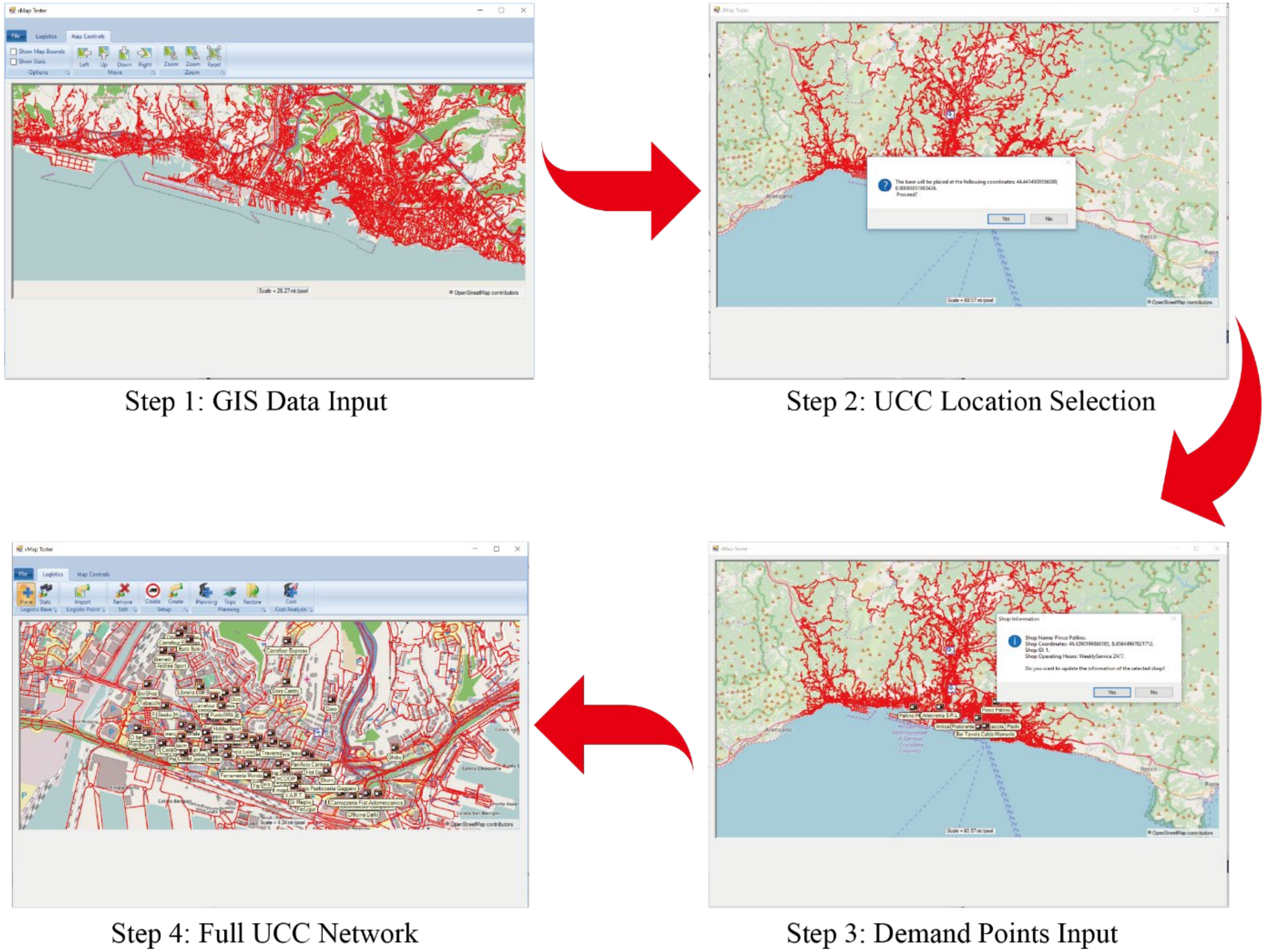

Figure 2 – GIS data acquisition process

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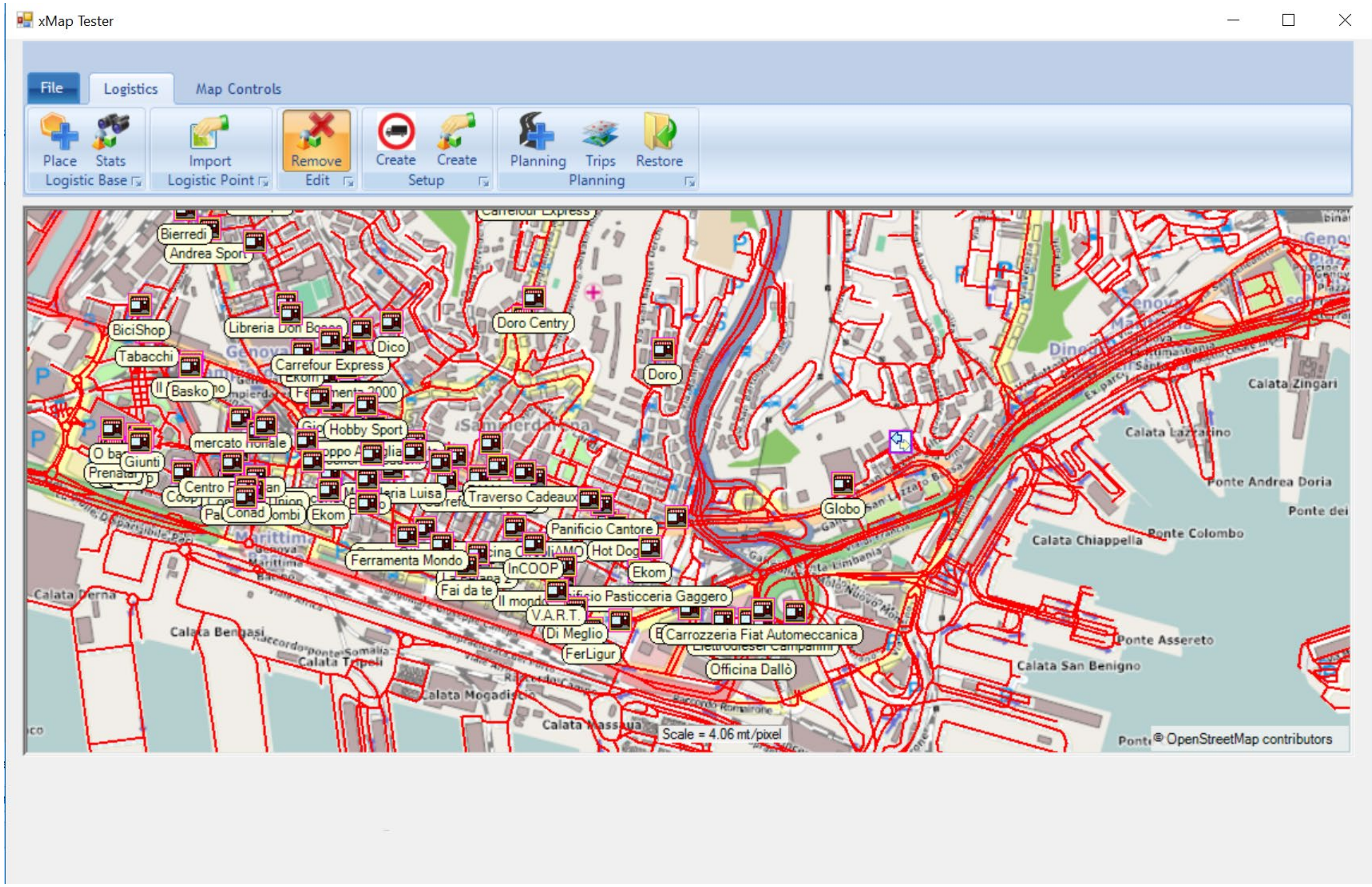

Figure 3 – Modification of the UCC network

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Specifics	Pre-requisites	Outcomes
Create UCC	None.	The base is created at the cursor position with a given ID and a given name.
Edit UCC/ Demand Point	At least a UCC or point must be present.	The base/point at the cursor position is moved to the updated coordinates, and/or has the name updated.
Delete UCC/Demand Point	At least a UCC or point must be present.	The base/point at the cursor is deleted from the corresponding data structures and the map is updated.
Restore Logistic Plan	A file containing the planning results previously generated.	The user is asked before proceeding, due to the fact that the previously created bases, points, orders, plan results, etc. will be removed from the decision tool. The data contained in the file are therefore imported.
Map Navigation/Zoom	None.	The user can select the corresponding buttons to navigate the map or zoom-in/zoom-out. Right-click can be used to navigate and wheel to zoom.
Coordinates on Click	None.	The user can left-click on the map in order to get the coordinates of that point.
Generate Fleet	A UCC must exist before creating the fleet.	The specified number of vehicles are specified (or randomly generated) at random and assigned to a UCC.
Generate Logistic Orders	A logistic point must exist before creating the orders.	The specified number and types of orders (i.e. first mile, last mile or point-to-point) are created (or randomly generated) and assigned randomly to the logistic points present.

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Import geojson	A file in the geojson format as obtained from openstreetmap.	The logistic points are imported from the geojson file and are given a new Id, the corresponding name (when present in the json), and the actual coordinates.
Sync/Async Planning	A set of vehicles, orders, demand points and at least one base are necessary. More specifically, the orders can be created in a randomised fashion, depending on their type: first mile, last mile and point-to-point. Vehicles can also be created in a randomised fashion. Demand points can be imported from openstreetmap. Bases are created on click.	The planning results are obtained and displayed to the user. The optimisation can be done for minimising distance or time or a customised objective function. In case of errors, the orders that are not delivered are given in a separate error message.
Export Planning Results	The planning results are necessary.	The planning results can be exported in json and converted to an excel document in order to be analysed. This would help produce statistics on the decision making problem of where to place the UCC.

Table 2 – DSS Specification

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3.3 Routing Planning Module

Once the problem has been defined, a planning scenario can be optimised for a given objective function, usually distance or time. As such, the problem to be solved can be represented as a Vehicle Routing Planning problem, with time windows and capacitated vehicles. The solution to this problem can be provided through a proprietary algorithm developed by Softeco Sismat, based on a Branch-and-Bound framework.

The generated report (see Figure 4) includes data about: the optimisation engine which has been employed, the planned location of the UCC, the vehicles associated with the plan, the total weight and volume associated to each delivery mission and to each vehicle, the demand points associated with each mission and their type (UCC, logistic point, load/unload area), the order identifiers and their type (first mile, last mile, point-to-point), the actual weight and volume aboard for each order (in kg and cm^3), the operations and their type, the distance travelled from the journey start and from the previous trip point, and the time duration from previous trip point.

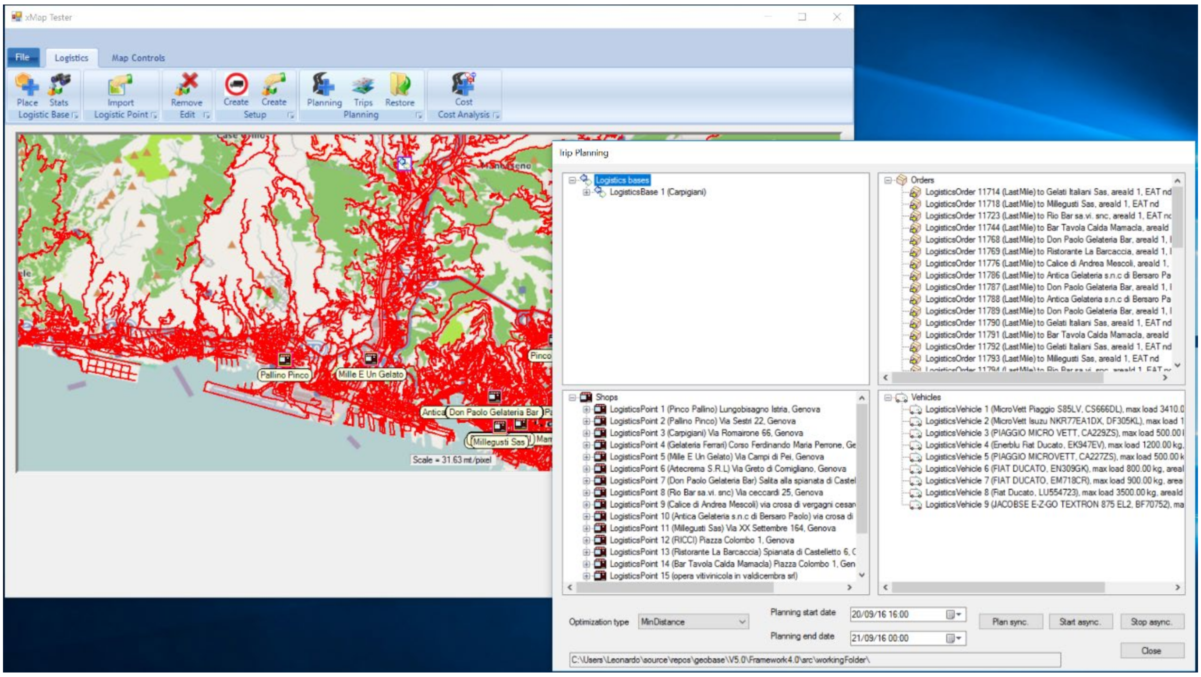

Figure 4 – Results of the Routing Planning Module

Based on the above data, statistics can be generated to evaluate costs related to: the vehicles and the driver for each vehicle, the trip points as different types of stops, the orders (depending on their weight/volume and the type), the kind of operation for each trip point, the distance from start or from previous trip point, the time duration from previous trip point or as aggregate data for the entire trip. Additionally, some derived statistics can be produced, based on the available

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data: e.g. the amount of $CO2$ produced, the amount of vehicles needed to complete the plan for all orders.

For a detailed overview of the cost calculations, readers can refer to Section 4.

After the planning has been completed, the user can also export the planning results in a *json* file for further analysis and elaboration in external tools (e.g. it can be converted in a MS Excel spreadsheet). The following Table 3 shows some key performance indicators which can be extracted from the Routing planning module.

Data Categories
Numbers of Demand Points served
Total Goods Weight transported
Total Travel Miles
Total goods handling time
Total driving time
Total stopping time

Table 3 – Key Performance Indicators from the Routing Planning module

3.4 Financial Evaluation

An important aspect of the DSS is the generation of an analysis report which can allow the user to decide whether the planned UCC is financially sustainable (in terms of cost-effectiveness) when placed in a specific location.

The input parameters provided in the "Facility Planning" module, and the data generated by the "Routing Planning" one will be processed in the "Financial Evaluation" module, in order to get an idea about the total overall cost which might be associated with the opening of an UCC in a given location. The following Figure 5 displays the users' interface (UI) of the Financial Evaluation Tool.

The data processing of the "Financial Evaluation Tool" can be divided in to three steps (see Figure 6). In the first step, the software automatically transfers the data generated by the "Routing Planning" module into the panel of "Planning Results" of the UI. In the second step, the UCC planner inputs the values of certain parameters into the control panel (such as the cost charged to users per parcel). In the last step, the DSS calculates the values of total cost and income. The cost associated with each logistics activities, in terms of "Cost of goods handling at UCC", "Cost of Last-mile delivery" and "Cost of goods receipt" are also be displayed in this module. The classification and calculation of the UCC cost is performed according to recent literature (see, for instance: Faure et al., 2016; Janjevic and Ndiaye, 2017).

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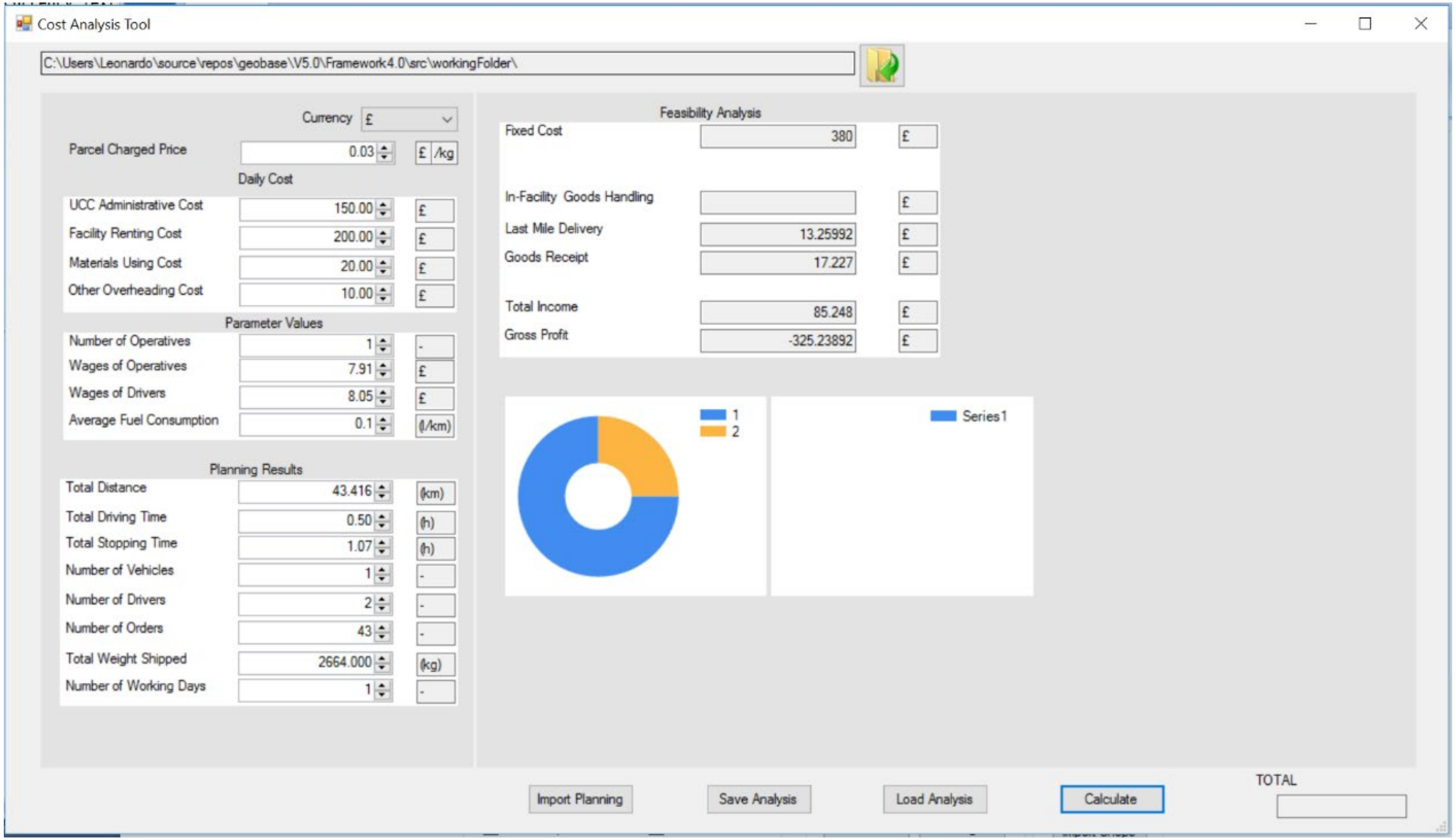

Figure 5 – Financial Evaluation User Interface

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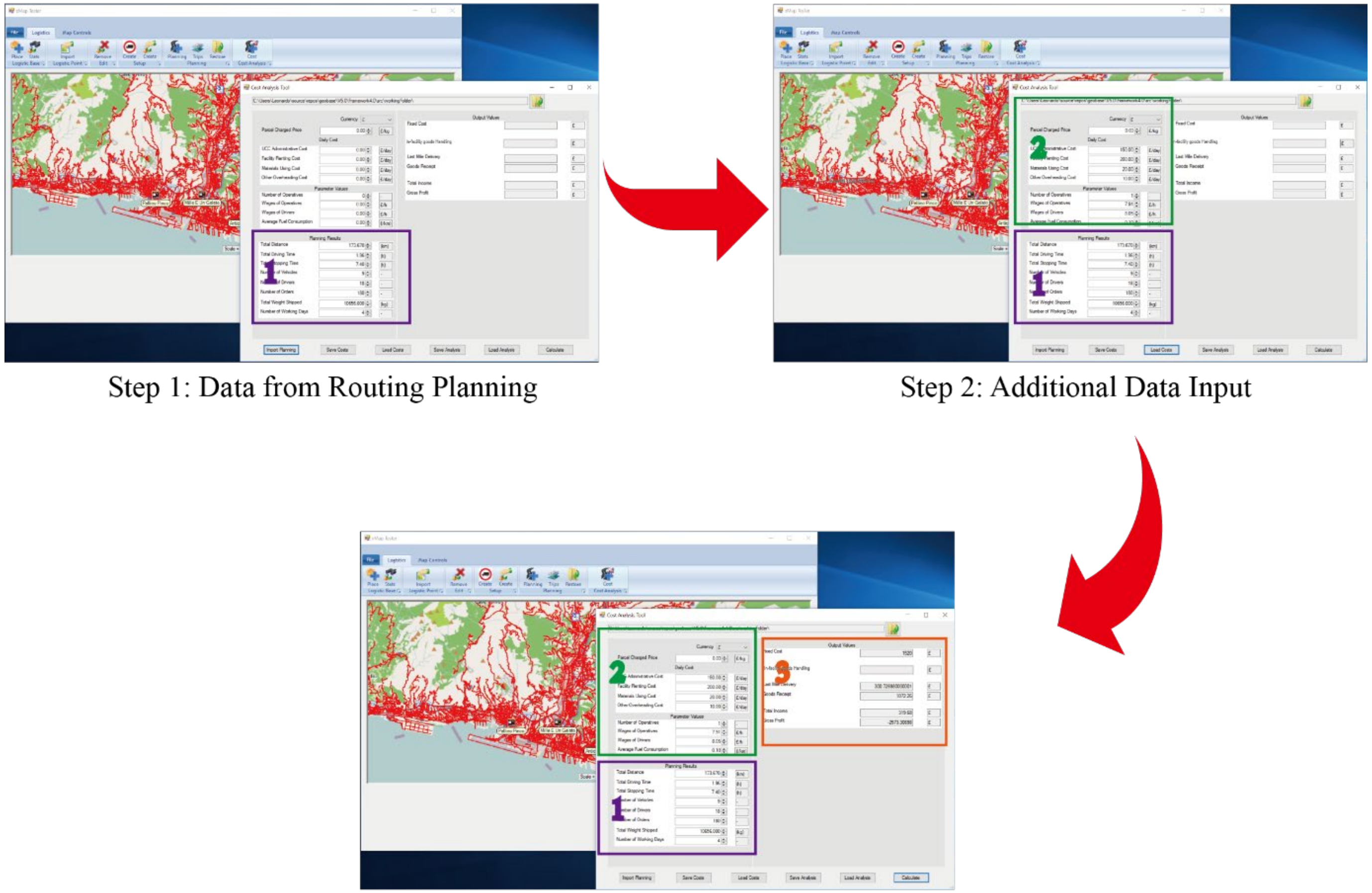

Step 1: Data from Routing Planning

Step 2: Additional Data Input

Step 3: Calculation Process

Figure 6 – Financial Evaluation calculation process

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3.5 Outputs and Decisions supported

Based on the current architecture, the DSS provides support against all the following decisions:

- *Use of UCC vs Direct Shipping.* The user can check what is the advantage of using a UCC for deliveries in an urban area or allowing direct shipping from carriers. In the first case, the base can be placed in the area of interest within the urban context. In the second case, the UCC can be placed at the boundary of the urban area and a virtual fleet can be configured so to model the scenario of direct shipping (with little or no consolidation happening). In order to acquire the data necessary to compare the two scenarios, the user can start with a set of logistic points that are identical in both scenarios and work with the same set of logistic orders created at random. Finally, the planning results can be used to derive measures to be used to compare the costs associated with the first scenario (UCC) with the second one (no UCC).
- *Location of the UCC.* The user can explore different options for the positioning of the UCC. In this scenario, the focus is on the place in the urban area that can be most beneficial in terms of cost-effectiveness. After importing demand points from OpenStreetMap data, the fleet can be configured and a suitable set of order can be generated. Then the set of candidate location, where the potential UCC would be placed, can be tested by running the planning model in each individual case. The planning results can therefore be used to analyse the costs linked to the UCC in each candidate location and draw out the relevant implications.
- *Type(s) of vehicles to be used.* One of the possible extensions to urban logistics planning is to consider the type(s) of vehicles that should be used in the UCC. The first choice can consider whether the vehicles to be used should be electric or diesel ones. The second choice can concern the size of the vehicles, which, in the DSS, is expressed in terms of capacity.

  One important measure for a public stakeholder (e.g. city council) that can be crucial in the urban freight transport decision making is the amount of CO_2 produced. By evaluating the deployment of electric vehicles, the corresponding planning results obtained from the decision tool can be analysed under this perspective. Therefore, by averaging the amount of CO2 saved per tonne-kilometre, measures can be derived to weigh the impact of such a policy. Finally, some measures can be derived also in the case of vehicles of different sizes. The stakeholder can consider the costs linked to having a set of larger vehicles or smaller ones, given the personnel needed to operate them and the amount of goods that can be transported in each scenario.

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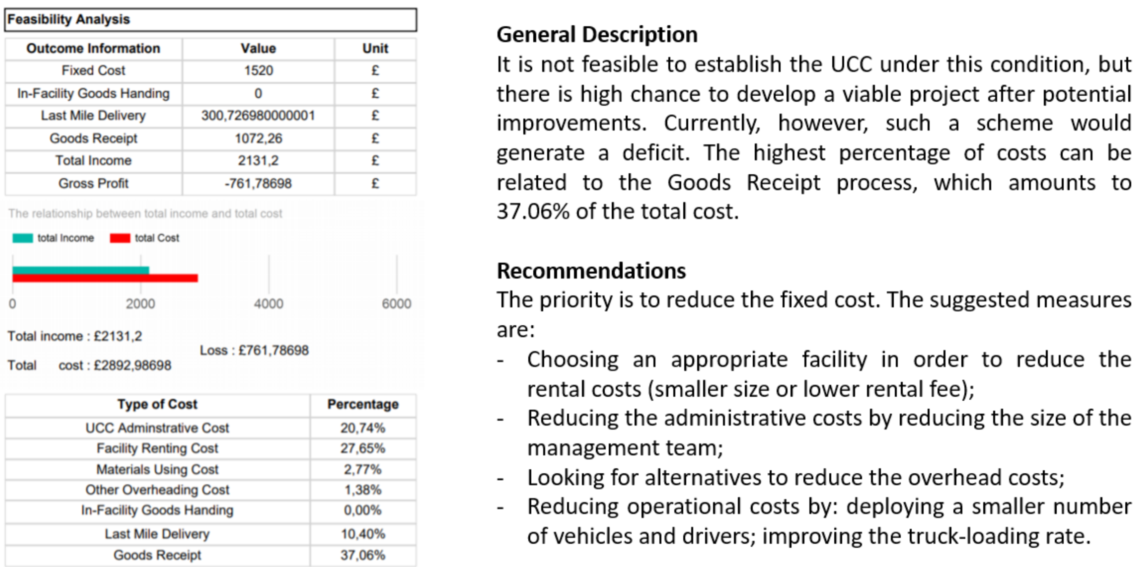
- *Number of vehicles to buy*. The user can be interested to understand the impact on costs due to the volume/weight of goods to be handled in a specific urban area. In this scenario, it is crucial to predict how many vehicles need to be bought. Therefore, a specific set of simulations can be run to check the impact of a certain number of vehicles compared to another. Finally, costs can be derived even in this case and compared in different scenarios. This will allow the user to plan the costs relative to the vehicles and the personnel involved. The outcome can eventually be compared to the income from the volume of goods processed and derive some measures on the optimal number of vehicles to be used.
- *Opening hours for the UCC*. An important aspect that can be taken into account involves the schedule of the UCC. This will include limiting the logistics operation to a predetermined set of hours where the vehicles can enter and leave the UCC to complete the logistic orders. A scenario like this could be motivated also to cope with the different opening hours of the logistic points. The scenario can be modelled to suit different operating times of the logistic points. The operating times considered can then be used to derive the schedule of the UCC. By running some tests, measures and insights on the cost-effectiveness of each schedule can be obtained.

The DSS provides a synthetic evaluation report, as shown in Figure 7, also providing some general comments about the feasibility of the scenario and some potential improvements.


Feasibility Analysis

Outcome Information	Value	Unit
Fixed Cost	1520	£
In-Facility Goods Handing	0	£
Last Mile Delivery	300,726980000001	£
Goods Receipt	1072,26	£
Total Income	2131,2	£
Gross Profit	-761,78698	£

Type of Cost	Percentage
UCC Adminstrative Cost	20,74%
Facility Renting Cost	27,65%
Materials Using Cost	2,77%
Other Overheading Cost	1,38%
In-Facility Goods Handing	0,00%
Last Mile Delivery	10,40%
Goods Receipt	37,06%

General Description

It is not feasible to establish the UCC under this condition, but there is high chance to develop a viable project after potential improvements. Currently, however, such a scheme would generate a deficit. The highest percentage of costs can be related to the Goods Receipt process, which amounts to 37.06% of the total cost.

Recommendations

The priority is to reduce the fixed cost. The suggested measures are:

- Choosing an appropriate facility in order to reduce the rental costs (smaller size or lower rental fee);
- Reducing the administrative costs by reducing the size of the management team;
- Looking for alternatives to reduce the overhead costs;
- Reducing operational costs by: deploying a smaller number of vehicles and drivers; improving the truck-loading rate.

Figure 7 – Final Feasibility Analysis Report

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4. Future Developments

As mentioned, the current version of the DSS was the result of a constant interaction between researchers, software developers and stakeholders from the urban freight transport sector. This has allowed the ProSFeT team to identify the needs of Local Authorities in terms of Decision Support Systems; this has also allowed the identification of dedicated training packages (thus informing the development of a purpose-made offer, which could also foresee the deployment of funding bids). Nevertheless, some further suggested improvements were identified as critical for the success of the DSS; these will be implemented in future development stages. For instance, the possibility of including cost and revenue sharing mechanisms (such as the ones developed in Ciardiello et al., 2018) in the financial evaluation module

It has to be remarked that, while the original commitment specified within the Grant Agreement just included the delivery of a specification and of a feasibility study, the ProSFeT project has managed to develop a functioning prototype of a Decision Support System. However, in order to foster the upgrade and upscale of the tool, the migration towards a *cloud-based* version of the system is probably required.

Another potential focus area for the follow-up of ProSFeT activities could be the development of an *educational* version of the DSS. Currently, the system has very similar features to the ones provided by similar packages (that are not much focused on last-mile delivery, though) such as *LogVRP*[1] and *Reveal*[2].

Specifically, this version could be equipped with a limited number of test-maps pre-determined locations for UCCs, and with some pre-loaded incoming orders (with the option for students to customise these). Students could then play with the tool, experimenting its functionalities related to the load consolidation and mission planning, optimisation and delivery operation stages. The educational version of the tool could be proposed to educational establishments delivering courses on Logistics and Supply Chain Management, Transport, Urban Planning. Also, an appropriate version of the tool could be developed for setting up an appropriate Lifelong Learning Programme (such as an *Erasmus+ Knowledge Alliance*) that could be targeting logistics and transport planners working at local city councils.

[1] www.logvrp.com
[2] https://www.verizonconnect.com/routist/

This project has received funding from the European Union's Horizon 2020
Research and Innovation programme under the Marie Skłodowska-Curie grant agreement No 734909

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Research and Innovation programme under the Marie Sklodowska-Curie grant agreement No 734909