Senator

Smart network operator platform enabling shared, integrated and more sustainable urban freight logistic

[D5. 6] Pilot Case 2 results and follow-up (Zaragoza) Report 2

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 861540

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Final version	2025-01-30	Final version including more information to complete the deliverable and partners contributions

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Table of contents

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 861540

List of figures

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 861540

List of Tables

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 861540

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List of abbreviations

ABBREVIATION	DESCRIPTION
AI	Artificial Intelligence
Am	Ante meridian
API	Application Programming Interface
CEx	Correos Express
CO_2	Carbon Dioxide
e. g.	Exempli gratia
GDPR	General Data Protection Regulation
GIS	Geographic Information System
GPS	Global Positioning System
H	hour
i. e.	Id est
IoT	Internet of Things
ITC	Information and Communication Technology
Km	Kilometre/s
KPI	Key Performance Indicator
LOS	Level of Service
NOx	Nitrogen Oxides
PDA	Personal Digital Assistant
pm	Post meridian
SUMP	Sustainable Urban Mobility Plan
SULP	Sustainable Urban Logistics Plan
ULL	Urban Living Lab
USE	Unidad de Servicio Especial (Special service delivery unit)
ZCC	Zaragoza City Council

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1 Executive Summary

The purpose of deliverable D5.6 – *"Pilot Case 2 results and follow-up (Zaragoza) Report 2"* is to report the results obtained in the Zaragoza pilot, considering its local requirements and peculiarities at month 53 (January 2025). Following the first issue of this report in month 30 (February 2023), this deliverable details the continued progress and final results of the pilot in Zaragoza. The dissemination level of this deliverable is designated as "public", it has been prepared by CORREOS, with the contribution of Zaragoza City Council (ZCC) and other partners and is based on internal procedures and templates by ZABALA.

2 Introduction

2.1 Purpose

The main objective of deliverable D5.6 is to report the final results and learnings obtained in the Zaragoza pilot. It describes background information, technical input, results and learnings related to *Local market consolidation and cross-docking, Network balance (virtual load exchange), Regional market (MercaZaragoza) consolidation and Smart management for loading bays around public market and in parking areas in four strategic points in the city*.

This deliverable also includes the physical, technological, legal, labour, etc. barriers faced by the project.

2.2 Relation to other Deliverables

This deliverable is closely related to:

- D1.2 Cybersecurity and Digital ID, which was submitted in month 12 (August 2021).
- D3.7 SENATOR ITC Platform and services integration. Release 2, which was submitted in month 49 (September 2024).
- D4.6 Design Catalogue for Zaragoza and Dublin, which was submitted in month 50 (August 2024).
- D5. 2 Pilot cases environmental assessment and guidelines for replication, which will be submitted in month 54 (February 2025).
- D5.3 Pilots cases requirements report 1 which was submitted in month 18 (March 2022).
- D5.4 Pilots cases requirements report 2 which was submitted in month 32 (September 2023).
- D5.5 Pilot Case 2 results and follow-up (Zaragoza) Report 1 which was submitted in month 30 (February 2023).
- D5. 7 Pilot Case 2 results and follow-up (Dublin) Report 1 which was submitted in month 30 (February 2023).
- D5.9 Data Quality process and validation rules, which will be submitted in month 54 (February 2025).
- Second Periodic Report Part B (August 2023)

3 Local market consolidation and cross-docking:

3.1 Data available

For the development of the Zaragoza pilots, the following data were made available to the project:

CORREOS data:

- Information on deliveries: anonymised using coordinates with a geopositioning error of 5 metres, volume, weight, dimensions and other characteristics relevant to the pilot. The quality of the information was not always complete from the source, so it had to be completed as needed. The information on deliveries to be delivered in the city of Zaragoza (predictive report) has been extracted and shared with the project teams daily since February 2024, and prior to that date through extractions based on historical data. Those files were not fully completed in terms of geoposition, and many extra developments had to be done from Correos to increase the data quality, however, it was not possible to exceed 40% of geopositioned shipments in these files, so for the 1C and 1D pilot specific corrective actions had to be carried out. This information, as well as the resources that logistic operators let available for the operation was necessary to feed the route optimisation and the KPIs.

Table 1: Example of coordinate density of one of the Correos distribution units proposed by SENATOR

Month	Total routes	Total stops	Total shipments
February	243	6989	5921
March	347	11262	9180
April	390	12727	10443
May	201	6074	5224
June	226	5334	4617
July	255	6672	5490
August	377	7477	6348
September	133	3960	3265

- Geopositioning information from Correos mail carriers' PDAs, anonymised and with a geopositioning error. These data have been necessary to monitor the current operation (not related to planification proposed by SENATOR), validating the real-

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time information tracking functionality by the logistics operator of the delivery, as well as feeding the aggregated display of shipment density for the City Council of Zaragoza.

Table 2 :Tracking of PDAs last year in Zaragoza´s ULL (Source Deliverable 3.7)

Month	PDAs	Tracks
February	37	1667980
March	30	1816612
April	35	2085367
May	30	1792580
June	28	1386622
July	32	1918341
August	30	1721465
September	29	594620

- Geolocation information of vehicles of Correos mail carriers, anonymized. These data have been necessary to monitor the current operation (not related to planification proposed by SENATOR), validating the real-time information tracking functionality by the logistics operator of the delivery, as well as feeding the aggregated display of traffic density associated with freight transport for the City Council of Zaragoza.

Table 3: Tracking of vehicles last year in Zaragoza´s ULL (Source Deliverable 3.7)

Month	Vehicles	Tracks
February	25	320835
March	25	259784
April	31	306134
May	28	556416
June	28	471450
July	28	498258
August	29	484779
September	27	156186

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Correos Express (CEx) data:

- Mainly anonymised information of the shipments has been shared, through one-off extractions according to the needs of the project, for pilots 1A, 1C and 1D. The data extraction of Correos Express was simpler than that of Correos, from the point of view of data quality, due to the fact that the product catalogue is smaller and better informed by type of product.

Guaranteeing the complete anonymization of the information was extremely complex. In addition, the obligation to inform all mail carriers and drivers of Correos in Zaragoza in writing was fulfilled, collecting the signed acknowledge, where information was provided on the data to be collected, the purposes and guaranteeing full compliance with current regulations on data protection.

Finally, it is worth highlighting the great complexity in obtaining the information necessary for the operation of the SENATOR platform, both in terms of the quality of the information and the standardisation of the data, which has been a great challenge for all the development and technology teams of the Correos and Correos Express that have participated in the pilots.

3.2 Pilot 1A: City optimization

Four stages are considered for this pilot (A, B, C, D). Phase A of this pilot consisted of putting together all the shipments from Correos and its linked third-party Correos Express of one day, run the system and quantify the savings and identify the needs for data normalization when they come from different sources.

Among the restrictions introduced in the optimization algorithm, two work shifts were considered for Correos and one work shift was considered for Correos Express, with an estimated average service time based on historical and geographic data from Correos, and for those shipments that did not have dimensions or weight in the logistics operator's database, a standard was assigned according to each operator rules, since this is essential data for optimization.

In order to use the data from the logistic operators for launching this pilot, the information regarding the shipments had to be anonymised due to the General Data Protection Regulation (GDPR), and following the recommendations of the legal team at Correos and Correos Express, so that:

- The complete shipping code is never shared, but rather anonymised, by replacing certain characters in it.
- Personal information (name, telephone number, address, etc.) is never shared.

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- The delivery coordinate is modified to introduce an error of at least 5 metres in the position, so that the exact delivery coordinate or position is not shared with the platform, guaranteeing the confidentiality of the information.

This anonymisation process was very complex and required a great effort from both the legal and technological sides.

Data of shipments delivered by Correos and Correos Express the 14th of May of 2024 were used for this pilot, reaching more than 18,000 parcel shipments in total.

The SENATOR's optimization was designed for comparing current operation of the logistics operators and the SENATOR proposed routes. The number of routes proposed by SENATOR is 15% lower than those made by the operators, but with 412 shipments from Correos and 118 from CEx not included in the optimization system. In the actual operation, all the shipments entered in the system were delivered or processed, so the delivery efficiency was lower in the SENATOR optimization. The SENATOR optimization planned 15% fewer routes than the actual operation, however, it must also be considered that there is a volume of shipments corresponding to unregistered letters and shipments that could not be entered into the SENATOR optimization system since they are "uninformed" shipments, and that were distributed in the actual operation, so this data cannot be analysed without considering this part of the delivery.

The analysis of the data and post-processing of the information from this pilot took several months of work, so in subsequent pilots the scope had to be narrowed to obtain optimization results in shorter times. Several testing were made as experimentations, and their results analysed exhaustively. Some adjustments (such as the pre-processor as a needed part of the system) arose in this process that were done in several months. This module manages all the information so it could be processed by the optimizer. As the data need to be sent standardized to the platform, it prevents of working individually with each new operator. In addition, another of the main conclusions of route optimization is that, if the delivery territory is divided into smaller areas, computational efficiency is gained, although on the other hand some operational efficiency is lost. Even that, as it was a really high volume of information the optimization took several days in Deusto premises so the completion and cleaning of data needed to feed the optimization module could be automatized along with launch of all the parallel tests also the reconstruction of the final resultant routes (planification). The time could be reduced by using servers with a higher computing power (but this would be costly).

Since the time is exponential with respect to the volume of the orders, Deusto team researched how to cluster the orders to divide the work into smaller tasks (i.e.: the orders to be delivered on the north have no relations to those on the south). Thanks to this approach, a 6-day workflow could be reduced to a one-hour workflow. Optimization at the city level is not feasible because the computing times required are too high, which is why in the following pilots' optimization is carried out by delivery unit.

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In most of the routes, all orders were delivered according to the simulation, but there were some instances where orders remained undelivered, as was the case of USE-1 in both shifts. In this case, the input data was reviewed and there were many orders undelivered in the old town area due to access restrictions being a low-emissions zone, because USE-1 only has motorised routes, both with combustion vehicles and motorcycles. This does not happen in the day-to-day operations since the distribution in this area is made using routes on foot.

The geopositioning of the shipments was carried out with a positioning error of 5 meters, which caused of one of the shipments to fall into the river so it couldn't be delivered by the system. This type of error could not be avoided because it is one of the restrictions necessary for data protection when sharing information on shipments between logistics operators and the platform, to guarantee anonymized information. In this case, the shipment was identified as unable to deliver and was not assigned to any route in the proposal planification.

Each logistics operator optimizes its operations in the cities quite well, and what SENATOR allows is to improve the performance of new mail carriers, as well as allowing the network balance between logistic operators, improving the overall efficiency of the network without compromising competitiveness.

Additionally, anonymized and aggregated information is of great value to city councils and the improvement of mobility and urban planning plans.

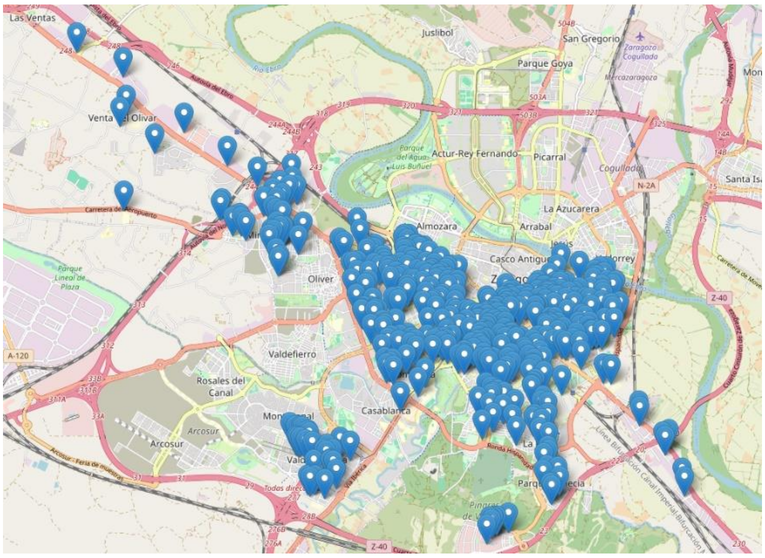

Figure 1: Example of coordinate density of one of the Correos distribution units proposed by SENATOR

Lessons Learned

Optimization at the city level is not feasible because the computing times required are too high, which is why in the following pilots' optimization is carried out by delivery unit.

Each logistic operator optimizes its own routes quite well, so the great advantage offered by SENATOR is the possibility to share (considering preliminary agreements) the logistic networks.

3.3 Pilot 1B: Including picking up in the planning

The pilot tested the planning system including the need for new orders from the markets. For this, shipment data from Correos' systems were sent (no integration was considered) so they could be manually included to the planning system. In this stage, real data of previous days execution was used to validate planning models and try new planning strategies. Once it was validated that the planning system could assume this new planning including new points for pick-up and delivery, a pilot simulating a real day operation with data of the deliveries already done could be made.

Starting data (Bilbao)

As starting data refrigerated routes from Correos in Bilbao and Zaragoza were used. The reason for initially using 3 routes from Bilbao was the urgency of having information, as the data for Zaragoza would not be available until later. It is worth mentioning that the use cases vary in each city, which required multiple approaches to tailor the optimization module's requirements and functionalities, as well as the platform, for each one individually.

The following information was used as starting data:

- Three routes that operate with diesel vans in Bilbao, and that transport refrigerated orders in isothermal boxes. These 3 routes were carried out on March 4, 2024.
- Three routes operating with 3 diesel vans in Zaragoza, two of them traditional diesel and another transformed to be a refrigerated van. These routes correspond to March 15, 2024.

These routes have been the ideal ones to carry out this pilot, since they correspond to routes that work specifically refrigerated shipments or that need active refrigeration, or to maintain the temperature, and are the ones in which orders from the markets should be introduced.

The original cold routes of Bilbao, optimized without the SENATOR algorithm correspond to the following picture:

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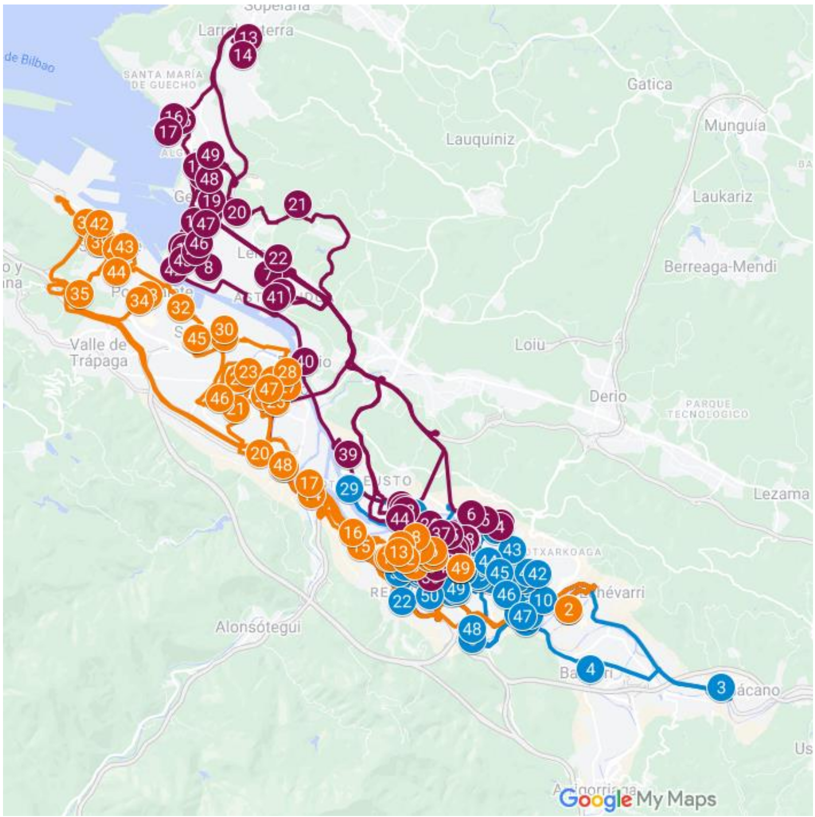

Figure 2: Original routes proposed by Correos customer in Bilbao (Pilot 1B)

There are three routes that are differentiated on the two banks of the estuary and the city centre (Figure 2).

According to the original planning, these routes leave the Correos operating unit (USE 1), go to the outskirts (Etxebarri area) to collect the shipments at the customer's facilities, and start delivering from there, at 9 am. Among the restrictions given by the customer, each delivery must follow the order given by them and must be delivered in a specific time slot.

These three routes must make a change of driver at 15:00 in the delivery unit, to start the afternoon shift and finish the routes again in the Correos operational unit (USE 1).

It must be taken into account that this Correos customer provides 3 optimised routes without considering the shift change at 3pm, so, according to the starting data, these 3 routes correspond to the following data:

Table 4: Original routes from Correos customer in Bilbao (Pilot 1B)

Route	Start	End	Time	Stops	Parcels	Km	Time (h)	Parcels/Km	Parcels/hour
Route 1	09:00	17:45	8:45	50	50	81.53	8.8	0.6	5.7
Route 2	09:00	18:15	9:15	50	50	144.98	9.3	0.3	5.4
Route 3	09:00	17:15	8:15	47	47	120.37	8.3	0.4	5.7

For this use case, the three routes started in Araba Kalea, 7 and ended in USE Bailén.

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Based on these data, two scenarios were modelled:

- Scenario 1: includes two delivery shifts, which must necessarily change drivers in the operating unit, leaving at 8am the 3 vehicles of the unit to the customer's facilities, with a change of driver in the operating unit, and an afternoon shift that starts at 3pm. The results show 2 routes that start in the morning, and continue in the afternoon shift with another driver, and a third route (route 1) that is carried out entirely in the morning shift.

Table 5: Scenario 1 in Bilbao (Pilot 1B)

Route 1	Route 2	Route 3	Indications
08:00	08:00	08:00	Leaves USE 1
08:13	08:13	08:13	Arrives to the client facilities (Etxebarri)
08:44	08:30	08:50	Starts delivery
14:32	11:47	14:24	Arrives to USE 1
	15:00	15:00	Starts evening route
	18:54	16:26	Arrives to USE 1 and ends the route

- Scenario 2: it is modelled as if you worked in a single shift in the day, but forcing a mandatory stop at USE 1 at 3pm, so that it is modelled as 3 routes in this way:

Table 6: Scenario 2 in Bilbao (Pilot 1B)

Route 1	Route 2	Route 3	Indications
08:00	08:00	08:00	Leaves USE 1
08:13	08:13	08:13	Arrives to the client facilities (Etxebarri)
09:00	09:00	09:00	Starts delivery
14:36		11:57	Driver change (start)
14:55		14:55	Driver change (end)
15:07	14:45	20:04	Arrives to USE 1 and ends the route

The comparison between the initial scenario and the two modelled scenarios is as follows:

Table 7: Comparison among original route and SENATOR proposal (Pilot 1B)

	Stops	Parcels	Km	Time (h)	Parcels/Km	Parcels/h
Original	147	147	346.9	26.3	0.4	5.6
Scenario 1	140	147	181.0	19.4	0.7	8.6
Scenario 2	140	147	280.1	25.7	0.6	6.0
Scenario 1			48%	26%	65%	54%
Scenario 2			19%	2%	31%	6%

The costs have also been analysed, considering not only the costs of the vehicles, but also the costs associated with load handling times, resulting in the following costs:

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Table 8: Total savings by scenario and per shipment (Pilot 1B)

	Scenario 1	Scenario 2
Total savings	23%	14%
Savings per shipment	23%	14%

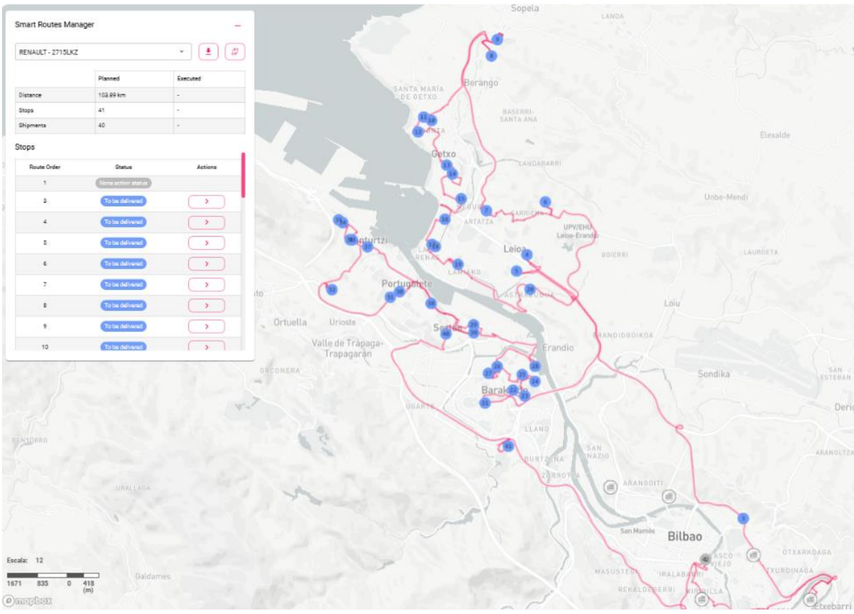

Figure 3: Route 1 SENATOR optimization for Bilbao (Pilot 1B)

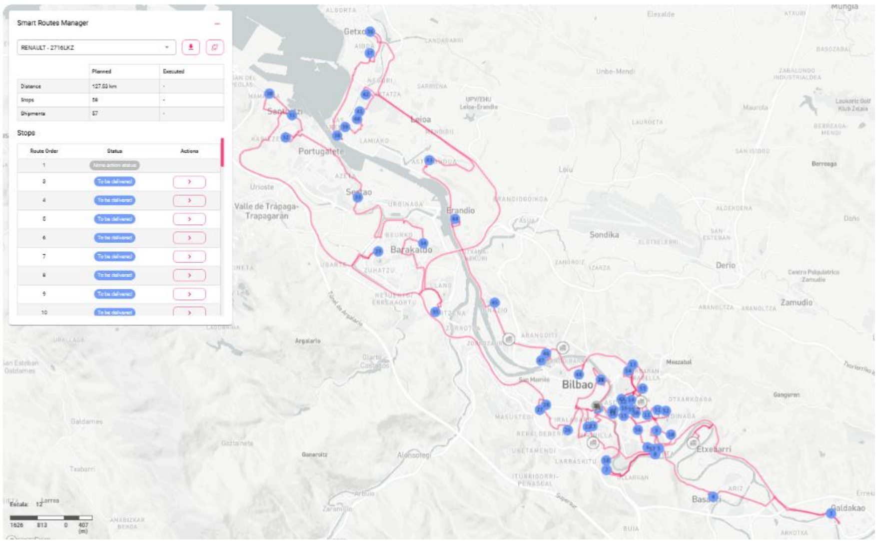

Figure 4: Route 2 SENATOR optimization for Bilbao (Pilot 1B)

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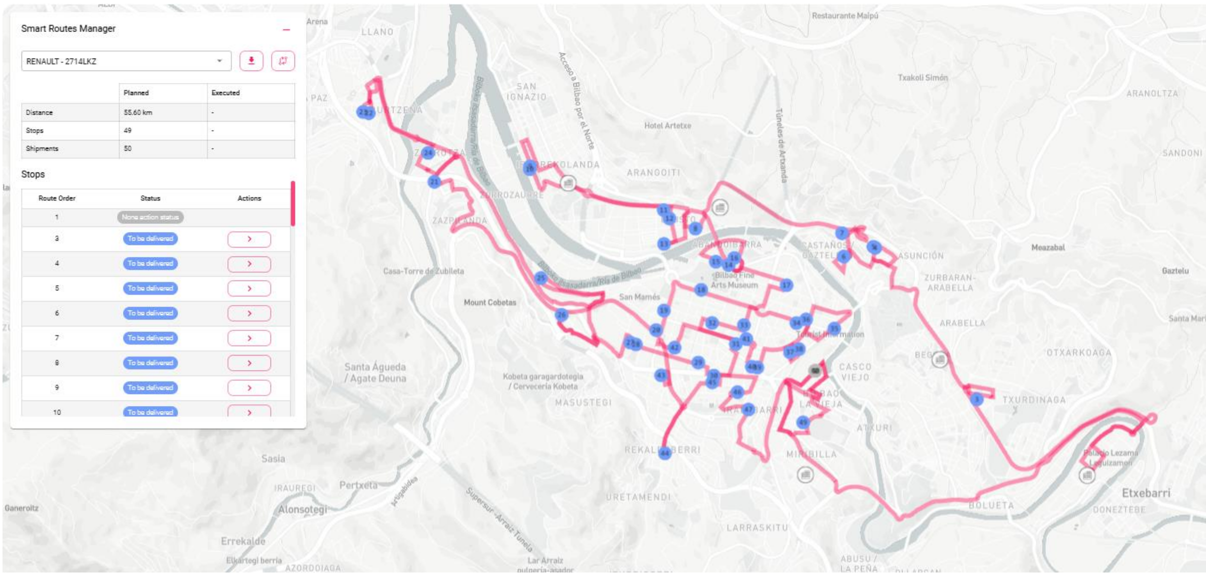

Figure 5: Route 3 SENATOR optimization for Bilbao (Pilot 1B)

Main conclusions:

- Both scenarios 1 and scenario 2 represent a significant saving in kilometres travelled compared to the initial optimization proposed by the customer. Scenario 1 is the one with the greatest savings in kilometres, and therefore emissions, with 48% fewer kilometres travelled.
- In time it is substantially reduced, especially in scenario 1, being 26%.
- Both modelled scenarios increase productivity (parcels per hour) by 54% and 6% respectively.
- Efficiency is also improved by 65% and 31% by increasing the number of shipments per kilometre travelled.
- In both scenarios, by forcing the start of the route in the afternoon at 3pm, you have several hours of routes that are not in distribution, especially in:
    - Scenario 1: Route 2 in the morning arrives at the unit at 11:47 and does not continue until 15:00 when the driver arrives in the afternoon.
    - Scenario 2: this happens with Route 3, which in the morning ends the shift at 11:57 a.m. and does not continue until 2:55 p.m.
- The routes do not have a homogeneous duration, so there are some in which there are downtimes (for example in scenario 1 route 2 from 11:47 to 15:00) but in the afternoon it ends at 18:54, much later than the other routes, which end at 14:32 (route 1) and 16:26 (route 3). This happens in a similar way in scenario 2.

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- From a cost point of view, scenario 1 is the most advantageous as it results in a saving of 23% of costs, followed by scenario 2 which represents a saving of 14%.

Zaragoza case results

The executed routes of Zaragoza, without using the SENATOR optimization algorithm are the following:

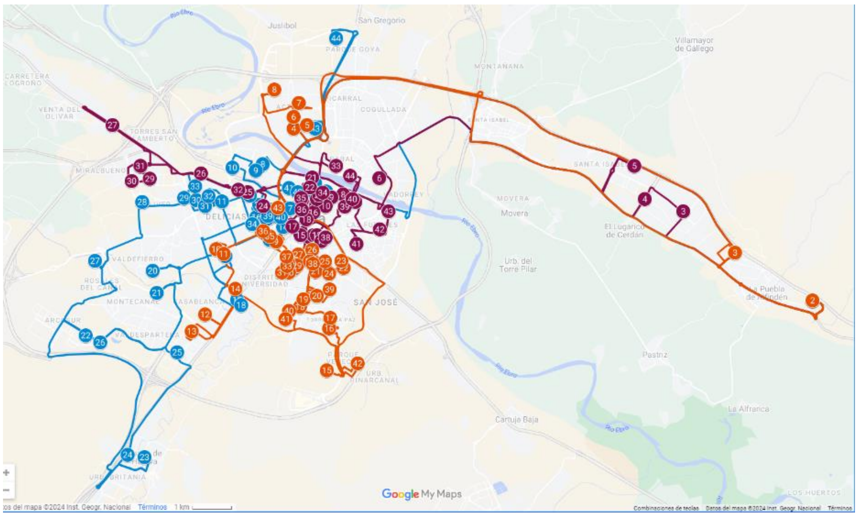

Figure 6: Original routes before SENATOR optimization

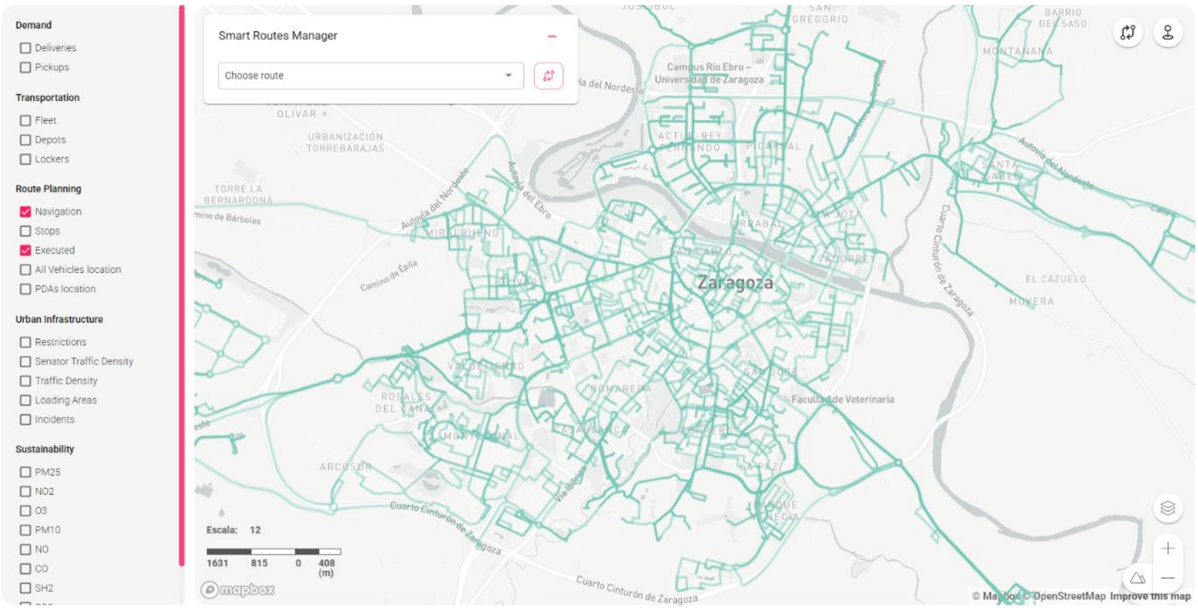

Figure 7: Original routes given by Correos customer for Zaragoza (Pilot 1B)

The 3 routes leave the Correos operating unit, go to La Puebla (location of the customer's facilities) and the 3 routes start the delivery from that location and end at the unit (USE 1 in Zaragoza) and correspond to the following data:

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The three routes of this pilot start at the customer's facilities and end at USE1:

Table 9: Original routes for Correos customer in Zaragoza (Pilot 1B)

Route	Start	End	Time	Stops	Parcels	Km	Time	Parcel/hour	Parcel/Km
Route 1	09:00	18:20	9:20	42	42	123,46	9,33	4,50	0,34
Route 2	09:00	17:20	8:20	43	43	93.62	8.33	5.16	0.46
Route 3	09:00	16:50	7:50	43	43	96.03	7.83	5.49	0.45
TOTAL				128	128	313.11	25.50	5.05	0.42

Based on these data, the following scenarios are modelled:

- SENATOR Optimization: we have 3 routes with morning and afternoon schedules that start at USE 1, go to La Puebla and load the orders, leave for delivery and return to USE 1. The driver change is made at 3:00 p.m. at the location where the route is at that time.

Table 10: SENATOR proposal for Correos customer in Zaragoza (Pilot 1B)

Route	Start	End	Time	Stops	Parcels	Km	Time	Parcel/hour	Parcel/Km
Route 1	08:15	15:24	7:09	29	30	117.09	7.2	4.20	3.90
Route 2	08:15	18:33	10:18	46	47	80.01	10.3	4.54	1.70
Route 3	08:15	18:33	10:18	50	51	87.13	10.3	4.95	1.71
TOTAL				125	128	284.23	27.8	4.57	2.44

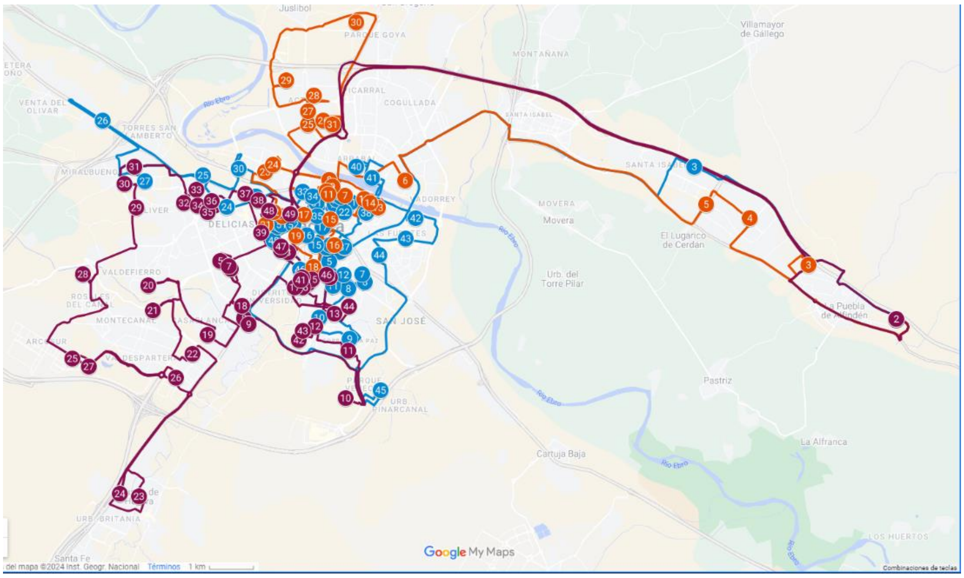

Figure 8: Scenario 1. SENATOR optimization for Zaragoza (Pilot 1B)

- Scenario 1: a single vehicle leaves USE 1 at 7:00 a.m. and goes to the customer's facilities in La Puebla (arrives at 7:16 a.m.), picks up the orders from the 3 routes and leaves (8:16 a.m.) to the San Vicente de Paul Market (arrives at 8:30 a.m.) to break and consolidate the load of the shipments to deliver the 3 routes from that location at 9:00 a.m., and finish the distribution in USE 1.

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Table 11: Scenario 1 for Correos customer in Zaragoza (Pilot 1B)

Route	Start	End	Time	Stops	Parcels	Km	Time	Parcel/hour	Parcel/Km
Route 1	09:00	18:35	9:35	48	49	67.9	9.6	5.11	1.38
Route 2	09:00	15:38	6:38	29	30	44.73	6.6	4.52	1.50
Route 3	09:00	18:27	9:27	47	49	103.48	9.5	5.19	2.11
TOTAL				124	128	216.11	25.7	4.94	1.66

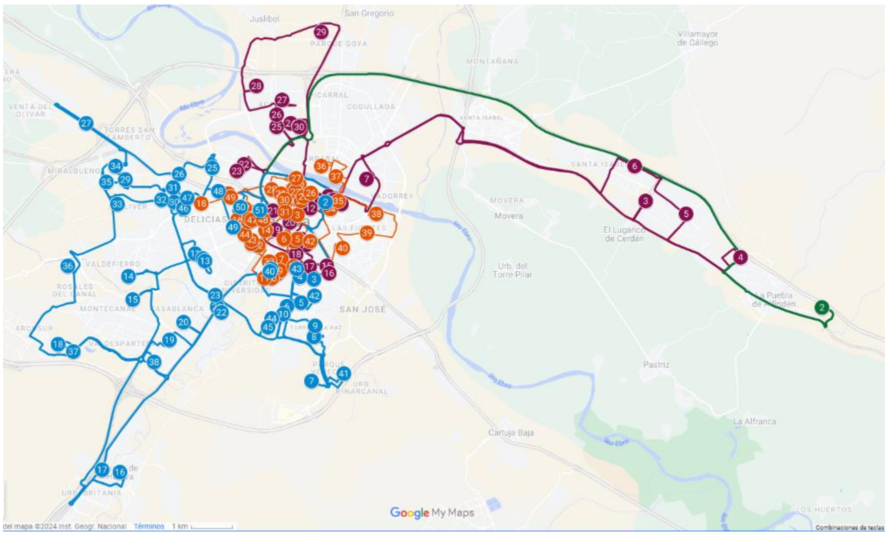

Figure 9: Scenario 2. SENATOR optimization for Zaragoza (Pilot 1B)

- Scenario 2: a single vehicle leaves USE 1 at 7:30 and goes to the customer's facilities in La Puebla, picks up the orders from the 3 routes and returns to the San Vicente de Paul Market to make the breakdown and consolidation of the load of the shipments to leave for delivery of the 3 routes from that location at 9:30am, and finish the distribution in USE 1.

Table 12: Scenario 2 for Correos customer in Zaragoza (Pilot 1B)

Route	Start	End	Time	Stops	Parcels	Km	Time	Parcel/hour	Parcel/Km
Route 1	09:30	18:35	9:05	46	47	87.06	9.1	5.17	1.85
Route 2	09:30	15:21	5:51	36	36	45.11	5.9	6.15	1.25
Route 3	09:30	18:29	8:59	42	45	79.49	9.0	5.01	1.76
TOTAL				124	128	211.66	23.9	5.45	1.62

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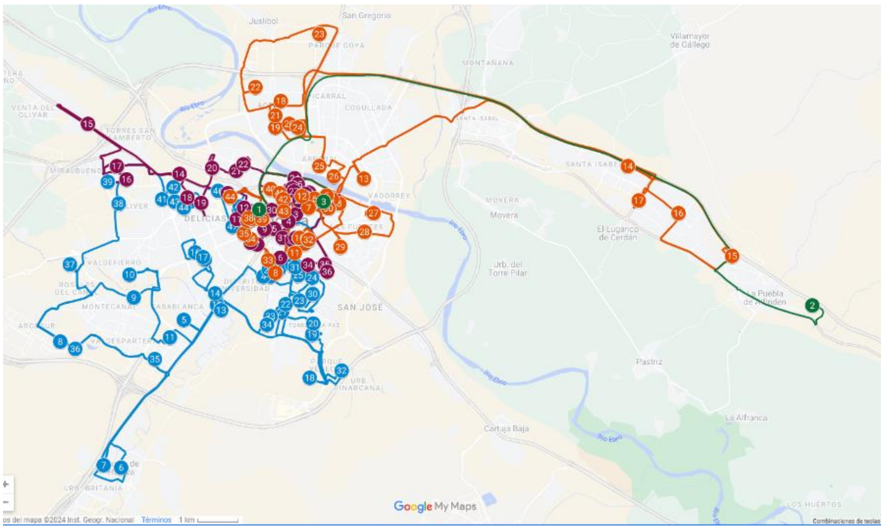

Figure 10: Scenario 2 for Correos customer in Zaragoza (Pilot 1B)

The comparison between the initial scenario and the two modelled scenarios is as follows:

Table 13: Comparison among original routes and SENATOR proposal in Zaragoza (Pilot 1B)

	Stops	Parcels	Km	Time (hours)	Parcel/hour	Parcel/Km
Original	128	128	313.11	25.5	5.05	0.41
SENATOR optimization	125	128	284.23	27.75	4.57	2.43
Scenario 1	124	128	216.11	25.67	4.94	1.66
Scenario 2	124	128	211.66	23.92	5.44	1.62
SENATOR optimization			9%	-9%	-9%	486%
Scenario 1			31%	-1%	-2%	300%
Scenario 2			32%	6%	8%	291%

The costs have also been analysed as in the previous case:

Table 14: Savings per scenario and per shipment in Zaragoza (Pilot 1B)

	SENATOR Optimization	Scenario 1	Scenario 2
Total savings	-7%	2%	10%
Savings per shipment	-7%	2%	10%

Main conclusions:

- The 3 scenarios represent a significant saving in kilometres travelled compared to the initial optimization. Scenario 2 is the one with the greatest savings in kilometres, and therefore emissions, with 32% fewer kilometres travelled.

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- In time it is reduced only in scenario 2, while in optimization and scenario 1 it is slightly increased.
- Only scenario 2 increases productivity (parcels per hour) by 8%
- Efficiency is also exponentially improved by increasing the number of shipments per kilometre travelled.
- It is striking that of scenarios 1 and 2, both being consolidation of the 3 routes in the San Vicente de Paul market, the one that is more advantageous is scenario 2, being the one that comes out for distribution later of the two.
- From the point of view of costs, scenario 2 is the most advantageous since it materializes in a saving of 10% of costs, while the other two scenarios represent a saving of 2% (scenario 1), and an increase of 7% in SENATOR optimization.

Including picking up in the planning (Pilot 1B part 2)

Once the optimization of the SENATOR system is validated, including the picking up functionality had to be tested.

The original idea of the project was to use the shipments from the Mercadeando municipal platform, in order to take advantage of the benefits of SENATOR and the routes in progress so that emissions from deliveries could be reduced. To this end, the vehicle typology functionalities were also included in the platform, identifying refrigerated vehicles, not just electric ones, in order to develop this part of the pilot.

The Zaragoza City Council was strongly committed, not only to the launch of the Mercadeando platform, whose first orders delivered by Correos were released in October 2023:

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Figure 11: Mercadeando screenshot (I)

Figure 12: Mercadeando screenshot (II)

But also, in order to facilitate the optimisation of market routes, testing the order collection functionality, and taking advantage of the synergies of the routes in execution, the City Council of Zaragoza made two spaces in the San Vicente de Paul market available for the project, as well as a cold storage room in said market. Those spaces were conceived to consolidate orders from the market and thus facilitate the breaking up and consolidation of loads for the logistics operator Correos, ensuring that the cold chain was not lost.

Figure 13: San Vicente de Paul market (SENATOR facilities (I))

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Figure 14: San Vicente de Paul market (SENATOR facilities (II))

However, the number of orders was not high enough to be able to use these spaces for shipment consolidation, despite the good results of the modelling. These good results of the modelling were due to the central location of the market with respect to the final recipients of the shipments.

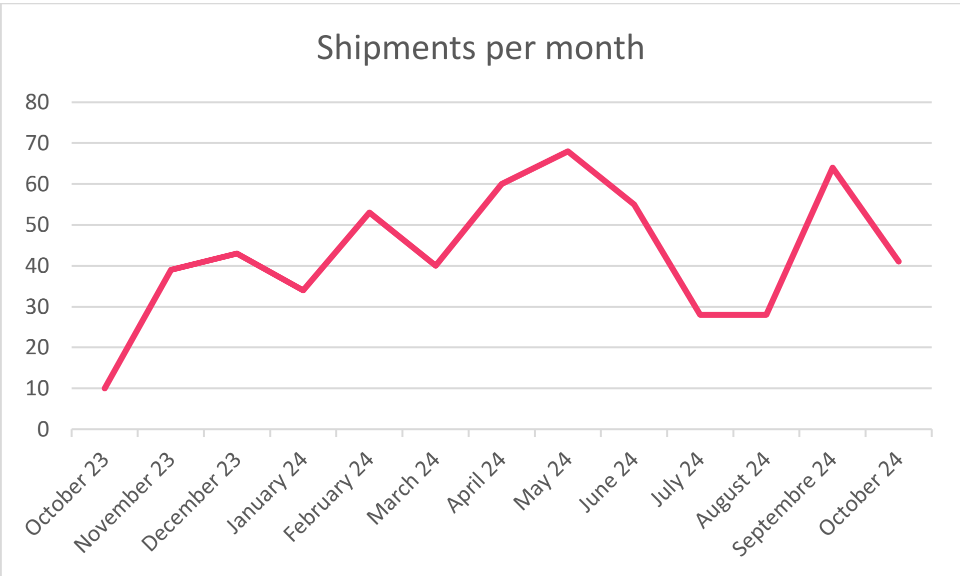

Figure 15: Shipments per month (from Mercadeando platform)

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The collection functionality has been tested on the SENATOR platform thanks to the joint work of the technological partners, University of Deusto, DotGis and Software AG, jointed with Correos; and yielding the following results:

In order to test the picking up in the planning part, three possible scenarios have been modelled:

- Original Route: refers to the route generated by the optimizer for 10 deliveries. In the map (Figure 16) the pick-up locations are marked as deliveries, differentiated in three colours (red, green and black) and with the letters P for pick-up and D for Delivery. In this scenario a total of 64.78Km have been travelled.

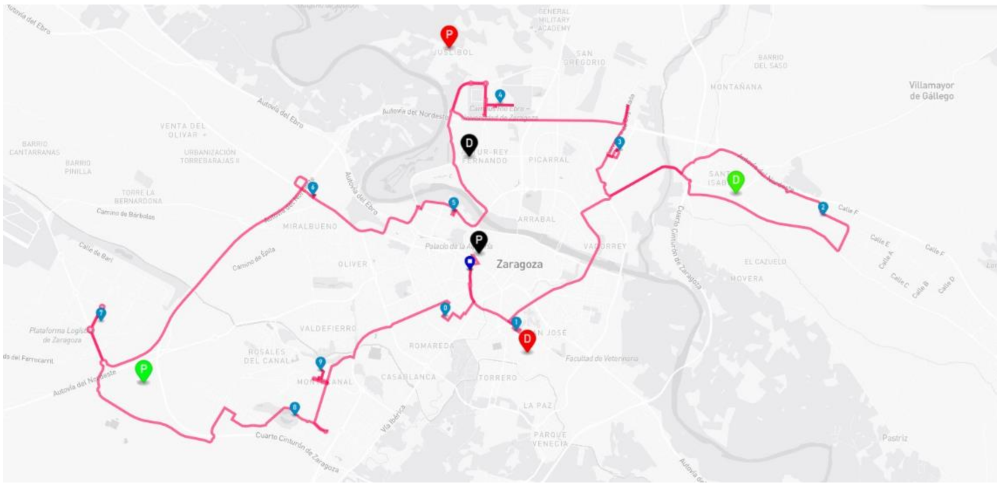

Figure 16: Original route (Pilot 1B part 2)

- Scenario 1 (Picking up at the beginning of the route): in this scenario (Figure 17) it is simulated that the first three packages of the original route have already been delivered, so the vehicle would be in the initial part of the route and three new pick-ups/deliveries arrive. In this scenario a total of 98.72Km have been traveled.

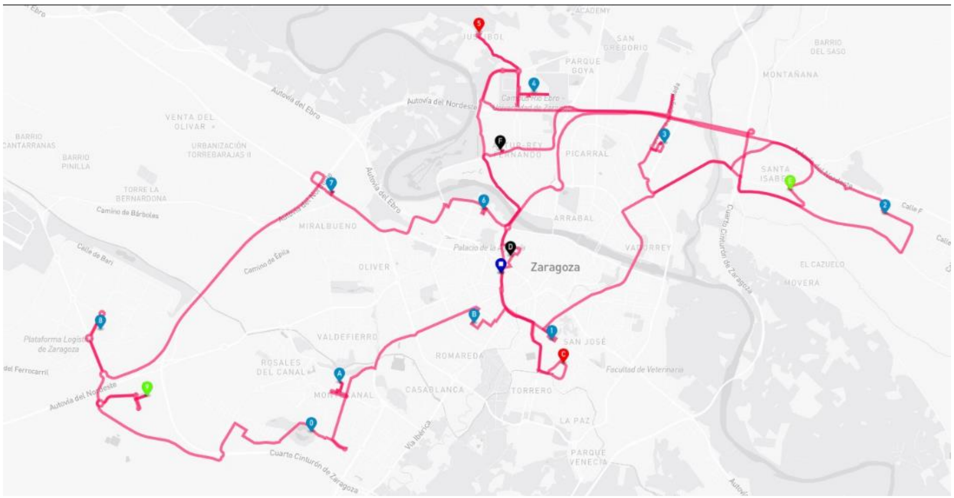

Figure 17: Picking up at the beginning of the route (Pilot 1B part 2)

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- Scenario 2 (picking up at the middle of route): in this scenario (Figure 18) it is simulated that the first six shipments of the route have already been delivered, so the vehicle is in the middle of the route and three new pickups/deliveries arrive. In this scenario the distance travelled is 101.78Km.

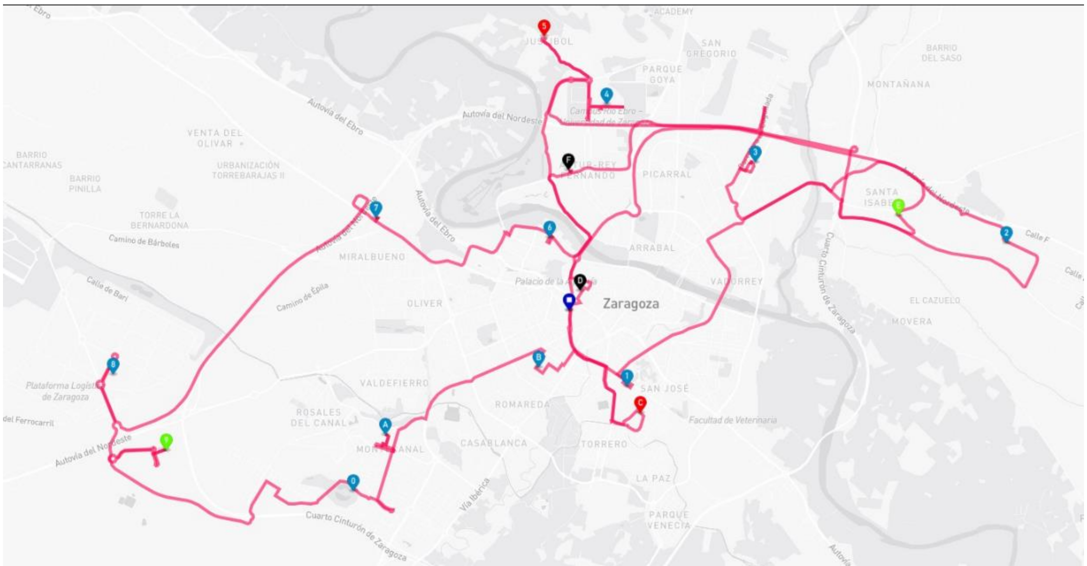

Figure 18: Picking up at the middle of the route (Pilot 1B part 2)

- Scenario 3 (Picking up at the end of the route): in this scenario (Figure 19) it is simulated that the first nine packages of the original route have already been delivered, the vehicle only has to deliver the last package, so the route would be practically finished, and three new pickups/deliveries arrive. In this scenario the distance travelled is 114.92Km.

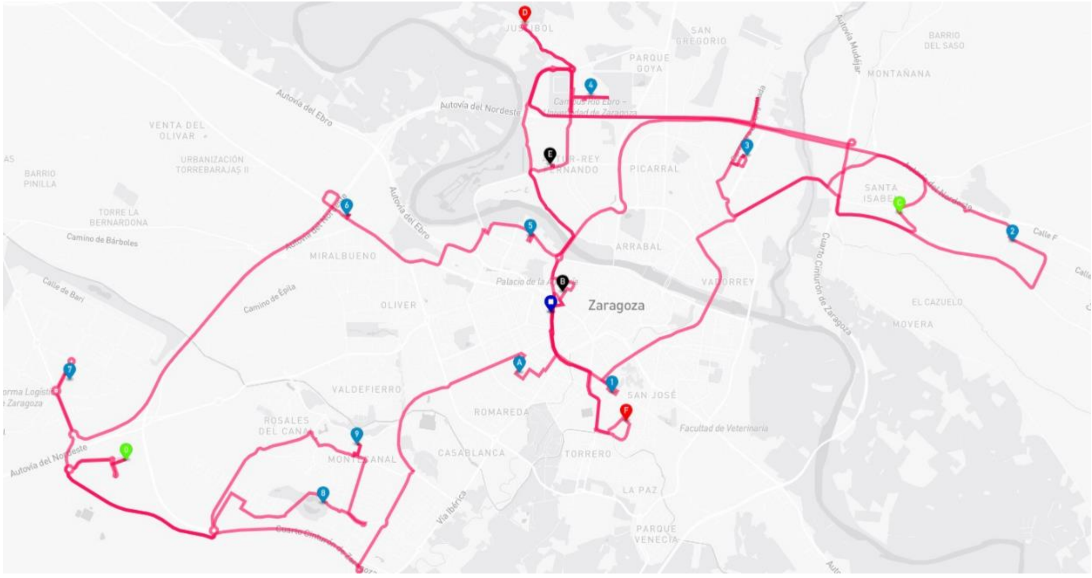

Figure 19: Picking up at the end of the route (Pilot 1B part 2)

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The different tests to perform this part of pilot 1B regarding the picking up in the planning were carried out between October and November 2024. In this simulation the run time of the optimizer for the test scenarios was less than one minute since it is about including new deliveries in already optimized routes and the assignment rules of a pickup/delivery usually condition the optimization.

Since October 2024, dynamic planning tests have been performed. First on scenarios in Bilbao (local, contained with few parcels) and then with synthetic routes, generated at random points, not based on the information provided by Correos for the pilots.

Tests have also been made from the planning scenario of the 1C pilot, starting from the 15 routes that came out as a result of the SENATOR optimization. That would therefore be the original scenario: 15 routes delivering 787 parcels in the morning shift from USE 1.

In this regard, three new shipments were introduced into the system. Depending on the parameters included and the freedom allowed to the optimization module, the results varied. It should be noted that the calculation time varied considerably: from two minutes if the routes were already established and could not be changed because all shipments were already loaded for delivery to about 20 minutes if the routes had not started and it was still possible to rearrange the shipments for delivery.

In all cases that were tested, the re-planning was able to take into account all new parcels and include them in the final routes, but in some cases, it significantly modified the established routes, so it would be advisable to assess other aspects of optimization in the daily operation of the delivery units before carrying out the re-planning.

3.4 Pilot 1C: Simulate a real day operation of one delivery unit and Correos Express activity

This pilot uses data of real deliveries, and the impact of merging networks of Correos and Correos Express, has been simulated and assessed, also measuring times for additional operations in cross docking.

Data used for the pilot:

The data corresponding to 16 October 2024 from the USE 1 delivery unit of Correos in Zaragoza have been used, and some Correos Express shipments that coincided in the postal codes corresponding to that Correos delivery unit.

Merging transport networks between different operators is far from straightforward, not only due to complex technological integrations, but also due to existing legal, labour and

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competition restrictions. These problems are common in the sector as detailed in the deliverable [D5. 7] Pilot Case 2 results and follow-up (Dublin) Report 1. The technological integrations between both operators Correos and CEx have been complex but not impossible due to the following reasons:

1. Existing technological synergies between both companies, both in the systems and in the devices used for delivery,
2. Commercial agreements between the two companies to be able to carry out this merger of networks in certain circumstances,
3. Participation of both companies in the SENATOR project as a partner and linked third party respectively.

In the same way, there have been certain restrictions, legal or competition, that have restricted this network-sharing between both companies so that it cannot be carried out bidirectionally. This has been the main impediment to being able to carry out the merger of networks as it is conceived and prepared in SENATOR, freely between different companies without restrictions. This functionality has been tested in the simulated environment of SENATOR.

For the start of the pilots, obtaining anonymized and geopositioned data according to the needs of the platform took a long time for the IT development teams of Correos. For this reason, the technological partners of the project developed a simulated scenario of Zaragoza that, based on historical data from Correos, shipments generated daily and considering all the fleet from Correos and CEx at disposal in Zaragoza. This allowed to continue and advance with the necessary developments of both the backend and the frontend of the SENATOR platform.

To carry out this pilot, a preliminary optimisation that considers CEx shipments corresponding to the delivery area of USE 1 has been carried out. This pre-optimisation between Correos and Correos Express includes:

1. Technological optimization of shipments information by Correos.
2. Physical transfer of the same, from the CEx logistics centre to the corresponding final delivery unit of Correos.
3. Technological integrations and pre-pilot developments carried out between both companies.

In this way, the list of shipments sent to the corresponding route planification proposed by SENATOR already included shipments from both companies. From this list of shipments, a cleaning of the data was necessary, because there were incomplete fields such as weights or dimensions in some cases, and others that were uninformed and had to be discarded as they could not be completed. Finally, it was necessary to hire an external service for

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geopositioning the real addresses, so all the shipments were anonymized. Once this process, which lasted approximately an hour and a half, was completed, the data could be converted to the format required on the platform.

This process was executed using an Excel Macro, which was developed by the Correos team to organize two Correos intake data files and CEx. Both files included, among other data, the pending shipments, the shipments registered in the USE 1 of Zaragoza to be delivered that day, as well as other redirected shipments, which were not to be taken into account for optimization.

The Excel macro was configured to prioritize by product type and by the identification code assigned to USE 1 Zaragoza. In this way, the shipment codes were prepared to obtain the geolocation of each one of them through an external tool and once this process was done, they were integrated into the master spreadsheet with the format required by the tool. In this way, the Excel macro applied all the required formats and automatically anonymized the item code, consolidating all the information in a single file. However, the “” text characters included in the files were changed manually by bulky editing with a pad note, since Excel does not use single quotes. This Excel macro saved at least several hours of data processing.

The data used was for 16 October 2024, and included a total of 1,150 shipments and 15 available routes beginning from the location of USE 1. This operation was effectively carried out by real means of Correos, on 15 delivery routes that covered 379 kilometres. Thus, establishing a baseline against which to compare the results of the optimization.

According to the proposed planification provided by the SENATOR platform, these routes were intended to be carried out covering a greater number of kilometres (392) in an estimated time per similar route, but with an increase in shipments worked of 3.4%.

Main conclusions:

- The information quality given by the clients originally is crucian in the process and affects to the time needed later to process al the data.
- Time needed to process the data (Correos) about 1,5h, and time needed by the system (optimization module within SENATOR) about 44 minutes. These results in time prevented the last pilot (1D) from being carried out in real operation, because the delivery unit could not be stopped for two and a half hours before going out for distribution, which will be explained in the following section (Pilot 1D).
- SENATOR optimization routes are quite reasonable, making a logical proposal and in accordance with both time and distances. This is especially due to the development of the optimization algorithm using historical data provided for the project and the

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joint work of Correos and the University of Deusto to establish the appropriate parameters.

- SENATOR proposes an increase in shipments delivered, and more kilometres, increasing the potential efficiency of the routes.
- This System is considered to be especially useful, perhaps not so much for real operations in the mornings, but for those shipments that are concentrated in the afternoons to make second attempts, since they encompass several delivery areas, and as they are second attempts, the information is available with enough time to be processed and properly entered into the system. In addition, as it covers large delivery areas (larger than usual) it is especially useful for those delivery drivers who are not familiar with these areas.
- The optimization system should be optimized (reduce time to no more than 10 min per unit) to be scalable to all delivery units.

3.5 Pilot 1D: real shipments

This pilot consists of carrying out a pilot with real shipments by merging the Correos and Correos Express networks one day of operation. To carry out this pilot, the following were integrated with the platform:

1. Real-time information on sensorised vehicles in Zaragoza for postal delivery.
2. Real-time information on the devices used for delivery by mail carriers.

This information also facilitated the visualization for the municipality of a map of shipment density and traffic density, in an aggregated form, since the heat maps of shipment density are presented in grids of 2 kilometres on each side, and the traffic density as a function of the number of vehicle passes on each section of road, as shown below:

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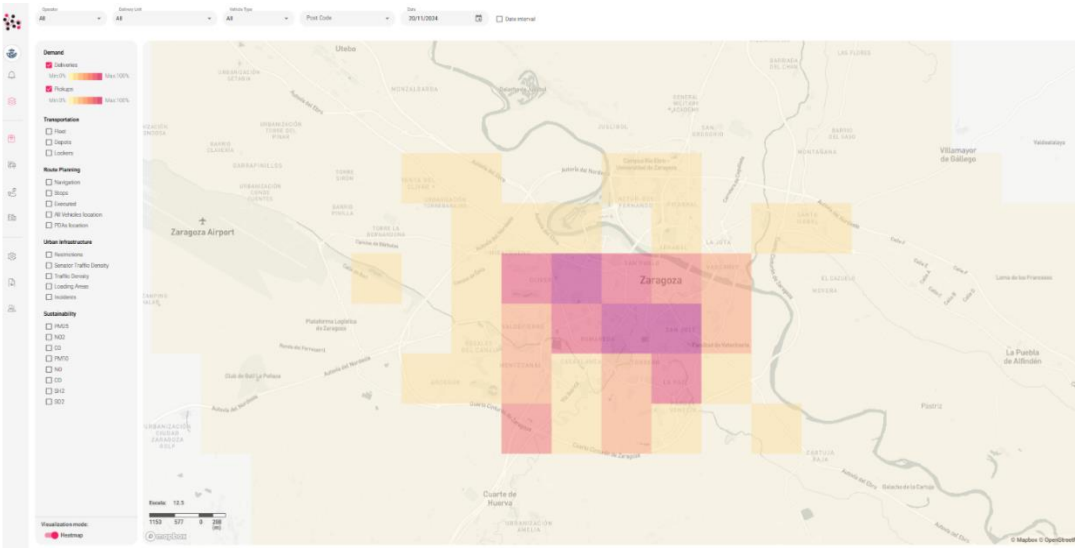

Figure : 2 Km side grid (Dashboard screenshot)

Due to the time needed to process the information as seen in the 1C pilot, it was not possible to consider the option of carrying out a pilot with postmen and real shipments. However, the actual pilot was carried out as explained below.

The starting data were those corresponding to previous dates, and the pilot was carried out on November 20, 2024.

The optimized planned routes were those proposed by the SENATOR system, and two project participants with no experience of delivery in Zaragoza were selected to carry out the trial.

In addition, the Deusto team developed a Mobile App to be able to manage the deliveries and allow to track the route within SENATOR, being able also to follow the execution in real time on the dashboard, without the need for integrations neither for a company that does not have a great technological advance nor even for a freelancer who would like to make use of the platform. Among the project documentation you can find a user manual for the app, as well as an explanatory video, both included in the deliverable D3.7.

The day of the pilot, the optimization system started at 7am with 1.150 shipments and 15 vehicles. At 8:05 am, routes were available to be consulted both at the dashboard and the SENATOR mobile app.

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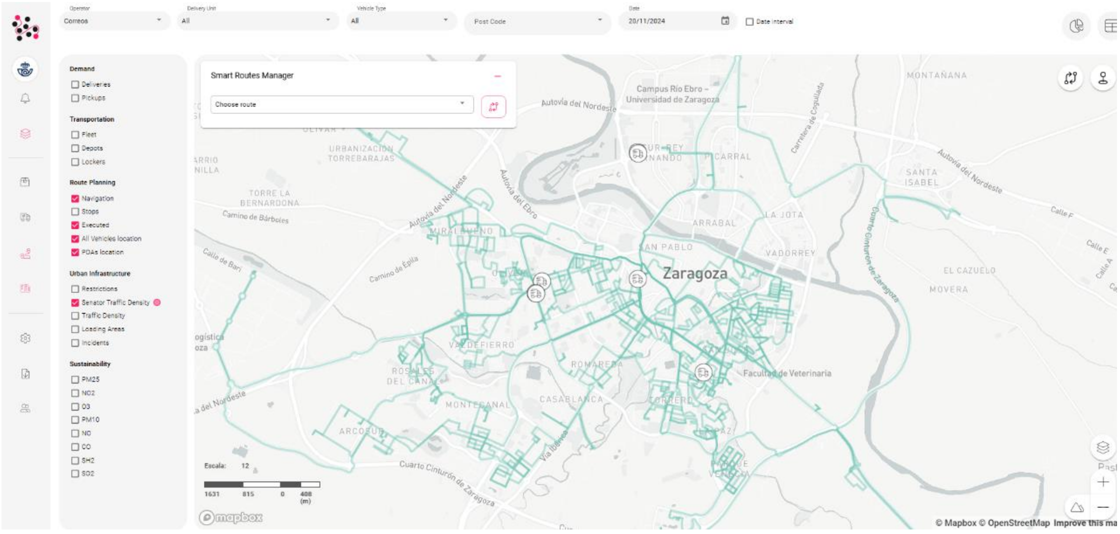

Figure 20: SENATOR Traffic Density screenshot

The objective of the pilot was to validate in real operations the return of real-time information to the platform, as well as the goodness of the routes proposed by the optimization system. To do this, one of the routes proposed by the platform for that day was followed by the participants through the mobile app, driving with a vehicle similar to those used in the daily delivery activity, parking near each delivery point, going to the portal and waiting for the estimated delivery time (service time), and continuing the route until the next planned stop.

The pilot delivery team was formed by two people, one trying the delivery operation and the other to take notes of the whole process, incidents, etc. In parallel a Correos team and a Deusto team were also following the development of the pilot on the dashboard. After the platform finished the internal calculations and proposed the complete planification for the selected delivery unit (USE 1), starts “assigning” the shipments to their route, this means, by each shipment, change the status to “on delivery” in the app. This process took about 6 minutes. Several login issues were faced, like the app closing unexpectedly, given the different issues that arose, several possible updates to the app are being considered, such as the option to remember user and password. The loading of shipments into the vehicle is simulated and estimated at the delivery unit, also considering the average time of the delivery personnel. The delivery process started at 8:50 with the first shipment.

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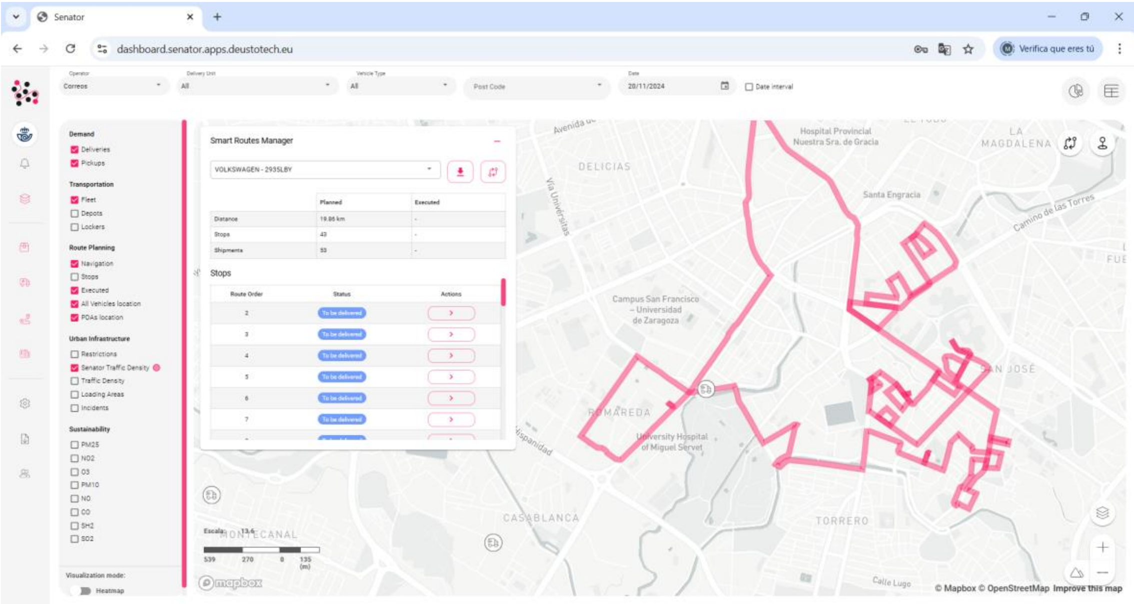

Figure 21: Dashboard screenshot (selected route)

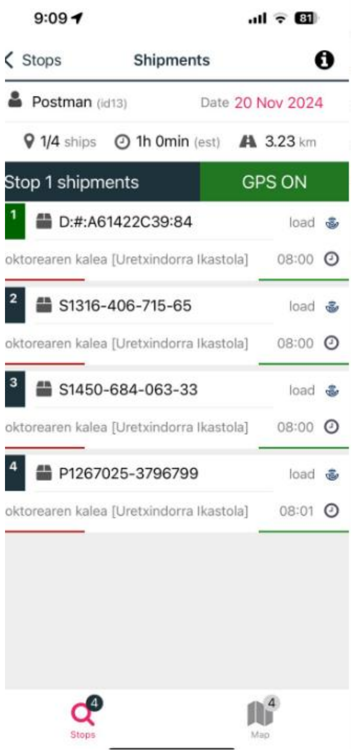

Figure 22: App Screenshot

Once the route begun, Deusto and Correos teams confirm that the GPS and the information of the selected route correctly appears on the dashboard, allowing them to follow the execution of the delivery route in real time. Additionally, the delivery team indicates that the GPS works properly and allows to geolocate the stops in the map and the route planned position.

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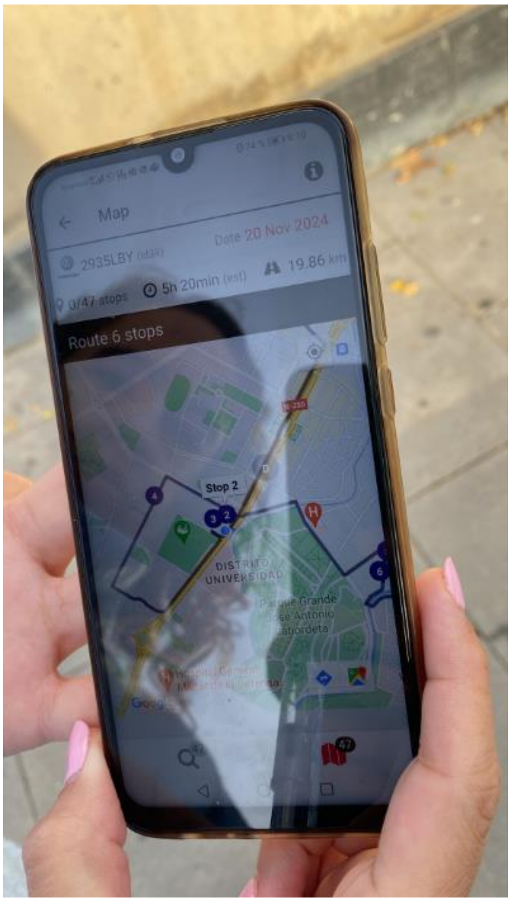

Figure 23: Mobile app visualization

The battery consumption was too high by the app during the first minutes of delivery, so it was necessary to connect the power cable of the mobile phone to the vehicle, in order to continue with the delivery. Among the lessons learned, it is necessary to optimize the efficiency of the app or consider a mobile/PDA charger (with or without cables) among the elements to be included in delivery vehicles.

Because neither the exact coordinate, nor the address, could be shared with SENATOR's system, due to the logistic operator data protection compliance restrictions, it was not easy in some cases to drive from one point to another. Concretely, one occasion the navigator located the GPS coordinate very far from the delivery area, wasting valuable minutes of delivery. However, it was the only incident in this regard.

During the distribution, the route that was being followed changed position in the global list of routes that appeared in the app, initially being 6 and later 7, this was not a problem because the team was clear about the route based on the license plate identifier, but being able to access different routes could cause problems of overlap or confusion.

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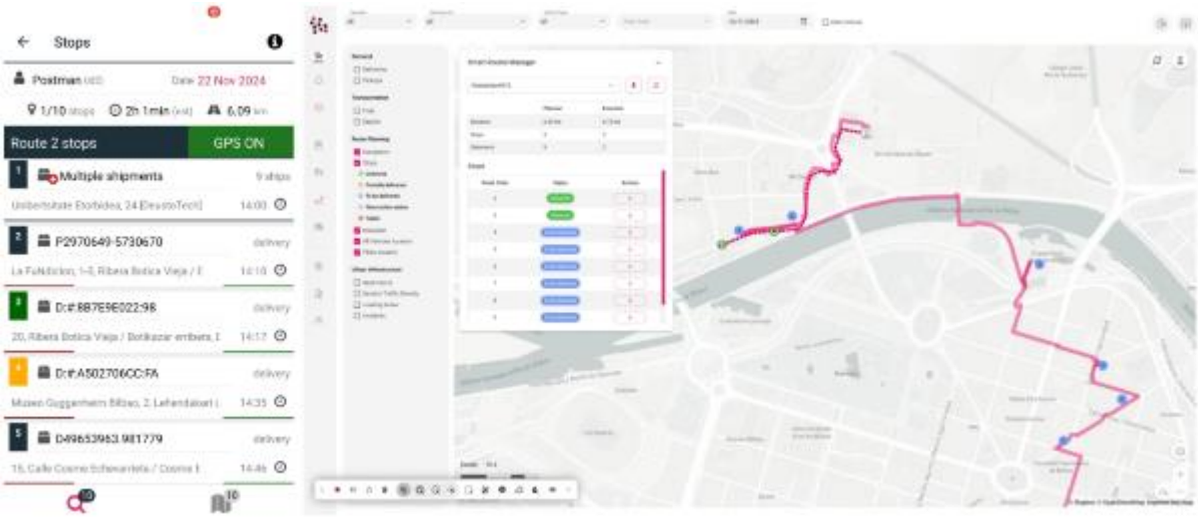

Figure 24: Mobile app and dashboard visualizations of Bilbao.

One of the best functionalities that could be tested of the optimization algorithm is the grouping of shipments, this allowed shipments that were less than 100 meters apart to group them to deliver them together in a single stop. This was very useful due to the great difficulty of parking in the city centre, and according to the route followed, more shipments could not have been grouped than those proposed by the application, since the rest of possibilities were not efficient. That is why this development was considered optimal. Only in some cases of great parking difficulty could the grouping of shipments be increased by making it coincide with loading and unloading areas, but in very few cases and due to this problem. These types of improvements could be introduced into these systems using well documented clustering algorithms, (e.g., DBSCAN).

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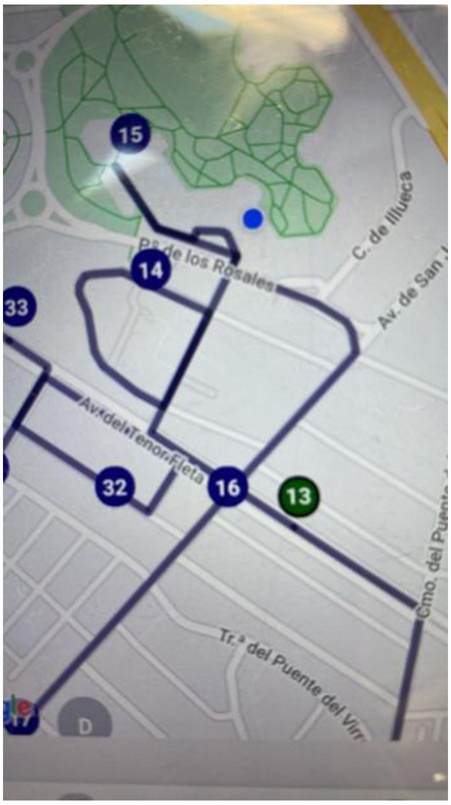

Figure 25: Mobile App visualization (GPS functionality)

The visualization of the route to be followed by the mail carrier, as well as their geo-position at all times with respect to it, was of great help, because on some occasions when the delivery team got lost, or due to the difficulty of parking and the directions of the streets, he distanced himself from the route to follow. This display of stops on the map can also facilitate the delivery of nearby shipments and thus avoid returning twice to the same area, even if the proposed route has estimated the delivery later on the shift.

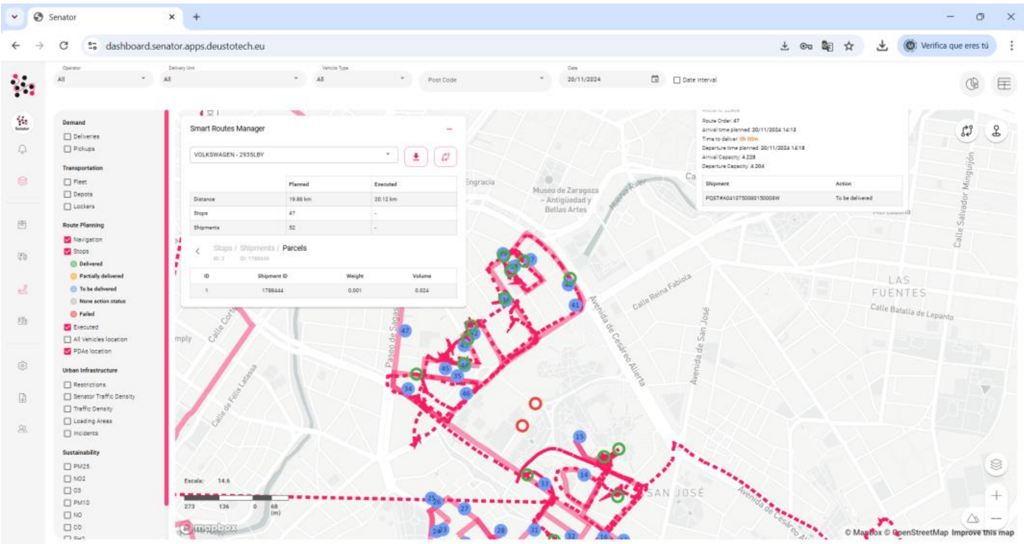

Figure 26: Dashboard screenshot (deliveries visualization)

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Both the Correos and the University of Deusto teams were able to monitor the performance of the route on real time through the dashboard with respect to the planned route.

During the delivery, a vehicle maintenance incident was reported, so it is indicated through the "vehicle breakdown" app, a functionality developed for the mail carrier that will be detailed later. This made it possible to check that the developments had been correct and to identify the incident, position and notification in real time on the dashboard. Because of this incident, the delivery team had to make a change of vehicle that delayed the route.

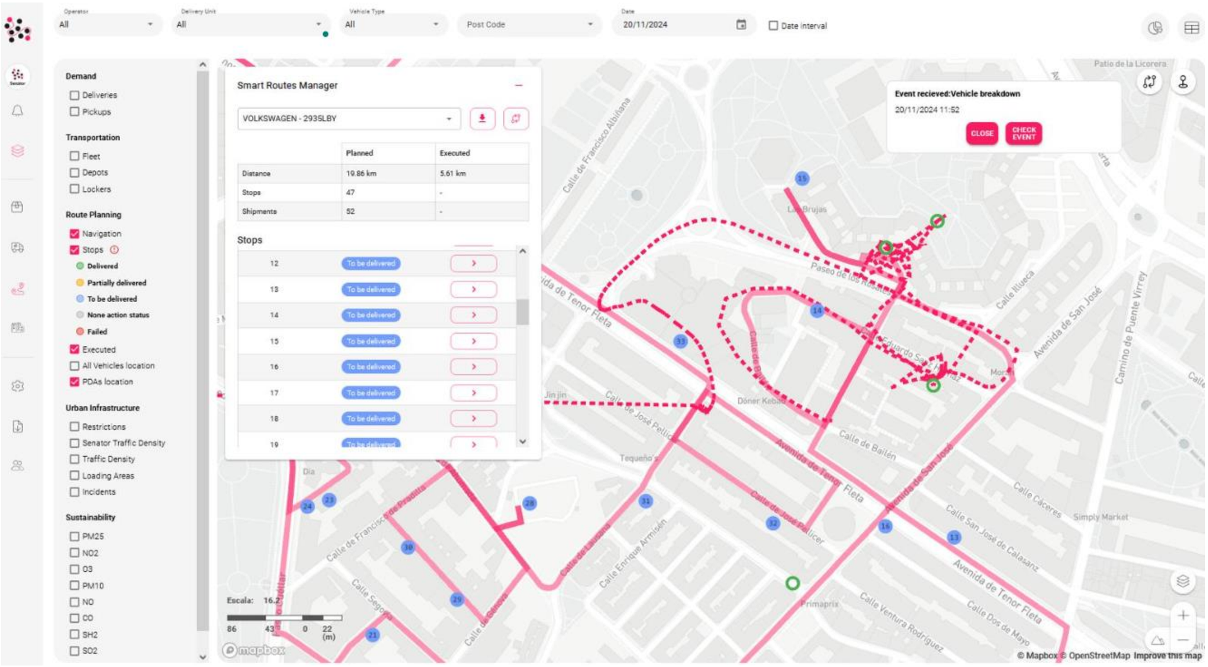

Figure 27: Dashboard visualization (Incident visualization)

Once the vehicle was changed, the last phase of the delivery continued without further incidents, following the route with ease and “delivering” the rest of the shipments. However, as mentioned above, the biggest inconvenient in carrying out the route was the lack of parking, as even the areas marked as loading and unloading bays were occupied by private vehicles, making it difficult to stop near the delivery points.

Therefore, the availability of this technology is a very positive conclusion for an inexperienced delivery mail carrier in a new area, since from the point of view of technological development, a necessary and sufficient application has been developed to minimize the difficulty of delivery.

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Figure 28: Loading/Unloading area (Pilot 1D)

Figure 29:Vehicle used during the pilot 1D

At 2:30 p.m., the route was marked as finished, with shipments from 46 onwards pending.

Lessons learned:

- The biggest problems have been parking, especially in very central areas of the city, with one-way streets and few loading and unloading areas. It felt like delivery team

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was passing through the same area several times due to the difficulty of parking and the urban planning of the city centre.

- Following the route was easy and simple, and the proposed route was reasonable, it made some sectorization and the groupings were good.
- The map configuration and the inclusion of real-time geolocation is a very useful feature that facilitates the work, as it allows new mail carriers to position themselves on the map, so that if they get lost or cannot park near the delivery point, they can see if it is possible to make other deliveries scheduled for later in the route, also allowing them to make groupings of deliveries “on the fly”.

- The visibility and communication of incidents in the distribution is real-time through the dashboard and the application, facilitating and speeding up the necessary procedures to minimise the impact on operations.

3.6 Pilot 2: Network balance (virtual load exchange)

This pilot explores different use cases:

i) Single operator: one route is in trouble and need help from other vehicles to fulfil the day deliveries;

ii) Operator transfer: the same idea but transferring load to another operator. What information is needed? How will we deal with the security of shipments (how we can rely in other networks? eID and physical security will be assessed. SENATOR “control tower” should enable communication between both networks and suggest the best point for load exchange (dynamic planning).

Below are the screenshots that allow you to visualize the functionalities developed:

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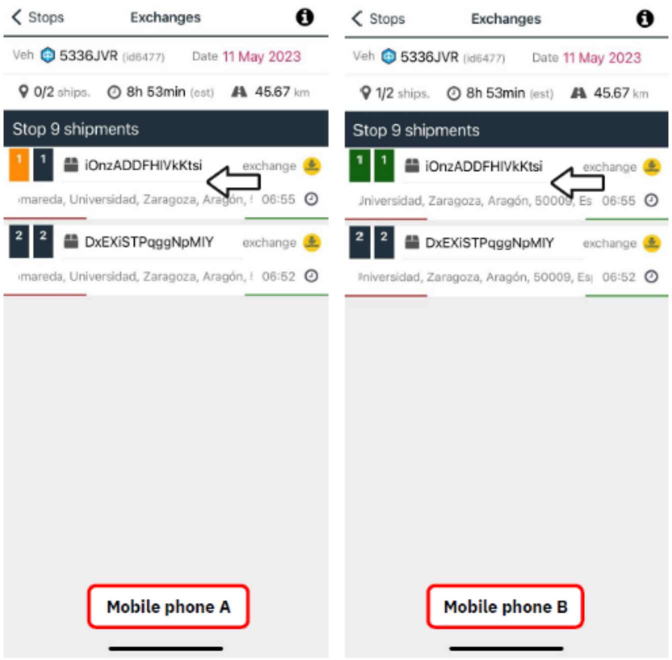

Figure 30: Virtual load exchange on the mobile app visualization (Pilot 2)

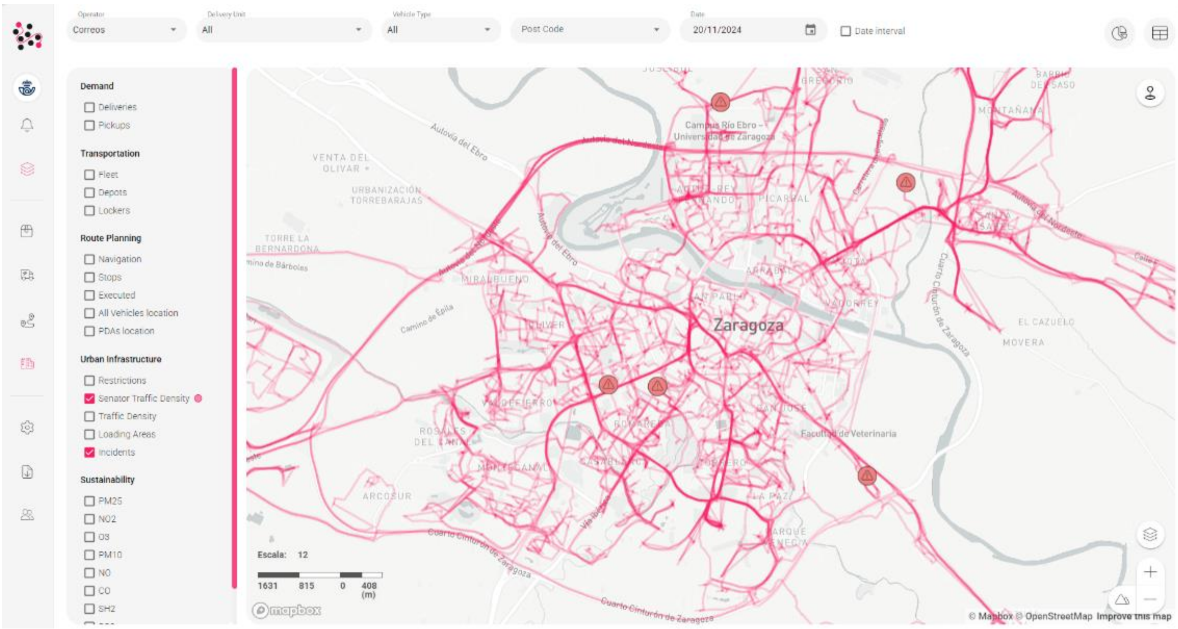

Figure 31: Incidents screenshot

By clicking any of the issues using the mouse, or by clicking the popup button during the entry of the incident, you can see the following screen in the dashboard:

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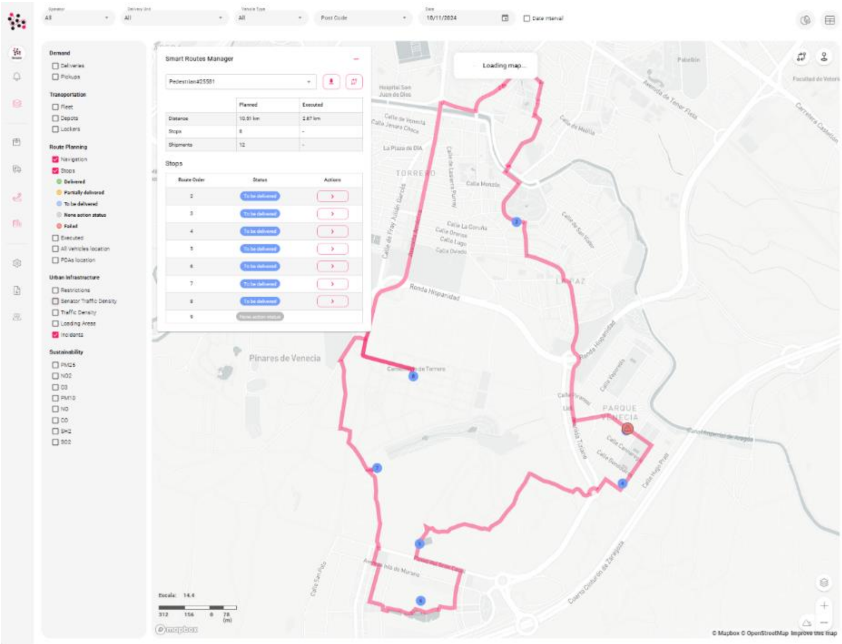

Figure : Incident selection

Incidents with a status other than "finished" can be displayed in one layer, which allows pending or open incidents to be easily visualized to the logistics manager by accessing the platform:

Figure 32: Open incidences

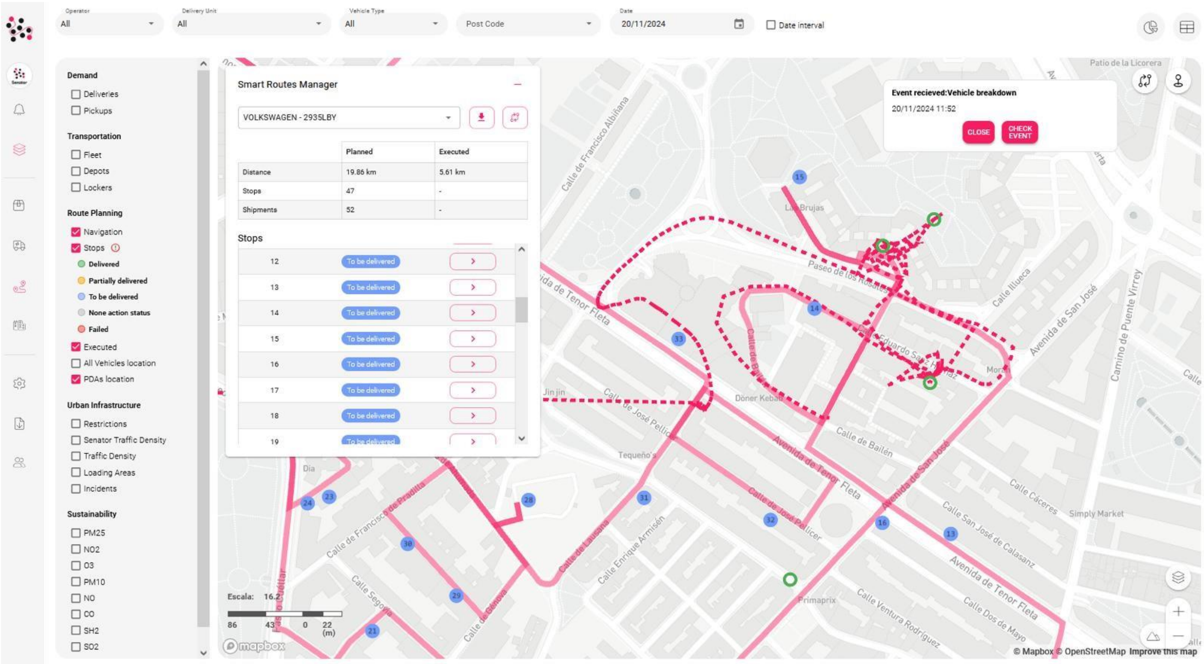

Figure 33: Car breakdown screenshot (Pilot 1D)

It also allows you to view the total number of incidents by day and type of incident:

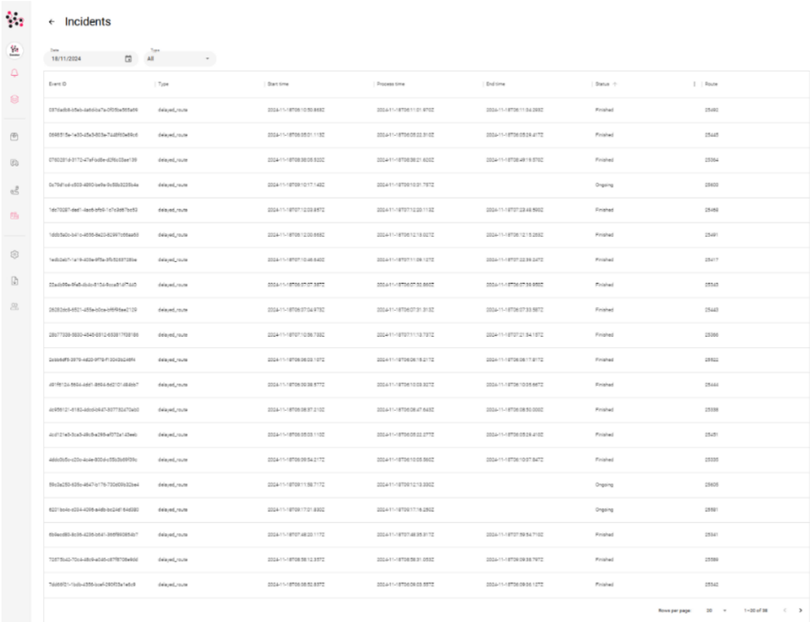

Figure 34: List of incidences

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3.7 Pilot 3: Regional Market consolidation (MercaZaragoza)

The pilot explores how to stimulate the consolidation for outbound regional market to attend the small retailers simplifying the number of connections between the central market and small markets (N single vans, one per retailer to one single route for all of them).

The studied solution tries to generate efficiencies through the consolidation of the shipments or goods in MercaZaragoza, reducing the number of trips and optimizing the load of the vehicles what will imply a reduction in the costs and in the environmental impact.

In this sense, the reduction of the logistic footprint will also have a benefit for the citizens. These benefits are crucial in a context where sustainability and carbon footprint reduction are becoming increasingly important.

3.7.1 Introduction

The agri-food industry is constantly evolving and adapting to meet the constant demands of society, whether as a result of new demands from consumers and/or regulations from international organisations, the European Union or the General State Administration.

Bearing in mind that the agri-food industry moves more than €120,000 million, the continuous demand means that all parties involved in the industry must take a step forward to achieve efficiency objectives and minimise the environmental impact that this entails.

One of the possible ways to achieve efficiency is to optimise the distribution network that currently exists around wholesale and retail markets, so that the associated logistics costs can be reduced by increasing the value of the food chain.

The main objective of this pilot is to minimise the number of distribution routes leaving from MercaZaragoza, one of the main logistics centres of this geographical area, to supply retail markets in Aragon and other neighbouring provinces, by consolidating merchandise and evaluating the possibilities and benefits (operational efficiency, reduce of cost and minimisation of environmental impact) of being delivered by a single logistics operator, which will be responsible for supplying the material to the retail operators.

3.7.2 MercaZaragoza Analysis:

MercaZaragoza is the most important logistics platform specialising in agri-food in the Ebro Valley. A distribution, marketing, transformation and logistics platform that operates 24 hours a day with the aim of guaranteeing the supply of food in its area of influence.

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Figure 35: Map of Zaragoza including MercaZaragoza

This platform sells around 150,000 Tn of food per year, concentrating one of the most important fresh food offers in Spain.

The turnover is approximately €14,300,230, corresponding to 61.6% of sales in the Slaughterhouse and the provision of services, 20.6% of the Complementary Activities Zone and the Business Centre, 11.5% of the Fruit and Vegetable Market, 3.5% of the Fish Market, and 2.8% of the Retail Market.

With more than 120 companies installed, every day it brings together more than 4,000 people who carry out their work in the field of agri-food production, processing and distribution.

Every day around 4,000 vehicle access MercaZaragoza, which implies a very high environmental impact. It is estimated that retailers who access the site with their vehicles use around 50% of their loading capacity, which creates major inefficiencies on the current logistics model.

3.7.3 Activity from the Markets

Fruit and vegetable market: This segment represents approximately 450 tons per day. Fruit and vegetables are perishable products that require careful handling and efficient logistics to maintain their freshness and quality. The high turnover of these products justifies the need for optimized logistics.

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Fish market: With around 70 tons per day, the handling of fish and seafood also requires specific storage and transport conditions, such as constant refrigeration. Consolidation can ensure that optimal conditions are maintained throughout the logistics process.

Meat Market: Around 100 tons of meat and meat products are distributed daily from MercaZaragoza. This type of product also requires a strict cold chain and efficient handling to avoid deterioration and ensure food safety.

Table 15: MercaZaragoza in figures

Market	Volume Sold	Turnover	Wholesalers	Points of Sale
Fruit and vegetable market	165,000 Tn	1,644,526 €	31	80
Fish Market	25,000 Tn	500,508 €	8	16
Meat Market	35,000 Tn	8,808,942 €	40	

3.7.4 Proposed solution

The solution studied aims to generate efficiencies through the consolidation of shipments or merchandise in MercaZaragoza, reducing the number of trips and optimizing the loading of vehicles, which will imply a reduction in costs and environmental impact. In this sense, the reduction of the logistics footprint will also be beneficial for citizens. These benefits are crucial in a context where sustainability and the reduction of the carbon footprint are increasingly important.

Below, it is detailed a brief quantitative analysis to quantify the savings in CO_2 emissions. Taking into account that, of the 4,000 vehicles that access MercaZaragoza daily, around 20% of them carry out distribution to the city of Zaragoza and surrounding districts and that the rest of the vehicles are long-distance distribution vehicles and supply other cities and provinces.

Basing the analysis on those vehicles that deliver on the city and outskirts of Zaragoza, the results of consolidation would be:

Table 16: Consolidation results

	Km from Zaragoza to MercaZaragoza	Average consumption per vehicle	CO_2 Emissions per vehicle	Number of vehicles/day	Daily emissions
Without consolidation	20	30 l/100 km	2.68 kg CO_2/l	800	12,864 kg CO_2
With Consolidation	20	30 l/100 km	2.68 kg CO_2/l	640	10,291 kg CO_2

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In a first phase of consolidation, the number of daily CO_2 emissions could be reduced by 20%, in addition to contributing to the reduction of other pollutants associated with road transport such as nitrogen oxides (NOx) and particulate matter (PM), which have adverse effects on air quality and public health.

Regarding the efficiency that it would bring to retail companies, they would have the opportunity to reduce costs, eliminating part of their fleet of vehicles and focusing these efforts and economic resources on the sale of products, the reason for this type of business.

Likewise, the consolidation model would generate economies of scale by proposing more efficient distribution routes that would help reduce delivery times and increase vehicle performance, all of which would imply an improvement in the economic efficiency of all the actors involved.

3.7.5 Revenue Scenario

Beyond cost efficiency, the consolidating company itself would experience an increase in its turnover, considering the following hypotheses:

Table 17: Revenue results

	€	Estimated Volume	Total revenues/day
Consolidation rate	€10-15/Tn	130 Tn	€ 1,623
Distribution rate	€25-30/Tn	130 Tn	€3,571
Additional Services	Storage services, stock control, temperature-controlled services, etc.	On demand	On demand

Table 18: Revenue results per year

	Year 1	Year 2	Year 3	Year 4	Year 5
% Consolidation	20%º	25%	30%	32.5%	35%
Revenue/year	€1,200,000	€1,500,000	€1,800,000	€1,950,000	€2,100,000

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3.8 Blockchain implementation

The Use Cases proposed in SENATOR as the most important ones to provide robustness to the platform where multiple third-party and end users will participate, providing services or consuming them, are transaction traceability and IoT.

3.8.1 Use case: Transaction traceability

This use case covers a key and a critical functionality within SENATOR. SENATOR will be responsible to provide the more efficient delivery of goods within an area (city) taking into the equation all delivery companies, what is known as “last mile Delivery”.

To provide a service to trace the movement of packages and goods between companies, it is proposed to leverage a blockchain solution based on Ardor. The approach is to trace within Ardor the critical and more important transactions within the delivery companies that participate in the process. The solution collects the transactions that represent a movement of a package between company A and company B. The solution will not trace movements of packages within the same company as this action is responsibility of every company and managed privately by them.

The implementation of this use case is important to reduce the time resolving issues when there are disputes on the work done by two or more parties responsible for the delivery. It will provide a simple and robust mechanism to validate transactions and give information to users and consumers about what companies were involved in the delivery process.

This scenario was tested sending payloads representing the movement of packages from one company to another one that accept it. The number of payloads sent is 85. For every payload we present the data and messages involved in each of them informing the following parameters:

- **File Name**: reference to the payload sent from SENATOR. This is used as a reference to locate the name of the file where the payload sent from SENATOR.
- **Sent-packageId**: Id of the package that is moved from one company to the other.
- **Sent-OriginCompanyId:** Id of the company giving the package to the company accepting the package.
- **Sent-receiverCompanyId**: Id of the company receiving the package from the company sharing the package.
- **SENATOR Sent**: payload sent from SENATOR representing the package movement.
- **Addon Response -Ack**: synchronous response from the Addon linked to the blockchain network informing the payload has been received and prepared to be processed by the blockchain network (Ardor)

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- **GroupId**: Id of the group used to process and register the payload in the blockchain network (Ardor).
- **GroupId Database_Reference**: Id representing the reference of payload processed stored for reference in the Addon database.
- **Blockchain Response - Ack confirmation**: this is the asynchronous message sent from the Addon after the blockchain network (Ardor) confirmed that the payload has being processed and registered in the blockchain network (Ardor).

All the payloads have been processed returning the expected values from the Addon.

3.8.2 Use case: Internet of Things (IoT)

IoT is driving the change to a more traceable good management, from manufacturing to the client delivery and services based on IoT devices and the information they generate on any stage of the service where they are setup. Integrating data generated by an IoT device within a Blockchain network will allow SENATOR and its participants to make decisions based on data recorded. There are two levels of integration on this scenario:

- Data is collected and later used to track goods and packages, for example: time to deliver a package from its origin to the client, track the path and the physical conditions: temperature, humidity, vibrations, on a sequence of events recorded taking into consideration the time when they were created. On this scenario all data is recorded and used to explore data to improve services.
- Same scenario as scenario 1, however, data recorded is extended with information related to a range of values that represent the physical conditions contracted by the involved parties. For example: Instantaneous temperatures from various sensors during the delivery process.

This scenario was tested sending payloads that represent the data collected from IoT real devices that were mapped into the SENATOR platform. The number of payloads sent is 378. For every payload we present the data and messages involved in each of them informing the following parameters:

- **File Name**: reference to the payload sent from SENATOR. This is used as a reference to locate the name of the file where the payload sent from SENATOR.
- **SENATOR Sent**: payload sent from SENATOR representing the IoT data parameters sent (Geolocation, Temperature, Vibration, Humidity).
- **Addon Response-Ack:** synchronous response from the Addon linked to the blockchain network informing the payload has been received and prepared to be processed by the blockchain network (Ardor)

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- **GroupId_N (N in [1...4])**: Id of the group used to process and register the payload in the blockchain network (Ardor).
- **GroupId_N (N in [1...4]) Database_Reference**: Id representing the reference of payload processed stored for reference in the Addon database.
- **GroupId_N (N in [1...4]) Blockchain Response - Ack Confirmation**: this is the asynchronous message sent from the Addon after the blockchain network (Ardor) confirmed that the payload has being processed and registered in the blockchain network (Ardor).

Note: on this scenario, 1 payload contains up to 4 attributes to trace: Geolocation, Temperature, Vibration, Humidity. All the parameters are sent in groups of 5 items to the Ardor Blockchain network. Depending on the number of payloads sent might be the case that not all the parameters in an IoT payload are processed on the same group. This is the reason why, for each IoT payload we include 4 columns linked to the Group_Id used, for some payload, the group_Id is the same for all the parameters sent on the same payload, on other cases, the group_Id is different.

3.8.3 Tests and results

Tests to validate their usage has been performed during all the period, although the mass trials have been performed from March 2023 onwards. The information about Blockchain successful operation confirmations is sent and received by the Messaging bus as can be seen in the next image:

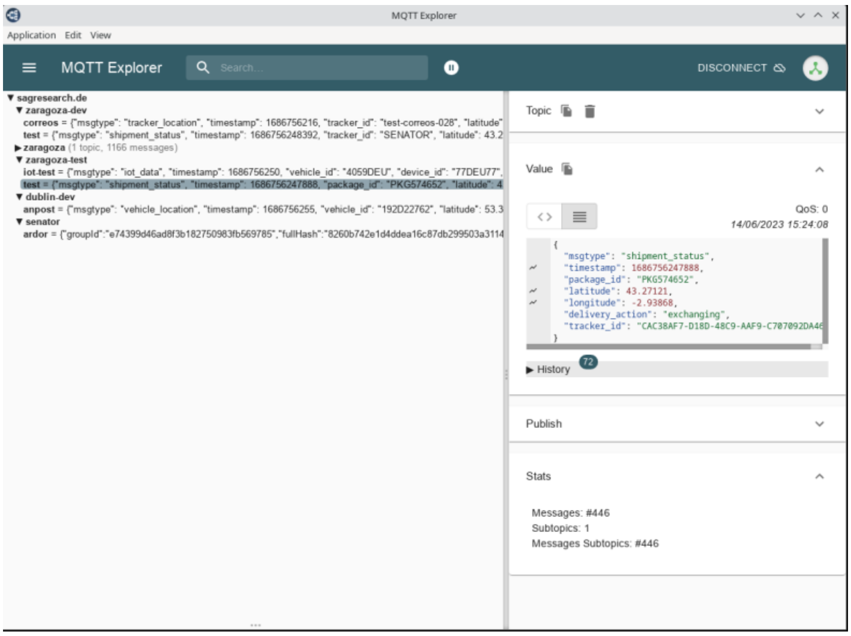

Figure 36. Package exchange transaction sent to the Blockchain (sent by SENATOR simulator)

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In the following captures, the web visualization tool that DEUSTO designed and developed to monitor all the transactions can be seen. That web allows to trace both Packages exchanges between logistics operators, responding to the first use case presented and all the parameters stored in the Blockchain, provided by the IoT devices integrated, also covering the first use case previously mentioned.

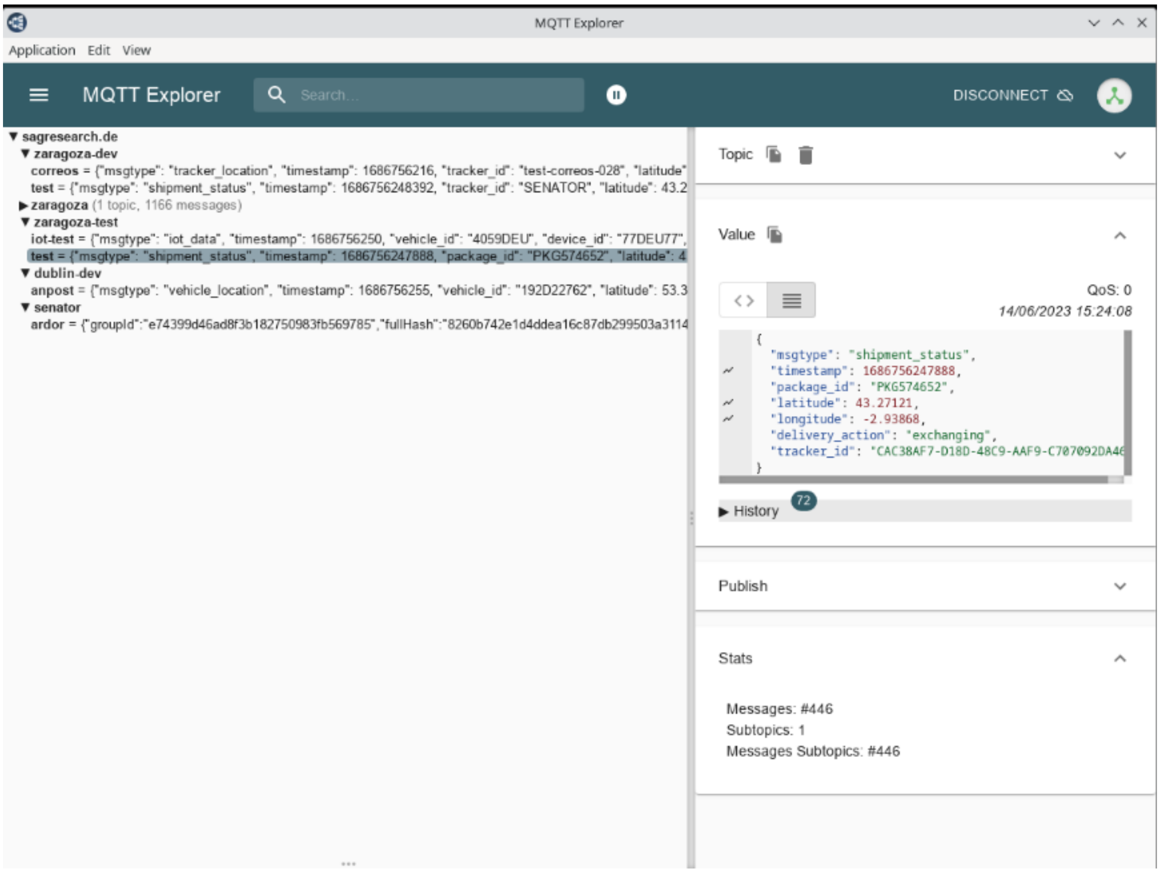

Figure 37. Successfully stored transaction from Blockchain node

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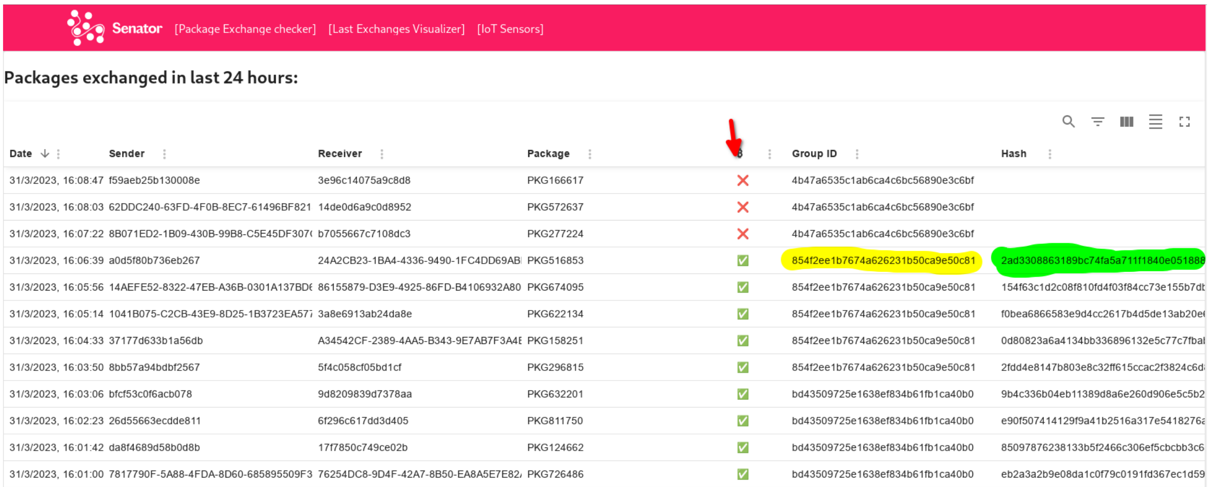

Date	Sender	Receiver	Package		Group ID	Hash
31/3/2023, 16:08:47	f59aeb25b130008e	3e96c14075a9c8d8	PKG166617	❌	4b47a6535c1ab6ca4c6bc56890e3c6bf	
31/3/2023, 16:08:03	62DDC240-63FD-4F0B-8EC7-61496BF821	14de0d6a9c0d8952	PKG572637	❌	4b47a6535c1ab6ca4c6bc56890e3c6bf	
31/3/2023, 16:07:22	8B071ED2-1B09-430B-99B8-C5E45DF307	b7055667c7108dc3	PKG277224	❌	4b47a6535c1ab6ca4c6bc56890e3c6bf	
31/3/2023, 16:06:39	a0d5f80b736eb267	24A2CB23-1BA4-4336-9490-1FC4DD69AB	PKG516853	✅	854f2ee1b7674a626231b50ca9e50c81	2ad3308863189bc74fa5a711f1840e051888
31/3/2023, 16:05:56	14AEFE52-8322-47EB-A36B-0301A137BD	86155879-D3E9-4925-86FD-B4106932A80	PKG674095	✅	854f2ee1b7674a626231b50ca9e50c81	154f63c1d2c08f810fd4f03f84cc73e155b7d
31/3/2023, 16:05:14	1041B075-C2CB-43E9-8D25-1B3723EA57	3a8e6913ab24da8e	PKG622134	✅	854f2ee1b7674a626231b50ca9e50c81	f0bea6866583e9d4cc2617b4d5de13ab20e
31/3/2023, 16:04:33	37177d633b1a56db	A34542CF-2389-4AA5-B343-9E7AB7F3A4	PKG158251	✅	854f2ee1b7674a626231b50ca9e50c81	0d80823a6a4134bb336896132e5c77c7fba
31/3/2023, 16:03:50	8bb57a94bdbf2567	5f4c058cf05bd1cf	PKG296815	✅	854f2ee1b7674a626231b50ca9e50c81	2fdd4e8147b803e8c32ff615ccac2f3824c6d
31/3/2023, 16:03:06	bfcf53c0f6acb078	9d8209839d7378aa	PKG632201	✅	bd43509725e1638ef834b61fb1ca40b0	9b4c336b04eb11389d8a6e260d906e5c5b2
31/3/2023, 16:02:23	26d55663ecdde811	6f296c617dd3d405	PKG811750	✅	bd43509725e1638ef834b61fb1ca40b0	e90f507414129f9a41b2516a317e5418276
31/3/2023, 16:01:42	da8f4689d58b0d8b	17f7850c749ce02b	PKG124662	✅	bd43509725e1638ef834b61fb1ca40b0	85097876238133b5f2466c306ef5cbcbb3c6
31/3/2023, 16:01:00	7817790F-5A88-4FDA-8D60-685895509F3	76254DC8-9D4F-42A7-8B50-EA8A5E7E82	PKG726486	✅	bd43509725e1638ef834b61fb1ca40b0	eb2a3a2b9e08da1c0f79c0191fd367ec1d59

Figure 38. SENATOR Blockchain Web Validator visualizer for Packages exchange actions validation

Additionally, the application provides a form wherein by introduction of several data of a concrete transaction, checks with the Ardor network if the related information sent has been successfully saved in the Blockchain or otherwise has not been identified there as granted.

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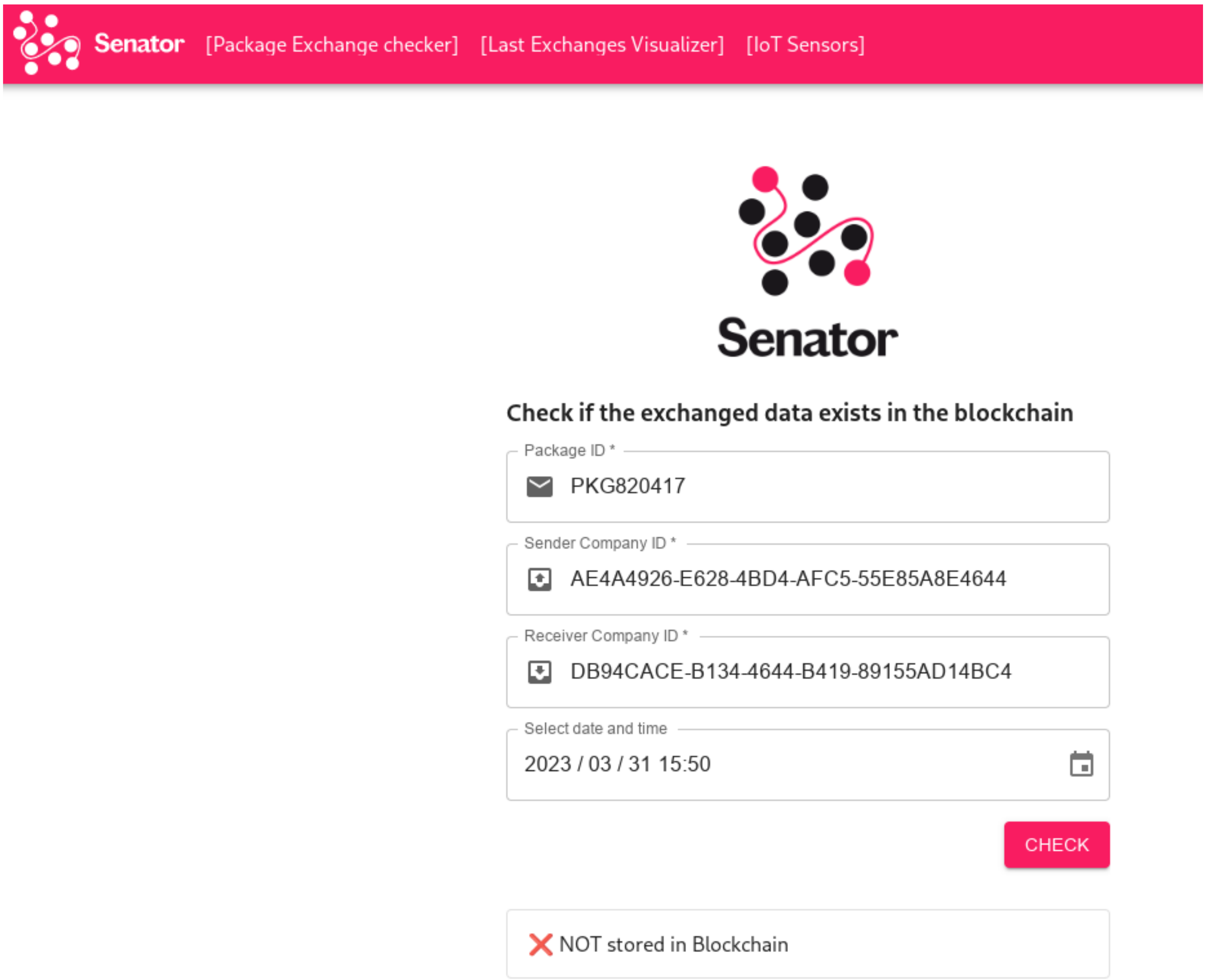

Figure 39. SENATOR Blockchain Web Validator form to check if a transaction has been successfully stored in the Blockchain. Result: Negative

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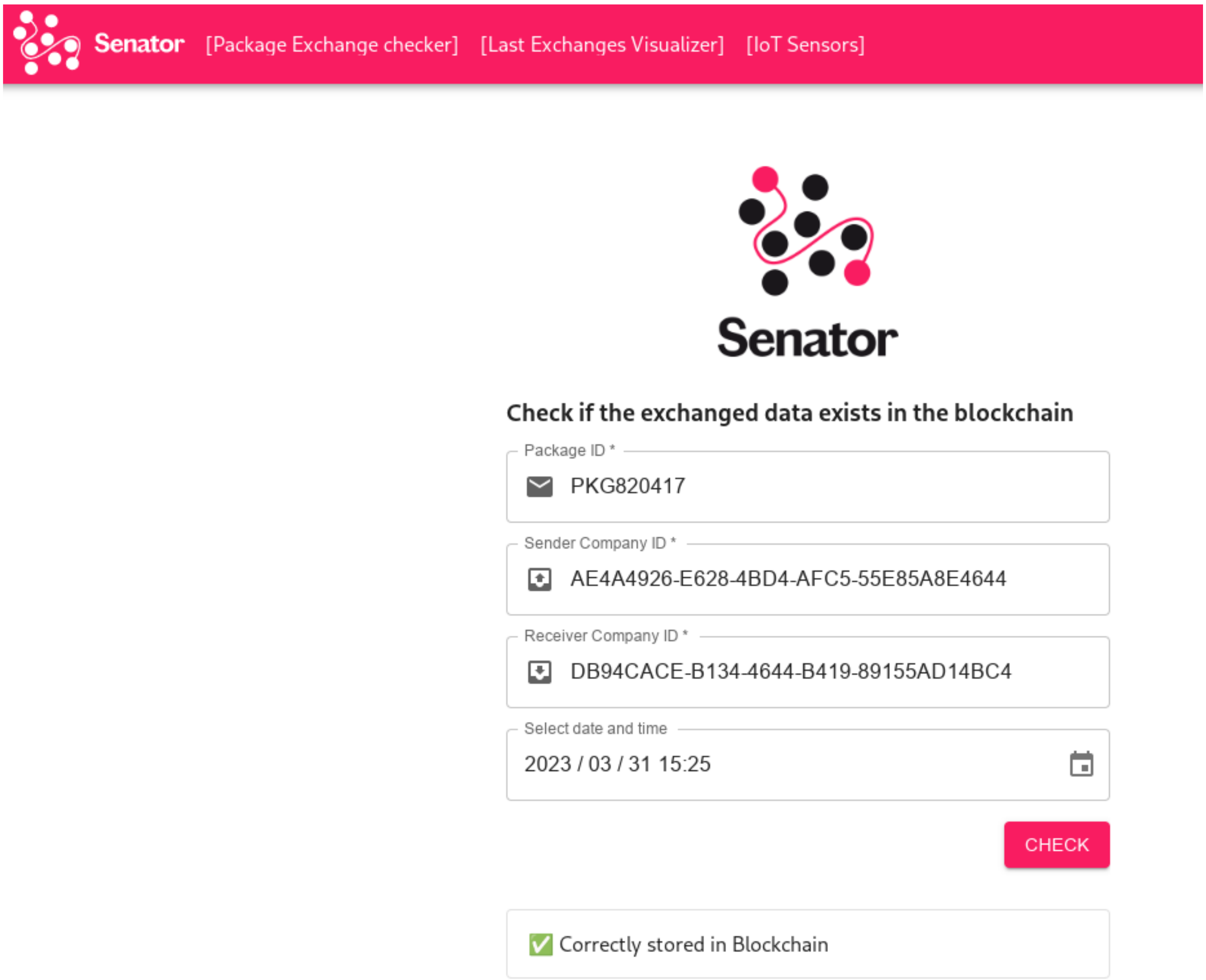

Figure 40. SENATOR Blockchain Web Validator form to check if a transaction has been successfully stored in the Blockchain. Result: Granted

Integration with fleet tracking providers

In cooperation with various vehicle fleet management systems providers of CORREOS, integration tests of the most of the vehicles participating in the Zaragoza ULL has been enabled. They accessed into the SENATOR Message Bus for periodic updating of their GPS position and the performance of the connection was tested between months of October 2022 and February 2023.

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Integration with PDAs

Furthermore, a similar functionality is integrated into the PDAs of CORREOS postal workers. The postmen from this company carry a mobile device, a rugged and commercial PDA, that help them into their daily operation giving them ability to trace their location, and hereby the position of the goods they are delivery. Also gives them tools to mark them as successfully delivered or failed goods for several reasons. By means of publishing that information within SENATOR using the Messaging bus, the system can monitor the locations and status of all the shipments “in-itinere”, and also the SENATOR Dashboard and the SENATOR Mobile APP (that provides the same functionality than a PDA to those logistic operators that cannot integrate their own systems into SENATOR platform or eventually do not have any) The SENATOR Mobile APP can show planned routes and allows performing the real execution (and even compare it with the planned operation).

In response to the requirements and use cases raised in the SENATOR platform, a scenario has been implemented in which two carriers must exchange packages between them (due to a breakdown or service needs, e.g., access by electric car to ZBE). It is one of the newest features supported by this APP, as can be seen below.

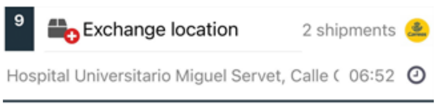

Figure 41. SENATOR Mobile App: Exchange location for goods transactions

Accordingly, to what has been explained before related to Blockchain use cases, secure merchandise transactions between logistic operators must been granted and this way they are taken into account within SENATOR Platform.

When is needed to interchange loads between logistic operators or shippers, the SENATOR Mobile APP will present those parcels in a differentiate way within the route, associated to one stop marked as “Exchange location”.

There the goods to be exchanged will be displayed. In this scenario, two indicators appear with the package number. When one of the carriers (Operator 1, in the left) marks a package as "Exchanged" its indicator will appear in orange. When the other carrier (Operator 2, in the right) accepts the exchange (also marking as "Exchanged" the same package in its own mobile application) its indicator will appear briefly in orange to change both to green then on both devices.

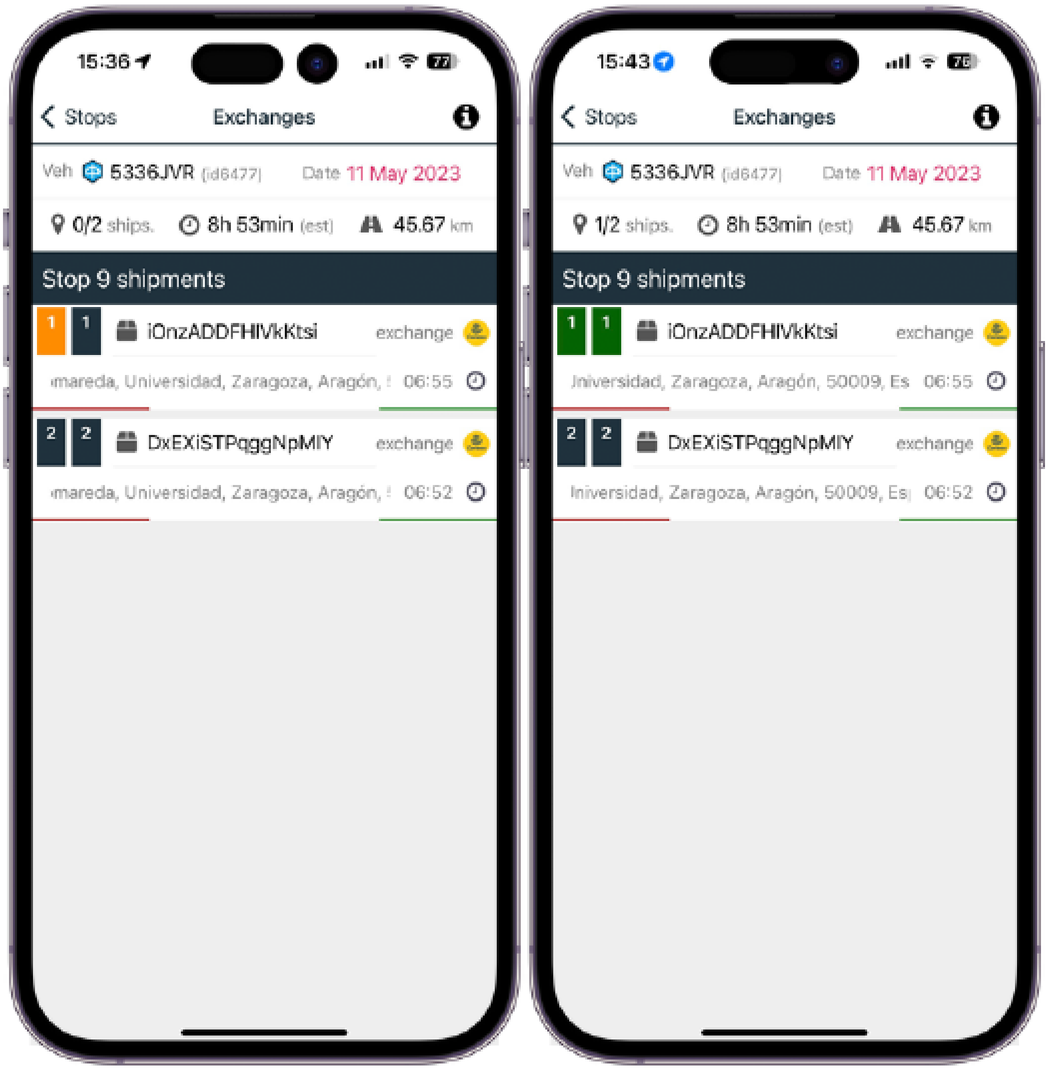

Figure 42. SENATOR Mobile APP: Exchange of multiple shipments between logistics operators

In order to guarantee the correct process, the exchanges must be confirmed by both carriers in a short time frame (20 seconds) and are registered in Blockchain for subsequent validation.

Integration with IoT devices

The access and connection to refrigerated boxes of dedicated to fresh food delivery fleet was completed by March 2023. The external provider that supports traceability and access to the registered data is a Spanish company that can register and sending precise and real time information about several temperature and humidity probes onboard, doors´ opening and closing actions and telemetry and identification information about the transportation where it is installed.

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Figure 43. APACHE Cold Tracer

To acquire that valuable data into SENATOR, these devices are publishing their information thought the Messaging Bus and when receiving it, SENATOR sends it to the Blockchain network to seal it, guaranteeing that the current operation conditions are safe-warded without delay and are available to consultation latter on with all warranties.

As has been commented before, this integration is directly related with the second use case of Blockchain, the management of the cold chain in food or critical shipments. As mentioned, DEUSTO designed and deployed a Web application where can be seen all the IoT information received from the Bus (including the generated simulators that can be identified as the Device ID “77DEU77”, created for functionality test purposes) and sent to the Ardor Blockchain integration and the confirmation whenever that data is correctly stored and confirmed by the Blockchain.

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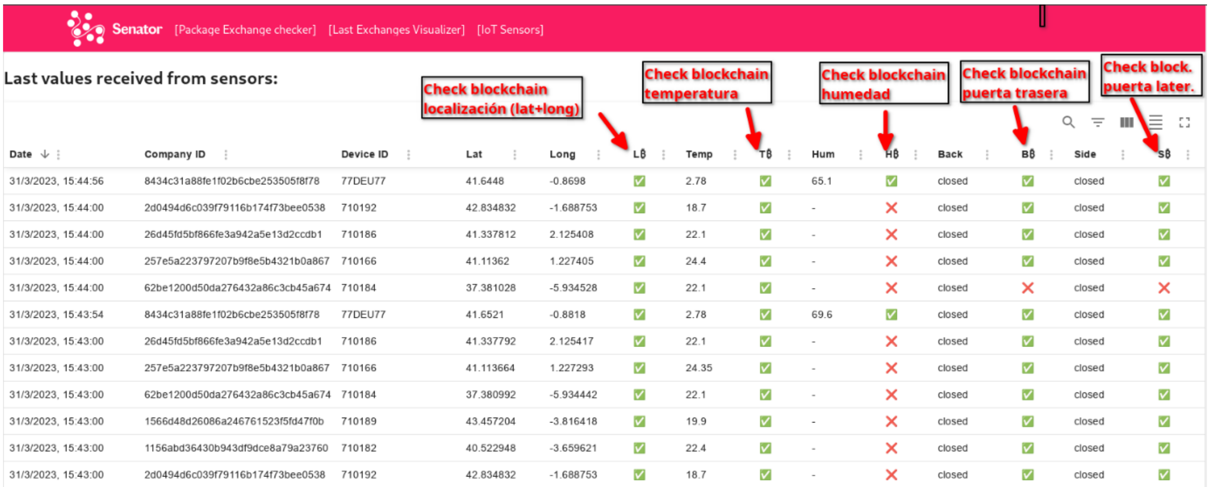
Senator [Package Exchange checker] [Last Exchanges Visualizer] [IoT Sensors]

Last values received from sensors:

Check blockchain localización (lat+long)
Check blockchain temperatura
Check blockchain humedad
Check blockchain puerta trasera
Check block. puerta later.

Date	Company ID	Device ID	Lat	Long	L₿	Temp	T₿	Hum	H₿	Back	B₿	Side	S₿
31/3/2023, 15:44:56	8434c31a88fe1f02b6cbe253505f8f78	77DEU77	41.6448	-0.8698	✅	2.78	✅	65.1	✅	closed	✅	closed	✅
31/3/2023, 15:44:00	2d0494d6c039f79116b174f73bee0538	710192	42.834832	-1.688753	✅	18.7	✅	-	❌	closed	✅	closed	✅
31/3/2023, 15:44:00	26d45fd5bf866fe3a942a5e13d2ccdb1	710186	41.337812	2.125408	✅	22.1	✅	-	❌	closed	✅	closed	✅
31/3/2023, 15:44:00	257e5a223797207b9f8e5b4321b0a867	710166	41.11362	1.227405	✅	24.4	✅	-	❌	closed	✅	closed	✅
31/3/2023, 15:44:00	62be1200d50da276432a86c3cb45a674	710184	37.381028	-5.934528	✅	22.1	✅	-	❌	closed	❌	closed	❌
31/3/2023, 15:43:54	8434c31a88fe1f02b6cbe253505f8f78	77DEU77	41.6521	-0.8818	✅	2.78	✅	69.6	✅	closed	✅	closed	✅
31/3/2023, 15:43:00	26d45fd5bf866fe3a942a5e13d2ccdb1	710186	41.337792	2.125417	✅	22.1	✅	-	❌	closed	✅	closed	✅
31/3/2023, 15:43:00	257e5a223797207b9f8e5b4321b0a867	710166	41.113664	1.227293	✅	24.35	✅	-	❌	closed	✅	closed	✅
31/3/2023, 15:43:00	62be1200d50da276432a86c3cb45a674	710184	37.380992	-5.934442	✅	22.1	✅	-	❌	closed	✅	closed	✅
31/3/2023, 15:43:00	1566d48d26086a246761523f5fd47f0b	710189	43.457204	-3.816418	✅	19.9	✅	-	❌	closed	✅	closed	✅
31/3/2023, 15:43:00	1156abd36430b943df9dce8a79a23760	710182	40.522948	-3.659621	✅	22.4	✅	-	❌	closed	✅	closed	✅
31/3/2023, 15:43:00	2d0494d6c039f79116b174f73bee0538	710192	42.834832	-1.688753	✅	18.7	✅	-	❌	closed	✅	closed	✅

Figure 44. Capture from SENATOR Blockchain Web Validator developed by DEUSTO

All the real and simulated transactions are sent to be stored in the Blockchain networks without incidents, and all the payloads have been processed returning the expected values from the Addon.

To show the evidence of the test done, we provide a description of the steps, including the payloads, the responses and the database record stored per each request send. Each request stored on the Ardor node (blockchain node) database is sent from the SENATOR platform for the two scenarios implemented. On the Excel file, one per each scenario, we provide the following entries, representing the complete sequence of integration in one line per record, having the following data:

- Payload request sent from SENATOR to the Blockchain Addon
- Acknowledge from the Blockchain Addon replying to the payload sent synchronously
- Confirmation from the Blockchain Addon informing to SENATOR with the confirmation sent from Ardor (Blockchain network) on the registration of the operation sent in the Payload

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3.9 Smart Management for loading bays

The main issue with loading and unloading operations in medium-sized cities like Zaragoza stems from the inefficient use of parking spaces and the lack of proper regulation regarding schedules and vehicle access. This often leads to congestion, delays, and disruptions in both delivery logistics and everyday traffic flow. To address this, a control system is being developed, which includes a mobile app and virtual ticketing, to regulate the use of loading zones and other high-demand parking areas. This system aims to optimize the management of these spaces, ensuring that they are used more effectively and in accordance with established timeframes.

Zaragoza's pilot project is addressing two interconnected logistics challenges:

- The first involves improving the regulation of public parking spaces designated for deliveries. This will be achieved through a new approach that incorporates technology to i) allow drivers to reserve parking spots for deliveries in advance, and ii) enable city officials to monitor the use of these spaces.
- The second challenge is better organizing last-mile deliveries around public markets and local commerce streets.

3.9.1 Optimizing Loading Dock Management for Efficiency and Sustainability

Smart management of loading docks in two key areas near public markets and/or congested areas of the city includes the installation of sensors and hardware, as well as the development of a mobile app to reserve parking spaces and ensure proper use of these areas. Some of the improvements expected from this initiative include:

- More efficient use of parking areas and loading bays by allowing drivers to book spaces in advance, helping them avoid traffic or waiting while loading and unloading their goods;
- The collection of valuable data to promote measures aimed at optimizing vehicle usage or use of public space;
- Reduced traffic congestion and, consequently, a decrease in CO_2 emissions.
- Minimisation of incidents and irregularities detected.

Two key locations in the city have been selected for the implementation of this solution, with each site featuring two dedicated parking spots for loading and unloading. The parking duration will be monitored through ground-installed presence sensors, which, together with a mobile application, will ensure an efficient use of the spaces.

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Each location will be equipped with a series of sensors that detect when a vehicle enters the zone, allowing for precise monitoring of parking time. Drivers will be able to check the occupancy status of the parking spots in advance via the app, enabling them to reserve a space and avoid circling the area. This will help reduce congestion around these high-traffic areas, which are often overcrowded due to their proximity to popular shopping destinations. As a result, the initiative will improve traffic flow and make the process of loading and unloading goods more efficient.

Figure 45: Loading and unloading zone regulating signal

Figure 46: Photo sensor and its installation on the ground

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Usage data can be integrated to optimize delivery operations, improve urban planning and facilitate traffic management.

Through the app, the user can initiate a parking session and receive real-time information about available parking spaces nearby. Contributing to decrease vehicle turnover, thus freeing up spaces to facilitate urban freight.

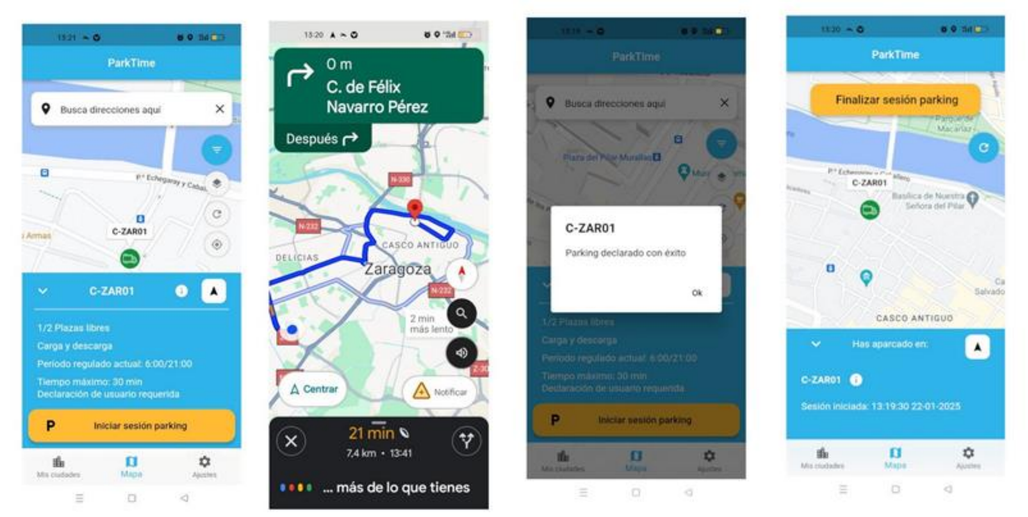

Figure 47: Reservation process through the App

In addition, the web application (backend) allows the management and control of the use and rotation of the places, allowing a strict regulation of the schedules.

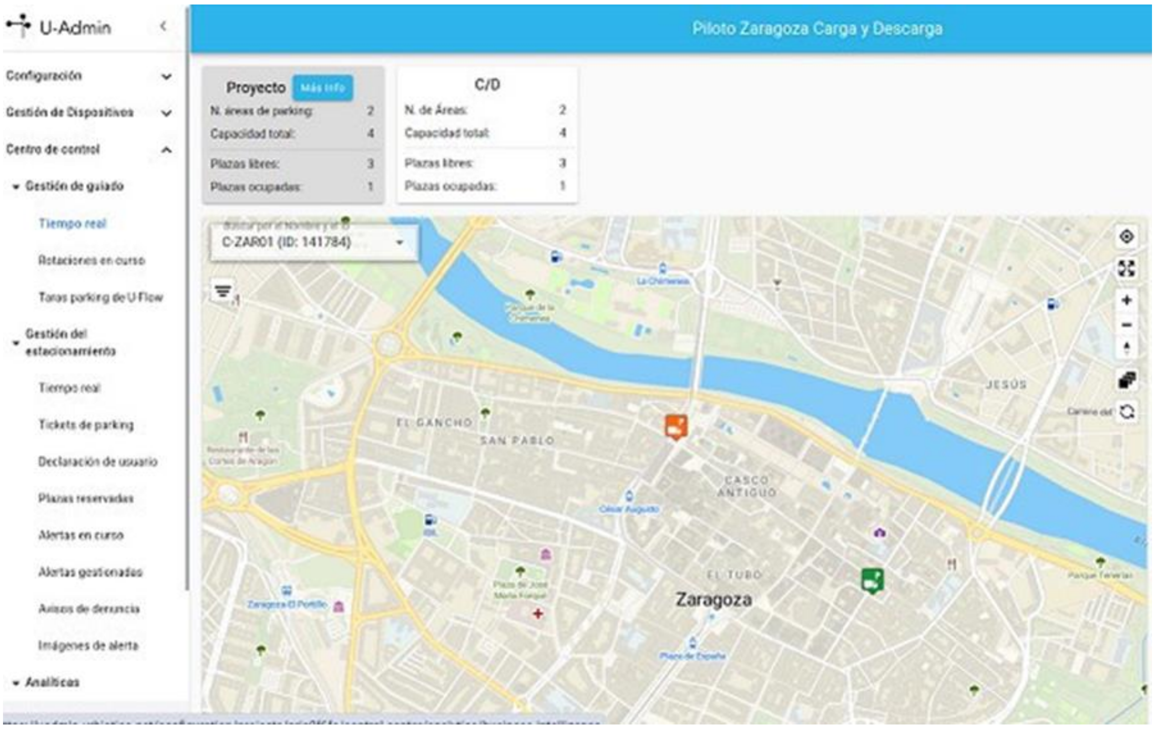

Figure 48: web application management and control of the places

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The data generated through the loading and unloading operations will be integrated (through the corresponding API) with the open data catalogue of the City Council of Zaragoza, published in open format with the appropriate guarantees in terms of privacy and security, for its analysis and/or exploitation by third parties. Indeed, the data generated will be part of the Zaragoza's open data catalogue.

1	Spot	Inicio	Fin	Duración	Período Regul
2	C-CSANLOREN02-01	06/01/2025 22:30:37	06/01/2025 22:33:58	3 minutos 21 segundos	No
3	C-CSANLOREN02-02	06/01/2025 21:36:51	07/01/2025 01:09:31	3 horas 32 minutos	No
4	C-CSANLOREN02-02	06/01/2025 21:11:33	06/01/2025 21:19:15	7 minutos 42 segundos	No
5	C-CSANLOREN02-02	06/01/2025 20:52:45	06/01/2025 21:04:15	11 minutos 30 segundos	No
6	C-CSANLOREN02-02	06/01/2025 19:03:11	06/01/2025 20:51:50	1 horas 48 minutos	No
7	C-CSANLOREN02-01	06/01/2025 18:36:27	06/01/2025 21:53:24	3 horas 16 minutos	No
8	C-CSANLOREN02-02	06/01/2025 17:13:52	06/01/2025 19:02:35	1 horas 48 minutos	No
9	C-CSANLOREN02-02	06/01/2025 10:50:52	06/01/2025 15:56:16	5 horas 5 minutos	No

Figure 49: Sample of open data ready to be upload to the Zaragoza's open data catalogue

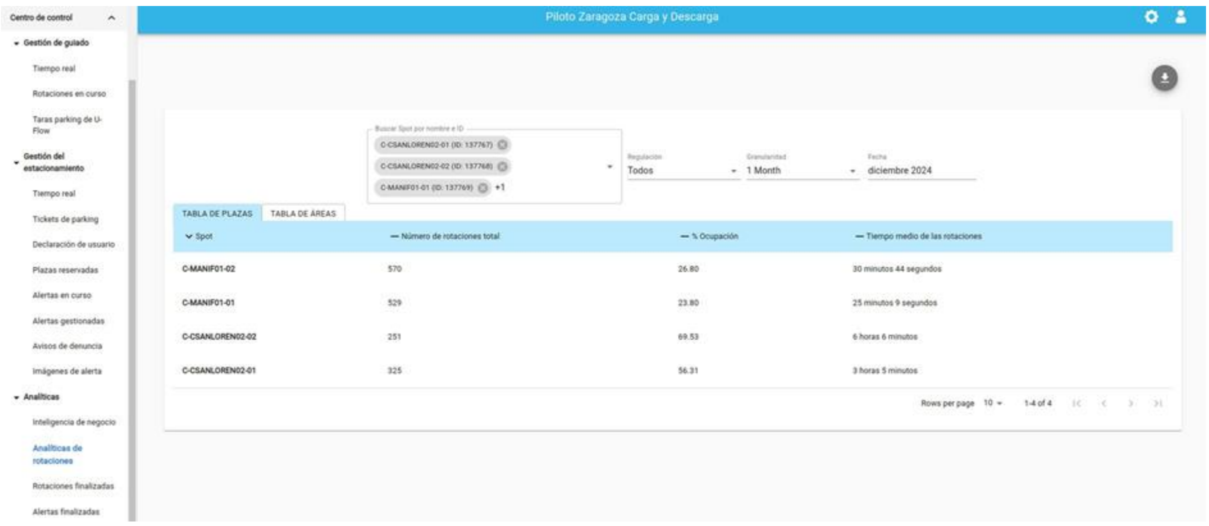

Figure 50: Sample usage summary data for one month.

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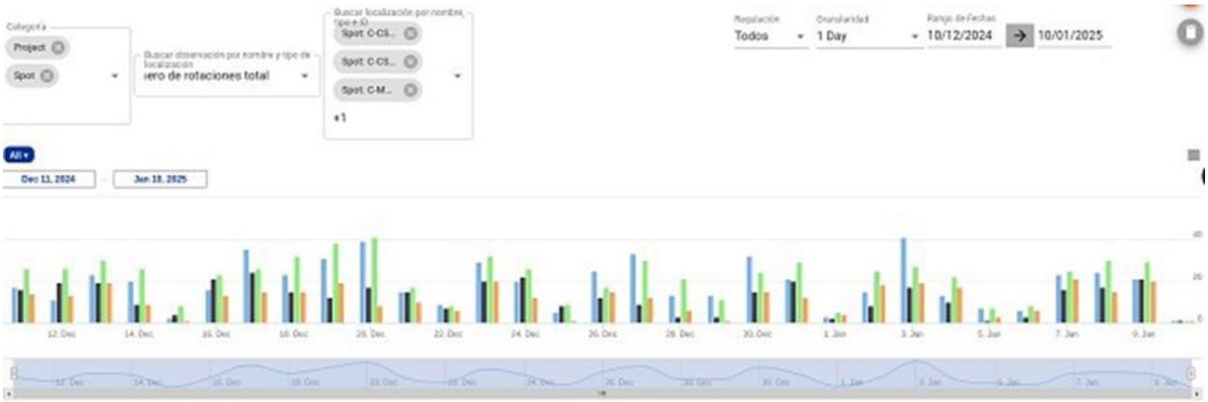

Figure 51: Vehicles rotations per day

The technical requirements to integrate the booking management application with the SENATOR platform have been identified and would be integrated into SENATOR.

3.9.2 Theoretical Assessment of the Loading/Unloading Zones' Level of Service in Zaragoza

This study assesses the Level of Service (LOS) of Zaragoza's loading and unloading zones, addressing two major challenges in urban freight planning:

- The lack of standardized guidelines for designing and managing these spaces and,
- The need for practical, scalable methodologies that can be implemented in real-world contexts.

The research aims to bridge the gap between academic studies and day by day municipal freight management by developing a structured methodology that integrates both empirical data collection and theoretical modelling.

The study focuses on identifying and classifying commercial activities that generate freight demand, analysing the capacity of loading and unloading zones, and applying a queueing theory-based LOS evaluation model.

The methodology has been designed to be scalable and adaptable, ensuring its applicability to other urban environments beyond Zaragoza: by offering a systematic approach to evaluating urban freight infrastructure, the study provides insights that contribute to the development of more efficient and sustainable freight management strategies.

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Research Design

The study was structured into two main phases to ensure both theoretical rigor and practical applicability:

- Theoretical Validation: The model was first tested using simulated data to evaluate its internal consistency and adaptability to different freight demand scenarios. This phase allowed researchers to verify the structure of the methodology, assess its limitations, and ensure that it could be applied effectively in different urban settings.
- Empirical Calibration: To refine the model, real-world data was collected through a survey of commercial establishments in key economic sectors, including daily retail, hospitality, fashion, and accessories. This data was then integrated into the model, ensuring that the LOS estimations accurately reflected actual freight operations within the city.

By structuring the research in these two phases, the study ensures a balance between theoretical accuracy and practical implementation, making the methodology useful for urban planners and policymakers.

Data Collection and Analysis

The study relied on official data from the Zaragoza City Council's open data portal, ensuring access to updated and reliable information. The collected data include:

- Commercial activity licenses, categorized into four major sectors based on their freight generation characteristics.
- Loading and unloading zone data, including their spatial distribution, size, and operational hours.

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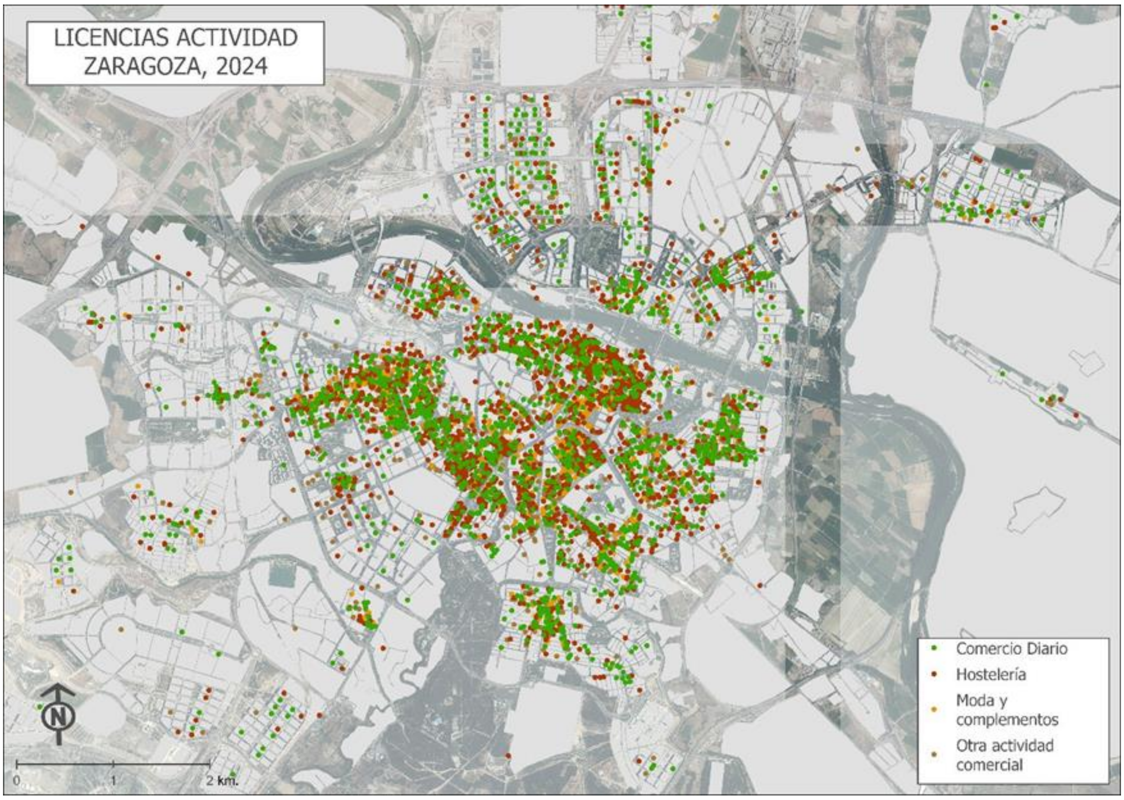

Figure 52: Spatial distribution of commercial activity. In green daily retail, red catering industry, yellow fashion and accessories, brown other retail activities

A Geographic Information System (GIS) was used to georeference this data, allowing for detailed spatial analysis. Zaragoza has 779 designated loading and unloading zones, distributed strategically throughout the city (figure 44). Each zone was analysed based on its capacity, operating hours, and usage demand, providing key insights into freight distribution patterns.

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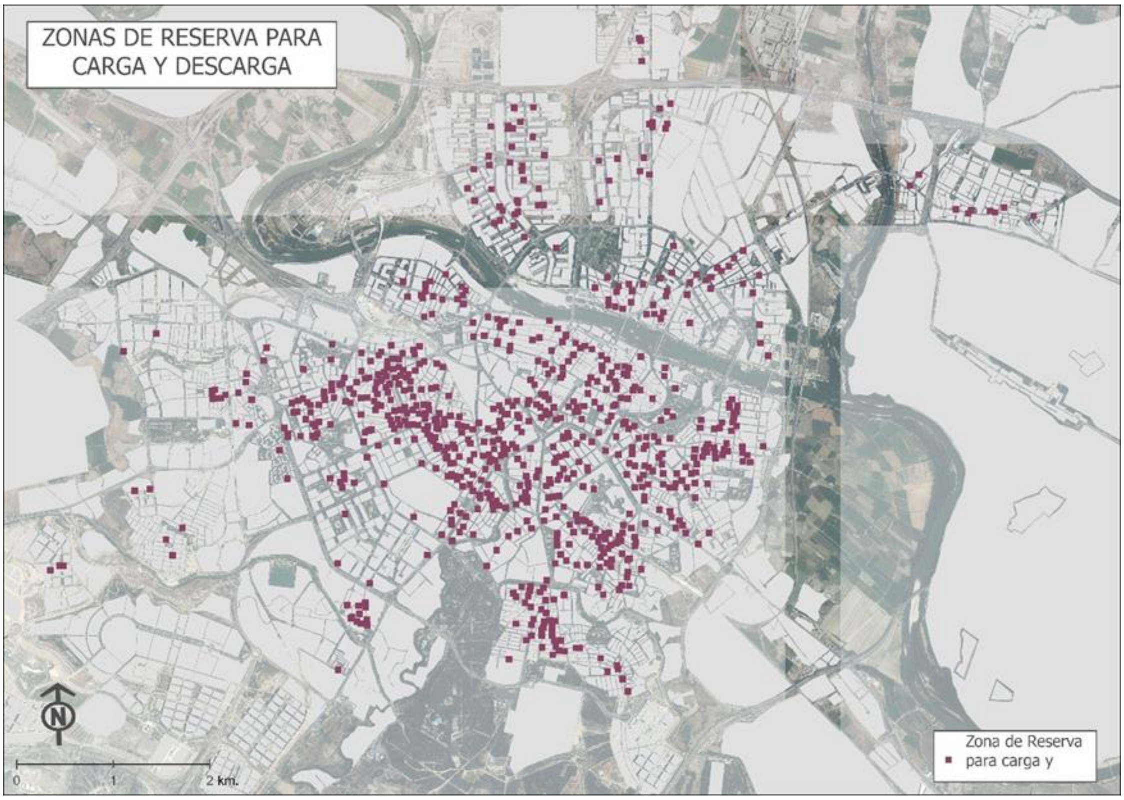

Figure 53: Loading / Unloading zones distribution

Methodology for LOS Calculation

The LOS of loading and unloading spaces was calculated using Poisson Queueing Theory, a statistical model that estimates the probability of vehicle arrivals and their accommodation within the available infrastructure.

To simplify the explanation of the methodology, the report presents a step-by- step application of the model using a single urban block as an example. This approach allows for a clearer understanding of how the model functions before extending it citywide. The same steps were applied in both the theoretical and empirical phases, with the main difference being the data used (simulated vs. real-world observations).

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Contributions and Practical Implications

This study provides a structured, data-driven methodology that enhances the efficiency of urban freight management. The key benefits of applying this model include:

- Better allocation of loading and unloading spaces, ensuring that freight demand is accurately reflected in urban planning decisions.
- Improving traffic flow and reducing congestion, as well as better management of freight zones minimizes illegal parking and double-parking issues.
- Integration into Sustainable Urban Mobility Plans (SUMP) and Sustainable Urban Logistics Plans (SULP), aligning freight management with broader sustainability and efficiency goals.

By combining theoretical modelling with empirical validation, this research presents a scalable framework that can be adapted to other cities looking to improve their urban logistics and mobility strategies.

3.10 Future Opportunity: Dynamic Logistics' Maps Using AI

Within the deliverable D4.6 "Design catalogue for Zaragoza and Dublin" a series of innovations were proposed to improve and adapt urban design to the needs of smart logistics. As part of this design catalogue new figures of physical logistics nodes, such as micro-logistics hubs, or parcel lockers, have emerged. Also, cities are adapting the concept of lockers to be installed in the so-called "friendly or informal delivery pick-up points". These are local shops that are used as pick-up points by users, who are encouraged to use them instead of having their parcels delivered to their homes.

Therefore, well-balanced urban logistics network can help three-fold to achieve important strategic goals of Zaragoza: reduce carbon footprint, decrease traffic congestion and revitalize street commerce (e.g., the so-called "corner stores.") However, the logistics infrastructure of the city should not be static, but it needs to change and adapt to the evolution of demographics, shopping habits, and urban fabric. Therefore, smart cities would need to permanently adapt their logistics urban plans.

This suggests that there is an opportunity to improve the innovation potential of the conclusions of SENATOR, by showing how to use new tools that help urban planners drive this permanent adaptation. Showing, for instance, how the urban logistics infrastructure can support dynamically the concept of the 15-minute city, or that it fulfils one of the premises of any Living Lab -to take into account citizen's preferences- by incorporating these

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preferences by introducing in the logistics' planning process behavioural data from citizens' perception.

3.10.1 Concept and Methodology

We will first build a static map to showcase the implementation potential of micro hubs. Based on this static map, we will define the baseline and structure for the future creation of a dynamic virtual map displayed on a user-friendly interface which, in the future, could be fed with daily data from logistic providers (for instance through the SENATOR platform exploited beyond funding). In turn, this data could be aggregated over time to conform layer after layer of low-frequency data feed on urban logistics.

This dynamic map will also include forecasting through machine learning, showcasing how a cutting-edge solution can be applied to optimize logistics across an average city such as Zaragoza, leveraging both static and dynamic data layers. This result might be inspiring to other cities in terms of the possibilities that AI offers for long-term dynamic planning of urban logistics (e.g., the dynamic creation of SULPs).

The methodological approach integrates logistics data, population density, and urban development projections to enhance parcel delivery services throughout the city. The study demonstrates how an AI powered model can produce a scalable and future-proof system, capable of adapting to changing urban dynamics and delivery demands.

It also will consider the deployment of advanced optimization techniques, including machine learning, to select the most effective locker locations. The aim is to balance multiple objectives, such as reducing CO_2 emissions, decreasing congestion, revitalizing street commerce, enhancing walkability and health amongst citizens, all while minimizing delivery costs and maintaining service efficiency.

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Figure 54: Baseline example of a static map for a urban logistic network adapted to the 5 minute city concept. (Source: Etopia's Datalab).

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4 Challenges

Obtaining the information: The first step in obtaining data was the extraction of information of Correos and CEx systems. This refers to:

- Shipping Information:
  - The data, according to our data protection department, had to be anonymized. This means completely anonymized, so that it is impossible to reverse the anonymization to access the original data. In addition, any reference to personal data, including exact address and shipping code, cannot be shared if it is not anonymized.
  - Data availability: many of the shipments that the Post Office works with on a daily basis do not have complete digitized information, so that the information available on the shipment label for delivery is not always available in the company's computer systems nor does it have the desired quality, requiring data processing to be able to use it in route optimization.
- Route information:
  - In order to complete the necessary information for the optimizer, we requested to be able to access the data of the PDAs carried by the postmen to obtain real-time information on the position of the routes. In order to obtain this data, it was necessary for the postmen to sign an information document on the information to be collected (geopositioning) and in which it is informed and guaranteed that no data that identifies the delivery personnel will be obtained, analysed, or shared.
  - The integration of the route sensorisation with the platform has only been possible with part of the Zaragoza vehicles, since including 100% of the vehicles had a cost that could not be assumed within the project and was not technically feasible due to the integration restrictions of some suppliers.
- Vehicle Information:
  - As happened with the PDAs, in order to obtain the geo-position information of the vehicles, all the postmen in the city of Zaragoza had to sign a document informing them of the information to be collected, the purposes, and that at no time would the person driving the vehicle be identified or obtained, analyse, or share any personal data.

Anonymization of information: The next challenge was to anonymize the information so that it could be used in SENATOR:

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- Geopositioning with a margin of error that guarantees not sharing the exact location of the recipient, guaranteeing the anonymization of the data but allowing the development of the route optimization agreed upon in SENATOR.
- The shipment code anonymized in a way that ensures that the exact code of any actual shipment is not shared.
- Address information could not be shared under any circumstances, nor any personal data, neither of postal staff nor of the recipients of the shipments.

Geo-position of addresses:

- The geo-position of the addresses has not been easy to resolve. It has been necessary to test three different internal tools and modify information manually to obtain the necessary percentage for the optimization of the routes of 100% of geopositioned addresses. Additionally, and external service had to be hired to solve this issues as an intermediate step.

Integration with the SENATOR platform:

- Integration with the platform in an automated way via API has not been possible due to the complexity of development by Correos necessary to be able to integrate with the SENATOR platform. However, the information has been able to be shared by email and uploaded manually on the platform daily thanks to the team at the University of Deusto.
- Correos' computer systems are prepared to be robust by efficiently processing the information of more than 1,200 million shipments per year, however, making a personalized extraction, with a different format than the data from the systems, with the requested changes and in a specific file on a daily basis, required months of development by several technology teams.

Time: Another of the great challenges, which has not been possible to optimize further, is time:

- Extracting predictive and accurate information about what will arrive at the delivery unit has been a problem that Correos has not been able to solve, despite multiple attempts.
- SENATOR's route optimizer needs to be optimized to reduce compute time to 10 minutes or less.

Data quality:

- After extracting the information from the shipments, it is necessary to complete, clean, anonymize, geo-position and format the information, to adapt to the requirements that SENATOR's route optimization needs to be able to return the optimized routes.

- The quality of the starting information must be complete and in the exact format required by the system, otherwise it does not work or discard items because of de lack of critical information such as weight or volume, which are not always informed in Correos or CEx systems as they are not mandatory for the logistic operator. This has been a challenge because the information is not always available with the required quality or it must be extracted from a different

European and national legislation compliance: other of the main challenges regarding this project has been law compliance regarding data sharing.

Regarding personal data protection there are three regulations that directly apply to the project:

- Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of individuals with regard to the processing of personal data and on the free movement of such data and repealing Directive 95/46/EC (General Data Protection Regulation).
- Organic Law 3/2018, of December 5, on the Protection of Personal Data and guarantee of digital rights.
- Law 43/2010, of December 30, 2010, on universal postal service, users' rights and the postal market.

Logistics companies may rely on **legitimate interest** to share customers' personal data with other logistics companies, provided that this interest does not override the fundamental rights and freedoms of the data subjects. However, this does not exempt companies from the obligation to inform customers about the processing of their personal data.

The General Data Protection Regulation (GDPR) states that data controllers must provide data subjects with clear and transparent information about how their personal data will be used, including any possible transfer to third parties[2]. This means that, even if legitimate interest is used as a legal basis, logistics companies must inform customers about the sharing of their personal data.

In summary, while legitimate interest may be a valid legal basis for data sharing, transparency and information to users remain key requirements.

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In summary, while legitimate interest may be a valid legal basis for data sharing, transparency and information to users remain key requirements.

In the case of the data shared in the project, as it was impossible to inform all customers about the use of personal data, such as address or shipment reference, for reasons of time and scope of the project, the anonymization explained above has been chosen, making it impossible to identify the recipients.

In terms of the system, the technology is sufficiently mature to be able to share information between different logistics operators, but not before making the necessary technological developments to standardize the format of the shared data. However, what makes the difference in the implementation of this type of solution is the willingness of companies to collaborate. Such collaboration could be achieved through collaboration agreements, as well as confidentiality agreements, which ensure, among other things: quality of service, confidentiality of shared data, security of both employees and shipments, as well as compliance and regulatory restrictions applicable in each case.

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5 Conclusions

Given the scenarios considered in the different pilots, the use of SENATOR has provided a considerable reduction in time and kilometres travelled, as well as considerable cost savings and improved employee productivity (increase in packages per hour and shipments per kilometre), significantly improving the environmental and economic impact of logistics operators. However, it is necessary to correctly define the optimization parameters, since in some cases there have been routes with only one shipment, routes that were not homogeneous in terms of duration and shipments that could not be delivered.

This route optimizer could be very useful for a new mail carrier as it allows newcomers to follow the route in the mobile app and it improves the efficiency of delivery. For a route optimizer to be optimal for a logistics company, it must take advantage of historical data in conjunction with an analysis and artificial intelligence tool.

SENATOR optimization routes are quite reasonable, making a logical proposal and in accordance with both time and distances. This is especially due to the development of the optimization algorithm based on historical data provided for the project and the joint work of Correos and the University of Deusto to establish the appropriate parameters.

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