PlastiCircle
Grant Agreement No 730292

DELIVERABLE 3.7
Final transport system
ITENE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730292.

Factsheet

Document name: Deliverable 3.7 - Final transport system

Responsible partner: ITENE

Work package: WP3 TRANSPORT

Task: T3.5 Post-pilot final design WP3

Deliverable number: 3.7

Version:

Version date:

Dissemination level	
X	PU = Public
	PP = Restricted to other programme participants (including the EC)
	RE = Restricted to a group specified by the consortium (including the EC)
	CO = Confidential, only for members of the consortium (including the EC)

Author: Mireia Calvo (ITENE), José Ángel Rodríguez (ITENE), Miguel Ángel Górriz (ITENE), Valentin Voinica (Alba Iulia Municipality), Julián Torralba (Las Naves), Amadeo Semper (SAV), Amparo Martinez (SAV), Jerónimo Franco (SAV), Francisco Ample (SAV), Frank Donkers (Utrecht)

Reviewers: All partners

Abstract

This document presents the results obtained from the *Task 3.5 Post pilot final design of transport*. Each technology included in the transport system is analysed individually. The modifications done along the project to improve the pilot activities are explained. The IoT cloud platform, the eco-driving & truck traceability, the route optimization, and the characterization protocol & compensation procedure are the technologies involved on this deliverable. There is a chapter per each technology. Initially, a brief definition of the technology is presented, later the cities assessed the technology tested on the pilots and finally the final design and the modification done during the project are explained.

Abbreviations

IoT: Internet of Things

PTO: Power Take Off

Partners short names

1. ITENE: INSTITUTO TECNOLÓGICO DEL EMBALAJE, TRANSPORTE Y LOGÍSTICA
2. SINTEF: STIFTELSEN SINTEF
3.
4. AXION : AXION RECYCLING
5. CRF : CENTRO RICERCHE FIAT
6. UTRECHT : GEMEENTE UTRECHT
7. Las Naves: FUNDACION DE LA COMUNITAT VALENCIANA PARA LA PROMOCION ESTRATEGICA EL DESARROLLO Y LA INNOVACION URBANA
8. ALBA: PRIMARIA MUNICIPIULUI ALBA IULIA
9. MOV: MESTNA OBCINA VELENJE
10. SAV: SOCIEDAD ANONIMA AGRICULTORES DE LAVEGA DE VALENCIA Spain
11. POLARIS: POLARIS M HOLDING
12. INTERVAL: INDUSTRIAS TERMOPLÁSTICAS VALENCIANAS
13. ARMACELL: ARMACELL Benelux S.C.S.
14. DERBIGUM : DERBIGUM N.V.
15. PROPLAST : CONSORZIO PER LA PROMOZIONE DELLA CULTURA PLASTICA PROPLAST
16. HAHN : HAHN PLASTICS Ltd.
17. ECOEMBES : ECOEMBALAJES ESPAÑA S.A.
18. KIMbcn : FUNDACIÓ KNOWLEDGE INNOVATION MARKET BARCELONA
19. PLAST-EU: PLASTICS EUROPE
20. ICLEI: ICLEI EUROPASEKRETARIAT GMBH
21. PICVISA

21.1. CALAF: CALAF INDUSTRIAL

22. SINTEF: SINTEF AS

Table of contents

Table of figures

Publishable summary

The main aim of this document is to present the final transport system developed in PlastiCircle project, including the remaining modifications needed to have a complete commercial system. The technologies included on the transport system are:

- Route optimization: algorithm that calculates the optimised route to follow by the collection truck based on the filling level of the containers.
- Eco-driving and truck traceability system: Technology that measures the efficiency of the driving behaviour of the truck driver and provides advices to the driver in order to increase the efficient driving.
- Characterization protocol and compensation procedure: Methodology developed to measure the quality of the individual plastic waste of the citizens taking into account the size of the bag (if it is full or not), the non-plastic packaging materials, if the materials are stacked, if the materials are plenty, if the materials are compacted. Based on the assessment of the individual bags and the quality obtained, a number of points was given to the citizen. Those points were able to be redeemed by rewards. Ideally, the benefit would be a reduction of the recycling tax.

  The main drawback of this methodology is that it is design to do manually, in the this document an alternative to make this characterization automatically is included.
- IoT platform: it is the centre of the system which receives all the information gathered, visualize the results and process it.

In this deliverable each technology is analysed individually. At the beginning a brief introduction about the main functionalities of the technology are explained. Continuing, a chapter where the pilot cities assessed the limitations, advantages and disadvantages of each technology found during the pilots. The next chapter explains the modification done from the first test in Valencia pilot until the end of the pilots. Finally, the final design of the technology is explained. Some cases the technology is almost ready to be commercialised and in other cases a new approach more automatic is presented.

Introduction

The main objective of this task is to improve and carry out the needed modifications to obtain a final PlastiCircle transport system. The transport system includes the IoT cloud platform, route optimization, characterization protocol and compensation procedure, truck traceability and driving guidance.

Per each technology have been identified the limitations after testing them on the pilots. All the developments were adapted and readjusted to the needs of each pilot and the situation of each city. Some solutions have been proposed to the limitations identified and the main advantages and disadvantages of the technology have been remarked.

The pilot cities have participated reporting their own experience testing the technologies. In order to gather the information required, the three cities have answered a questionnaire regarding each technology assessing the limitations, advantages, disadvantages and proposing new solutions or functionalities.

Finally, the final proposal per each technology have been explained. The main objective is to analyse the performing of the transport technologies in order to increase the efficiency and capabilities of the system.

In the following document each technology is explained and analysed separately, and all the requirements explained before are analysed.

1. IoT cloud platform

1.1 Definition

The IoT platform aims to integrate all information received from the different sources of data of the PlastiCircle system as filling level status from sensors, the geolocation of the container, routes and truck traceability.

The eco-driving application on board of the truck sends the data from the truck (location, speed, RPM and engine load) to the IoT platform where it is stored.

The IoT platform receives the information of the labels dispensed from the smart containers. The score of the characterized bags is registered in the platform too.
In addition, the IoT platform allows also to manage the registration of the citizens and compute their earned eco-points. The platform allows to visualize statistics of the citizens participating in the pilot as well of statistics of the labelled dispensed by the smart containers.
The platform allows also to manage the stock of the rewards and register the information of the rewards requested by citizens participating in the pilot.
Citizens participating in the pilots are able to check their earned eco-points through an Android application connected to the IoT platform. The application allows users to request their rewards and it provides information of how to improve the waste segregation, as well as information of events performed during the pilot. The application also provides questionnaires to the users. The main functionalities are summarized**:**

- User definition and user authentication
- Assets geolocation from the truck
- Filling level status from the container
- Truck traceability system visualization
- Eco-driving and route optimization
- Citizen registration system
- Waste characterization and citizen reward management
- Eco-points APP for citizen’s rewarding.

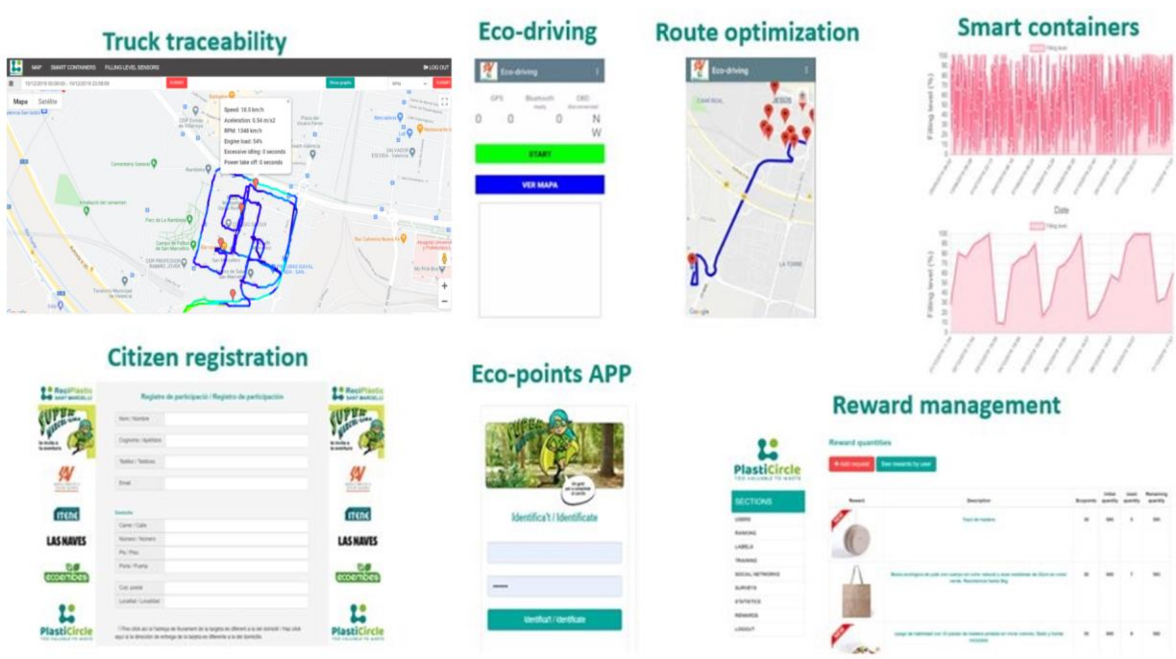

Figure 1: Functionalities of the IoT platform

The deliverable 3.6 explained all the specifications and functionalities that the IoT platform develops.

1.2 Information gathered from pilot cities

On this chapter each city has answered per each technology the following questions in order to know their experience testing the technologies and propose new functions for future work. In the case of the IoT platform, Valencia and Alba Iulia answered based on their experience during the pilot testing the PlactiCircle IoT platform while Utrecht answers are related their own platform.

1. **LIMITATIONS: Which limitations have you identified from the IoT platform? You can include the citizen's point of view.**

PILOT	ANSWER
Valencia	• Citizens have an APP to check their points. Points from weekly participation or missions were computed regularly but points for characterization was computed once the characterization was done. The characterization points weren't in real time. • Platform does not allow the communication between users and organizers. For instance: containers that does not work or direct questions about specific waste treatments. • Platform does not include information about smart

	devices status, preventing citizens to go to containers with malfunctional devices.
Utrecht	Our IoT platfrom does not have citizen registrations, therefor it is not used of cannot be used for citizen feedback, eg. Broken/full container, questions about waste types etc. IoT platform is not linked to other open data sources from Utrecht. The information gathered on the platform is therefor only used for the route optimization. Could be used for more applications in the city: eg, "where is the nearest container with room". At first, there was a lot of time to calibrate the sensors. After a few weeks this works perfectly
Alba Iulia	Citizens: Once registered (many details being required in order to filter participants from the pilot area), IoT Citizen's platform is clear and easy to use. Points, activities and rewards are clear but points are presented as overall value. Probably as a future option, notification to citizens for new activities and accumulated points change can be useful. Admins: filling sensors need extra protection to harsh environment and to be tested for longer periods and higher frequency transmission; mechanical part of labelling system can be improved for better stability aftershocks (like those generated by emptying containers); to be analysed if is possible to close/ lock containers lid (compromise with battery consumption and extra costs); combination of different transmissions (GPRS for filling sensors, LoRA + 3G for labelling boxes) can be optimized in a single low power transmission (ex. LoRA local system) if available at city scale (future possible development). An interesting development was the integration of questionnaires in platform, easing the acces and eliminating need for personal and social data, already available in platform.

2. **SOLUTIONS: Which solution do you propose to face the limitations explained?**

PILOT	ANSWER
Valencia	• Integration of IoT Cloud platform into VLCi platform, This platform already collects data that could complement those obtained by the IoT cloud platform: air quality, location of containers, streets cut off (no included in the project scope) • Incorporation of more services for the citizens

Utrecht	API interfaces with an open data source.
Alba Iulia	Citizens: Option for a notification engine. In case of individuals having contracts with operators, based on customer number, personal data can be loaded directly in platform from client database. Admin: improvements in devices and simplifying communication network and maintenance costs as future developments. System can be integrated in a larger smart city IoT platform, where available.

3. ADVANTAGES: Which are the main advantages of using an IoT platform?

PILOT	ANSWER
Valencia	• Accessibility of the data through both mobile app and internet website to the citizens • Integration of valuable information about correct domestic waste sorting.
Utrecht	Real time insight in the status of the container Immediate feedback when a container is emptied Data used for route optimization.
Alba Iulia	- Users complete data in a single place and updated reports for admins - Registering users data, email notification and anonymization based on single 4 digit user's number, RFID cards, activities, points and questionnaires - Very difficult to manage users without that platform - Clear to use and easy to upscale – to be tested for more (thousands of) users in order to address large city platform

4. DISADVANTAGES: Which are the main disadvantages?

PILOT	ANSWER
Valencia	The Iot platform should provide open data to be integrated into Vlci and these would be available to any developer.
Utrecht	Contracted with a third party. Any changes (like the API interfaces) will be a result of new negotiations
Alba Iulia	Pilot developments already improved platform with

	facilities like: participants filters based on address, access to questionnaires without introducing again personal data, access to manually set training points according to participation. Platform still needs minor specialized support and access to some data, but main core is stable, and adaptation is fast.

5. **Would you find interesting to adopt an IoT platform like the PlastiCircle to your city? Why?**

PILOT	ANSWER
Valencia	Yes, it is interesting as long as it can be integrated in VLCi. The VLCi Platform is an advanced computer and storage system that allows local authority managers to collect a large amount of information in a single repository, analyse it using Big Data advanced tools and then develop dashboards in order to help city service managers to draw conclusions and easy and quick on the spot decision-making. • VLCi Platform is the repository that feeds digital public services focused on different stakeholders: • VLCi open data allows entrepreneurs to develop new services based on open city data • VLC APP is an app oriented to citizens offering different public services • "Valencia al minut" (http://www.valencia.es/valenciaalminut/) is a web page showing real time data about city indicators • "Cuadro de mandos" is an intranet oriented to policy makers which them to make decision.
Utrecht	Yes, in our experience the route optimization possibilities with the data collection of the IoT platform alone are enough for a good amount in efficiency. Emptying container at 80% instead of at 50%.
Alba Iulia	It would be interesting to adopt filling sensor and card access to container, in order to improve recycling and collection efficiency, together with registered users, filtered/ accepted for a designated area. System can be integrated with a larger platform for local services and citizen feedback.

1.3 Final technology

The data received from the trucks (location, speed, RPM and engine load) were recorded in the database. The platform allowed to visualize the routes and graphics of the eco-driving system as well to identify the locations where the alarms to the driver were emitted.

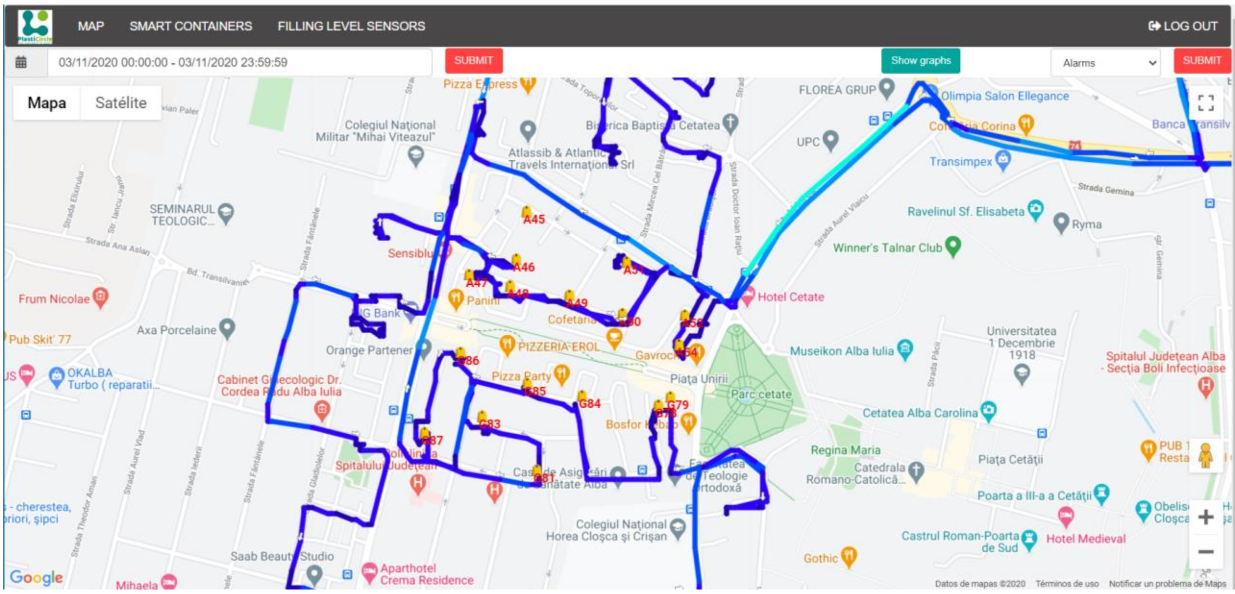

Figure 2: Screenshot of the PlastiCircle IoT platform showing a route performed in the Alba Iulia pilot.

The IoT platform allowed to receive and register the information of the labels dispensed from the smart containers in the pilots. All data sent from the LoRa nodes were received and recorded in the database. Data from the filling level sensors were received and recorded in the server. The IoT platform allows to visualize the filling level graphs and manages this information to calculate the optimized routes.

The platform computed in real-time the eco-points for the weekly participation of the citizens, together with the eco-points earned from the participation in the "missions" and questionaries, as well as the points obtained from the characterization protocol. Users were able to request the rewards at the end of the pilots through the eco-points APP. The platform allowed to manage the stock of rewards without any incident reported.

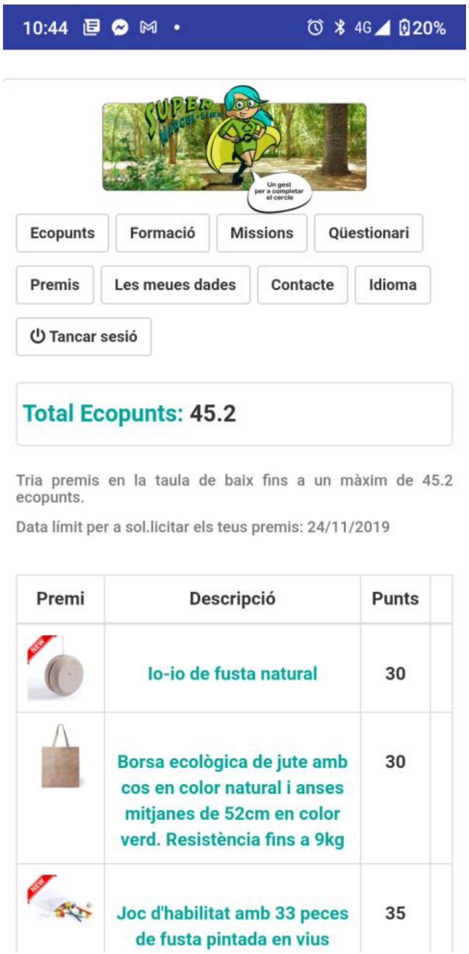

Figure 3: Screenshot of the Eco-points APP. Users were allowed to visualize their earned eco-points as well as to request rewards through the APP.

Modifications done

The initial approach for the eco-driving system was designed to read the data from the trucks trough the OBD II port. But not all vehicles allowed to provide data from the OBD II, for example the trucks in Alba Iulia and Utrecht pilots. But alternatives were found to read the data from the CAN-Bus of the vehicles. This was solved for the Utrecht and Alba Iulia pilot where a specific CAN-Bus reader for the vehicle was found. Then, the same experience could be applied to other vehicles were data is not easily accessible through the OBD II port.

In order to easily analyse the data for the vehicles, new functionalities were added to the IoT platform. In the current version, the locations where the sound alarms were emitted to the driver can be visualized in the map, see image bellow:

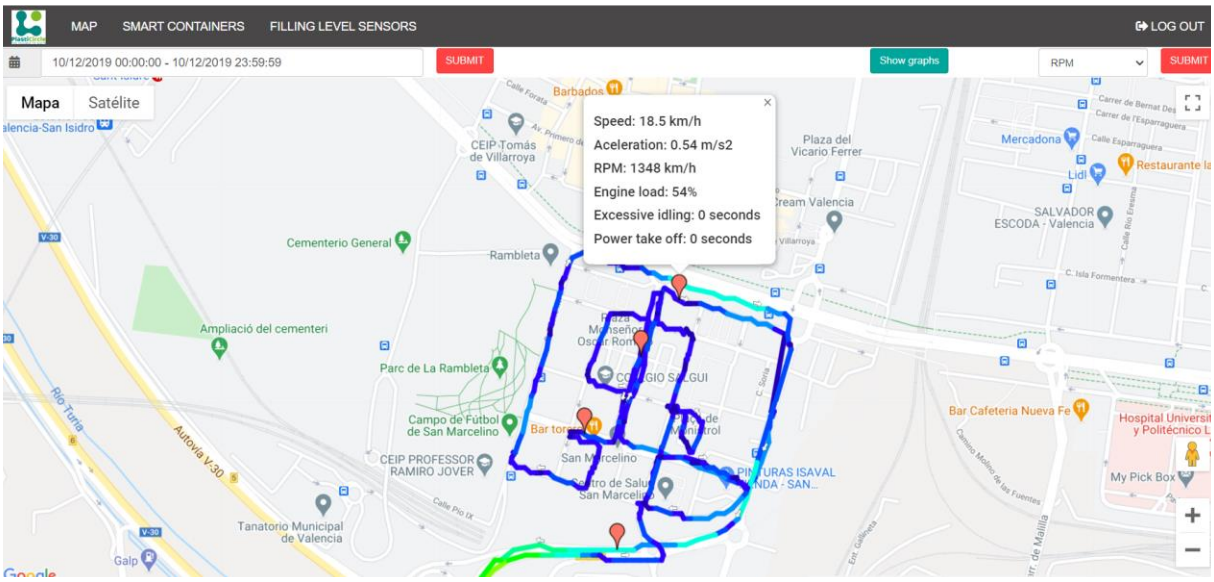

Figure 4: Screenshot of the PlastiCircle IoT platform showing locations were eco-parameters were exceeded. The driver is advised in this case with a sound alarm in the eco-driving APP.

In addition, the current version of the IoT platform allows to display the data collected from the trucks in graphs for an interval of time. The data that can visualized in the graphs are: speed, RPM, acceleration, excessive idling and use of the Power Take Off (PTO).

Figure 5: Screenshot of the PlastiCircle IoT platform showing speed and RPM graphs.

2. Route optimization

2.1 Definition

Traditionally, all containers are collected daily regardless of the level of filling, which produces a higher cost because some containers not full enough are collected daily, causing unnecessary consumption of time and fuel.

In addition, a smart waste collection provides a better service level. Automatic warning is given if a container has exceeded a certain filling level which may avoid it to overflow before collection.

The main objective of the route optimization technology is the development of a collection system capable of recording and predicting container filling levels in real time and planning optimised collection routes based on this information.

The sensors installed on the containers send information about the fill level and location of each of the containers. The algorithm calculates whether or not to pick up each unit container and calculates the optimal route. This optimal route is presented through the platform by an APP to the waste truck driver.

The implementation of the route optimization has three phases:

1. Measure and analyse the current route performed by the driver:

   In the first phase the traceability of the non-optimized route is recorded. These recorded routes will be the baseline for comparison of the following stages.

2. Optimise the current route collecting all the containers in order to minimise time and cost:

   In the second phase, the route is optimized using the PlastiCircle technology and taking into account all the containers.

3. Optimise the route based on the filling level of the containers, skipping those containers which are not full the collection day.

   The third phase includes the optimized route collecting only the containers with a filling level higher than a percentage established by the waste manager. The value is chosen to avoid possible overfilling since the plastic containers are not usually emptied every day.

The complete specifications and performance of the route optimization is explained on the deliverable 3.2.

2.2 Information gathered from pilot cities

On this chapter each city has answered per each technology the following questions to know their experience testing the technologies and propose new functions for future work. In the case of the route optimization, Valencia and Alba Iulia answered based on their experience during the pilot testing the PlactiCircle route optimization while Utrecht answers are related their own route optimization because the test in Utrecht was theoretic.

1. **LIMITATIONS: Which limitations have you identified from the route optimization?**

PILOT	ANSWER
Valencia	The system considers the level of filling, but not other factors that may condition the optimization of the route such as containers that have suffered damage (fire, vandalism) or containers that have been displaced (geolocation) The information is sent every 8 hours, which means that an effort is made to coordinate the transport operation with the most up-to-date data possible, thus avoiding too wide a range to make the state of the containers several.
Utrecht	Route optimization on the basis of filling level is just a first step in a bigger picture. Collecting the containers at 80% works fine.
Alba Iulia	Because in Alba Iulia routes are short, containers are smaller, are filled fast and emptied daily, optimization and eco-driving have a smaller effect compared with other cities. Also, as trucks are 7 years old, system installation on CANBUS required special attention. Mobile application is easy to install and use, but requires a recent iOS, over 6”display and power supply, because display, data and bluetooth requires higher consumption. Drivers are tented to consider to frequent the sound notifications, especially if their style wasn’t attentive to some aspects like idlling.

2. SOLUTIONS: Which solution do you propose to face the limitations explained?

PILOT	ANSWER
Valencia	Include sensors that incorporate smoke detection and report their location, emitting alarms when they move irregularly. Real-time communication systems for sensors.
Utrecht	Further development of the optimizations algorithm. Also taking in account the area, prediction of filling level for the next few days. Example: if you see that 2 containers are going to need emptying in the next 2 days, but other containers in the same area are not. It could be efficient to empty them while you are already there, so you don't have to drive back the next day. Algorithm are not this far yet.
Alba Iulia	As future projects will change routes and waste collection to 4 fractions, actual operating model will definitely also change, optimised routes becoming critical for operational efficiency. As eco driving style was tested on a single truck inside city area, we estimate that applying this concept to the entire fleet and on new longer routes will generate important cost reductions. Newer trucks, with CANBUS connection can ease installation. Also, newer models usually have a display and probably can be used or are already integrating eco driving signals/ notifications. Adoption of an eco-driving style can be improved by usage of simulation games, monitoring and rewards for best drivers.

3. ADVANTAGES: Which are the main advantages of using a route optimization?

PILOT	ANSWER
Valencia	Saving emissions Reduction of noise pollution (fewer operations)
Utrecht	Saving emmissions Saving costs More entertaining work More management insights

Alba Iulia	Reducing consumption, pollution and operational costs. Better route/ personnel programming, better service quality (when needed).

4. **DISADVANTAGES: Which are the main disadvantages?**

PILOT	ANSWER
Valencia	Higher cost due to purchase and maintenance of the sensors
Utrecht	It takes time to adjust
Alba Iulia	Requires viable and tested systems; more difficult to adapt/ change routes; specific traffic conditions can impose route changes.

5. **Would you find interesting to adopt a route optimization like the PlastiCircle to your city? Why?**

PILOT	ANSWER
Valencia	Yes, reducing emissions is one of the city's goals. It should be linked to VLCi to take advantage of already existing traffic information and data on pollution levels.
Utrecht	Yes, because of the advantages.
Alba Iulia	Yes, because transport is an important part of waste management, in terms of quality of service and costs, together with environment aspects.

2.3 Final technology

Modifications done

The optimization route was tested in Valencia and Alba Iulia, while in Utrecht a theoretical comparison was done. In the following chapter are explained the modifications done:

DOUBLE A CONTAINER IN VALENCIA CITY

During the pilot development one of the containers has a very high filling speed. The waste manager was aware about it before the pilot started, by implemented the filling sensor and measuring the speed of filling, the sensor confirmed that the container was overfilled every day. The decision was adding another plastic packaging container in order to provide a better service to the citizens and not to interfere on the daily collection operative.

SCALABILITY FROM ONE TRUCK TO SEVERAL

A limitation of the route optimization has been identified and solved regarding the number of trucks used. The algorithm developed for Valencia pilot only accepted one truck per route. This limitation was solved and for Utrecht pilot it was demonstrated that the changes performed in the route optimization system worked properly for more than one truck.

The scalibility done was modify the route optimization from one truck collecting 25-40 container to 6 trucks collecting more than 200 containers at the same time. More information can be found at the *deliverable 6.3 Utrecht pilot.*

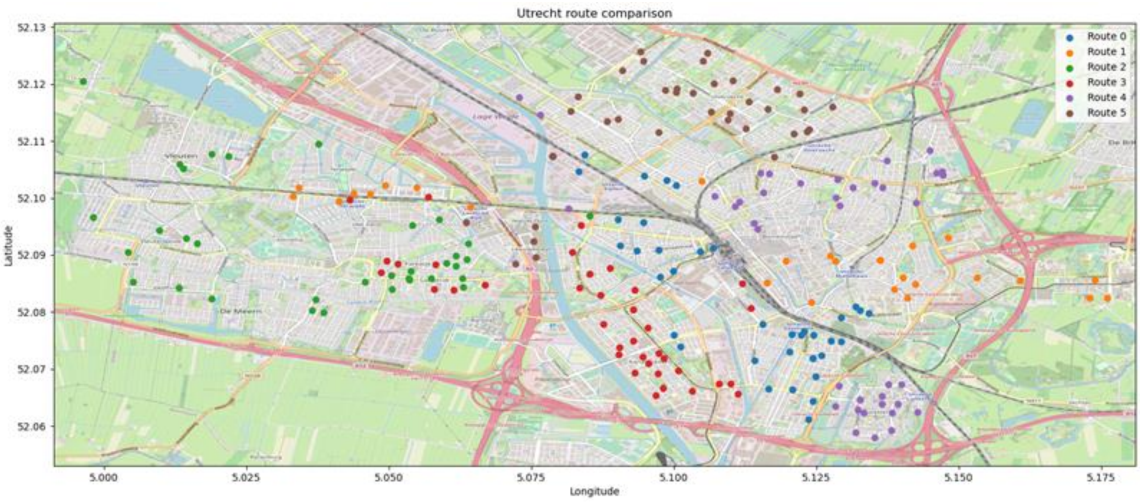

Figure 6: Scalability of the route optimization from one truck to several.

COMPARISON TO COMMERCIAL SOFTWARE

The PlastiCircle route optimization was compared to the optimization system used by Utrecht. The comparison was done between the results obtained by PlastiCircle software versus the software results of commercial software and performed by the drivers. The results showed that both optimization systems are similar. So PlastiCirlce route optimization is at the same level than to a commercial optimization system.

More information can be found at the *deliverable 6.3 Utrecht pilot.*

ROUTE 3: 13/09/2019	Time Cost (s)	Distance Cost (m)	Improvement	
Utrecht route	13586	76500	Time	Distance
PC per time	12280	74715	9.61 %	2.33 %
PC per distance	12515	67034	7.88 %	12.37 %

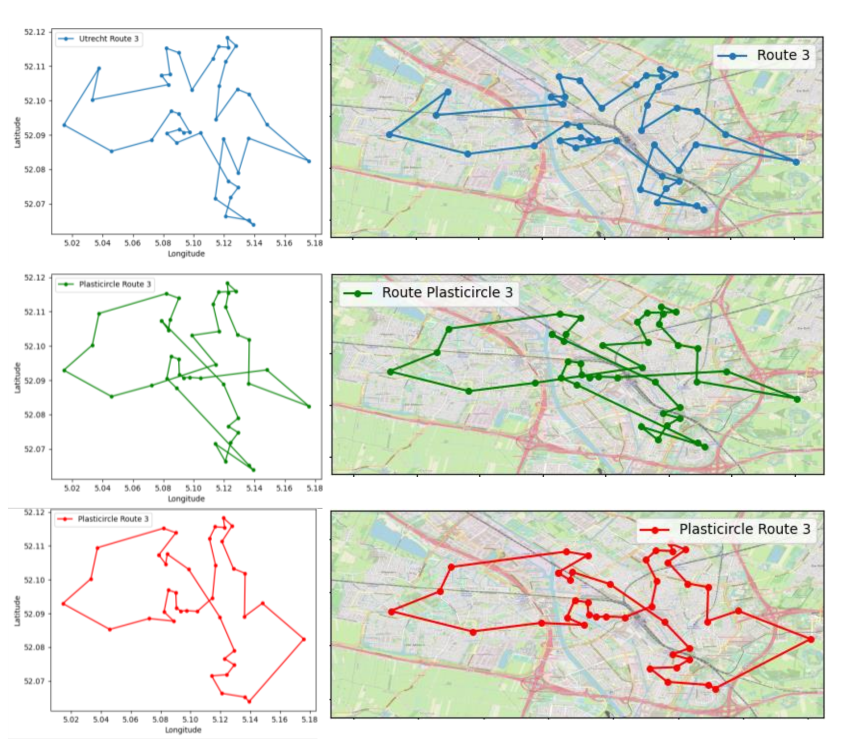

Figure 7: Theoretical comparative of the PlastiCircle route optimization to a commercial one.

FILLING LEVEL: DATA EVERY 8h to 1h

The frequency of collecting data form the filling level sensor was modified to gain more data. In Valencia the sensor collected and sent data every 8 hours, for Alba Iulia pilot the sensor was modified to collect the data every hour. This modification allows the route optimization system to have a more accurate data to decide few hours before the collection which would be the proper route and which are the containers needed to collect. That means, a more flexible and accurate transport system.

Figure 8: Data obtained from the filling level sensors.

OPTIMIZATION ROUTE APP

The APP shows the optimized route that the driver should follow and the containers that should collect. The APP shows to the driver the best way from one container to the next one.

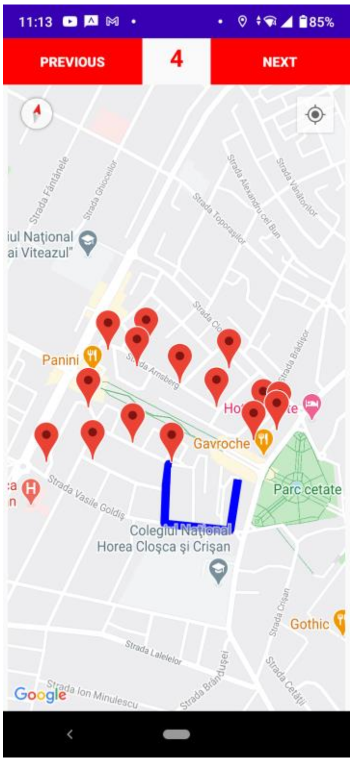

Figure 9: Screenshots of the eco-driving APP displaying the location of the containers and the optimized route to go from one container to the next one

Final design

The final design of the route optimization can be done from two different perspectives depending on the commercialization done:

A. Commercialise together with the IoT platform

The route optimization needs the support of the IoT platform to get the containers filling level from the sensor and send the data to the platform in order to visualize the route and send it to the driver.

In the case of PlastiCircle the full system can be commercialized together although the platform and the optimization route technologies has been developed by different partners.

In this case some improvements should be made in order to be fully commercial:

1. Make the elements dynamic (to be able to add/remove)

   In the current system the number of containers, trucks, positions… are fixed numbers. The technicians make the modification needed. In the commercial solution, these changes should be directly done by the user to provide flexibility on the implementation.

2. Make the distance matrix and containers (currently static) more dynamic.

   Currently, the matrix distance between the containers are calculated using a commercial distance provider and using an API. But, if the position of one container is modified, it is needed to implement the distance changes by the technicians using the tools named before. The ideally situation is that these distances would be dynamically calculated.

3. Development of a payment gateway to offer a user license offering the needed resources from the software in different parcels. For example:

   - Basic: 1 user, maximum 10 containers, 50 routes/month
   - Standard: 5 users, 50 containers, 500 routes/month
   - Pro license: 20 users, 1000 containers, 3000 routes/month

The basic pack would be the cheapest and the pro license would be the most expensive.

In addition to the previous developments, it is also needed to provide to the clients with technical service and the software needs to be periodically updated too.

B. Individual commercialisation

The route optimization technology can be also commercialised individually such a Software as a Service (SaS). In this case the route optimization is offered as a service to be integrated in the company server and the client would use it as their own software. The company would choose how to visualize the information and the communication between the company's server and the route optimization software would be by an API.

In this case are also needed further technical developments:

1. Development of a payment gateway.

   In this case the payment would depend on the number of queries done by the client. Different price packages would be offered based on the frequency of use foreseen by the customer.

   For example:

   P1 Basic = 100 queries per month

   P2 Expert = 300 monthly queries

   P3 Pro = Unlimited consultations

   Monthly payment depending on the number of consultations.

2. Model the number of queries to be made by the route optimizer and limit the number of consultations depending on the package selected.
3. Make the distance matrix and containers (currently static) more dynamic.

   Currently, the matrix distance between the containers are calculated using a commercial distance provider and using an API. But, if the position of one container is modified, it is needed to implement the distance changes by the technicians using the tools named before. The ideally situation is that these distances would be dynamically calculated.

In the route optimization as a service, the customer should have their own server or platform and they would have to include in the system his own filling data and distances. In addition, the customer needs to have a software developer as well in the company.

Concluding, both approaches are feasible although the most completed and competitive is the joint marketing. The target customer would be any waste manager or city having their own server or not.

In the case of individually commercialization the route optimization is a complementary service that requires that the company already has a management platform. But probably the optimization of routes can be offered by the company that provides the platform

The target client would be waste managers with their own management platform but without route optimisation development.

3. Driving guidance system

3.1 Definition

The driving guidance system is formed by the truck traceability and the driving guidance. Truck traceability is the technology used to monitor the truck and record the speed, position, acceleration and other variables in the platform. It is the basis that feed the driving guidance which is the tool that alerts the truck driver if they do not follow an efficient driving. The driving behaviour system had two phases:

1. Measure the driving behaviour of the driver during some months in order to know which actions the driver should improve, through the truck traceability system.
2. Implement the alarm systems that alerts the driver when they are not driving in an eco-way.

All the specification related to the truck traceability and eco-driving are collected in the deliverable 3.3 and deliverable 3.4

3.2 Information gathered from pilot cities

On this chapter each city has answered per each technology the following questions in order to know their experience testing the technologies and propose new functions for future work.

1. **LIMITATIONS: Which limitations have you identified from the driving guidance system?**

PILOT	ANSWER
Valencia	The driver receives instant feedback, with visual/audio indications correcting his driving style or inefficient actions and can then readjust them in real time. However, he does not receive indications, recommendations to prevent inefficient actions. No personal or group monitoring system is established to encourage continuous improvement.
Utrecht	The connection with the fuel registration works for 2 cars but for one is troublesome.
Alba Iulia	If too frequent can be stressful for some drivers, especially those with a more "dynamic" stile; requires training and adaptation; requires large scale implementation and adoption.

2. **SOLUTIONS: Which solution do you propose to face the limitations explained?**

PILOT	ANSWER
Valencia	To include warning or messages to prevent bad customs that the driver can acquire.
Utrecht	-
Alba Iulia	Monitoring, rewarding good driving, promoting as an

	internal policy.

3. **ADVANTAGES: Which are the main advantages of using a driving guidance system?**

PILOT	ANSWER
Valencia	• Emissions reduction • Fuel saving • Saving on maintenance • Increased security
Utrecht	Traceability for eco performing
Alba Iulia	Avoiding accidents, lower consumption and pollution, truck availability between major parts replacement, costs.

4. **DISADVANTAGES: Which are the main disadvantages?**

PILOT	ANSWER
Valencia	These systems must be accompanied by incentive systems created through clear performance indicators for drivers. The ability to create customized reports is key to personalized monitoring.
Utrecht	Extra sounds and screens in cockpit driver
Alba Iulia	If not implemented in clear steps and on large scale, together with monitoring and rewards, will not be adopted by all drivers, or will be neglected after a while. Some drivers can have the impression that one route takes a longer time than usual.

5. **Would you find interesting to adopt a driving guidance system like the PlastiCircle to your city? Why?**

PILOT	ANSWER
Valencia	Yes, following a set emission reduction and cost saving target so that the contribution to the total emission reduction target can be monitored.
Utrecht	The testing has not finished yet, the alarm phase to the driver has been delayed.
Alba Iulia	Yes, as a long-term policy able to reduce costs and emissions without major supplementary investments.

3.3 Final technology

Modifications done

FROM OBD READER to CAN-Bus

The initial approach for the eco-driving system was designed to read the data from the trucks trough the OBD II port. But not all vehicles allowed to provide data from the OBD II, for example IVECO Eurocargo trucks in Alba Iulia and Utrecht pilots. But alternatives were found to read data from the CAN-Bus of the vehicle.

The device used in Utrecht and Alba Iulia reads the data from the CAN-Bus instead of the OBD II port. This CAN-Bus reader allowed other functionalities not available from the OBD reader as detailed in the following table.

Data collected in real time	Previous OBD reader	Current CAN-Bus
GPS		x
Fuel consumption		x
Speed	x	x
Acceleration	x	x
Engine spinning	x	x
Break use	x	x
Start&Stop		x
Excessive idling	x	x
Power take off	x	x
PILOTS	Valencia	Utrecht + Alba Iulia

Figure 10: Comparative between the previous OBS reader and the current CAN-Bus

ECO-DRIVING APP

This APP integrates the route optimization and eco-driving sound alarms. When the driver excess the eco-driving parameters, a sound alarm is emitted to advise the driver to amend the driving in a more sustainable way. In addition, the type of alarm is displayed in the screen of the APP as an indication. But driver does not need to visualize this indication, since the APP is designed to advise the driver with a beep sound instead of visualizations in the screen.

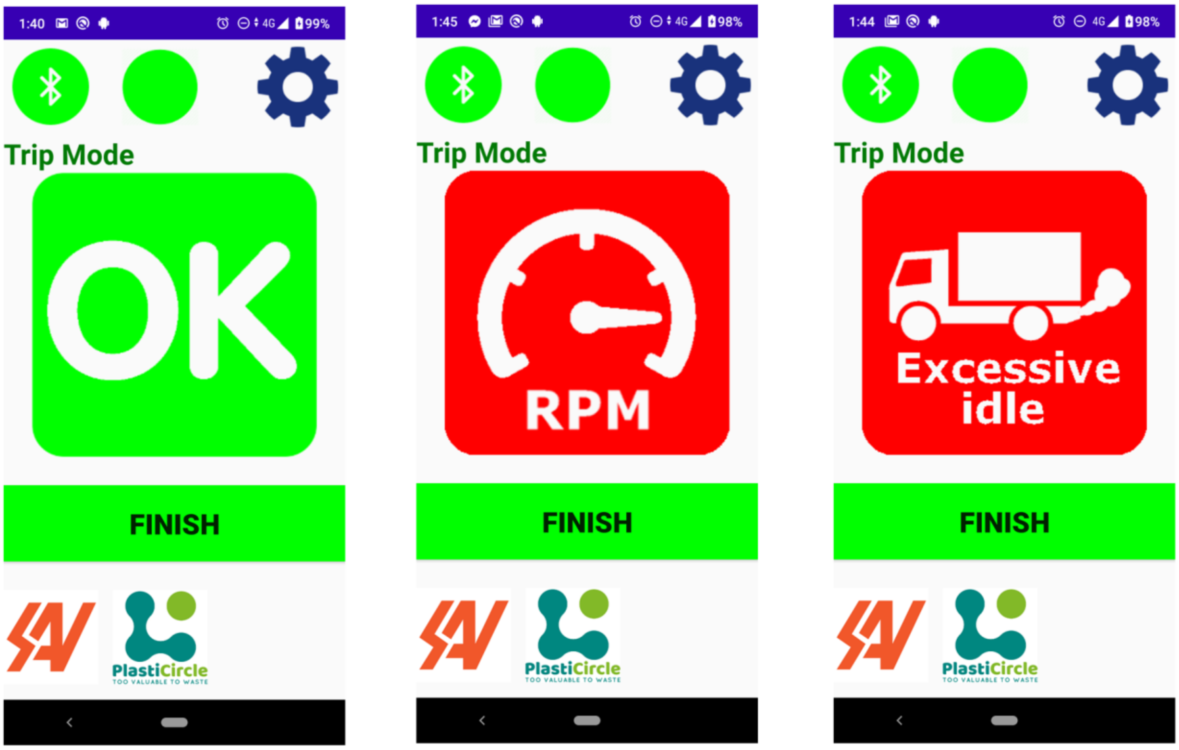

Figure 11: Screenshots of the eco-driving APP displaying visual messages. In the first screenshot, driving accomplish the correct eco-driving parameters while in the second and third screenshot, RPM and excessive idling parameters are exceeded, respectively.

The same APP also displays the optimized route to collect the containers that must be collected in function of the filling level.

NEW TESTING IN VALENCIA[1]
The pilot was done using the OBD reader, in order to get better results and more data the pilot for ecodriving in Valencia is currently being repeat using the CAN-Bus.

Final design

The final design integrates two solutions, one with an OBD II reader for the cases where data from the vehicle is accessible with standard OBD II readers. And the second solution involves a CAN-Bus reader accessing data from the CAN-Bus.

[1] More information will be provided in WP6 deliverable.

Figure 12: OBD II reader with ELM 327 integrated chip to interpret the CAN protocol with Bluetooth connectivity.

Figure 13: FM3607i CAN-Bus reader used for the IVECO Eurocargo.

In both cases the device connects to the eco-driving APP via Bluetooth. The eco-driving APP receives data from the truck from the OBD II or CAN-Bus reader. Alarms are displayed with sound beeps and an icon on the APP screen when the driver exceeds one of the eco-driving parameters. In addition, and as commented above, the driver can see the optimized route to collect the containers that overcome a filling level threshold.

4. Characterization protocol and Compensation procedure

4.1 Definition

Characterization protocol is the methodology developed to make the individual characterization. It gathers the sampling and the analysis of the bags. The points assignment for the bags and the points assignment to the activities performed during the pilot are the compensation procedure.

1. Characterization protocol: Steps to analyse the bags:
    - Count all the items
    - Count the unwanted material
    - Check if there is some pack full
    - Check if there are some stacked packaging
    - Count all packaging suitable for compaction
    - Count the bottles that have been compacted
2. Compensation procedures are the different activities designed to collect points by the citizens:

- Points assignation based on the results obtained from the by individual bags characterization and with the formula used in each pilot:

$$C = \left[\frac{S_i * W_i + S_{i+1} * W_{i+1} + S_n * W_n}{W_T}\right] * 10$$

C = Compensation result
Wi = Weight of parameter i
Si = Score of parameter i
WT = ∑ Wi = Sum of all parameters' weights = 28

- Workshops
- Questionnaires
- Training
- Social media
- Daily participation

4.2 Information gathered from pilot cities

On this chapter each city has answered per each technology the following questions in order to know their experience testing the technologies and propose new functions for future work.

1. **LIMITATIONS: Which limitations have you identified from the characterization protocol and compensation procedure?**

PILOT	ANSWER
Valencia	The characterization points earned were set at the end of the period. The settlement of points at the end of the period discouraged the participation of those citizens who joined in the second half of the pilot.
Utrecht	Not tested
Alba Iulia	Individual characterization is made manually during the pilot. There are technical limitations related to correct functioning and usage of the labelling system, dedicated collecting and resources limitations, because on long term is difficult to characterize manually large quantities of bags, from the entire city. Also, individual characterization is difficult for bloc associations, having a collective contract for waste processing and common containers. Probably future solutions based on automatic characterization will ease the process. Compensation is of major importance in order to accelerate an improvement in people's behaviour related to sorting. On long term, probably focus should be on main factors (quantity and quality of plastic/ other recyclables).

2. **SOLUTIONS: Which solution do you propose to face the limitations explained?**

PILOT	ANSWER
Valencia	- Personalised analysis of 100% of the population or replace it with aggregated assessment at district, street level, etc. - Shorter periods of point settlement
Utrecht	Not tested
Alba Iulia	Probably future solutions based on automatic characterization will ease the process. As symbolic gifts are difficult to administrate on long term, probably the best option will be a discount to waste processing costs.

3. **ADVANTAGES: Which are the main advantages of using a characterization protocol and compensation procedure?**

PILOT	ANSWER
Valencia	• Increased motivation to improve correct separation
Utrecht	Not tested
Alba Iulia	- Motivate people to find info related to correct sorting and participate in pilot - Small "competition" between best recyclers - Reward and promote good behaviour as model for other citizens - Accelerate adoption of correct sorting for recycling - Obtain data about quantity, quality and composition of waste

4. **DISADVANTAGES: Which are the main disadvantages?**

PILOT	ANSWER
Valencia	• Citizens perceive a false sense of control over their behaviour • Acquisition and logistic costs related to awards and their delivery
Utrecht	Not tested
Alba Iulia	- Difficult to implement - Create sensation that a good recycling must be rewarded - Not all people are interested/ involved - Behaviour change is quite a long process

5. **Would you find interesting to adopt a characterization protocol and compensation procedure like the PlastiCircle to your city? Why?**

PILOT	ANSWER
Valencia	Yes, but other alternatives need to be explored, such as community benefits or via tax reduction.
Utrecht	Not tested
Alba Iulia	It would be interesting to adapt it to several fractions and compensation to be automatically calculated to costs.

4.3 Final technology

Modifications done

APP TO CHECK BAGS

APP to check the users characterized in the individual characterization. As the objective was to characterize at least once each user, this APP supported to check if the bag to be characterized belongs to a characterized user or not reading the code bar from the sticker.

a) b)

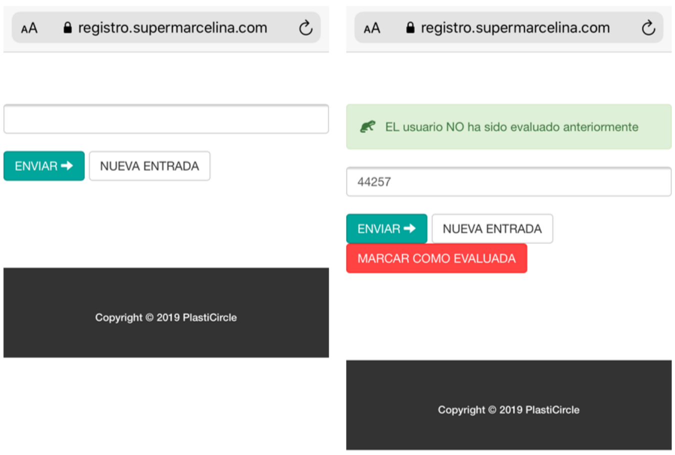

Figure 14: APP developed to check the bags.

EXTRA CONTAINER IN ALBA IULIA

One extra container dedicated to PlastiCircle in Alba Iulia

Adaptation of the characterization protocol to Alba Iulia. In Alba Iulia the waste containers are divided in wet and dry. Nowadays, they are adapting the waste system to a selective collection in different fractions. In that sense, an extra container was incorporate exclusively to the pilot activity and to educate the citizens to separate the plastic as a new fraction.

Final design

1. PROBLEM & CONTEXT

A characterisation protocol was developed to acknowledge the quality segregation of single garbage bags with packaging waste. It pretends to evaluate the quality of the material sorted in origin by each individual participant. The process has been developed manually which is endurable for a pilot scale, however, unable to be scaled up to a real context due to the amount of waste commonly generated. In response to this inconsistency. In order to face this challenge the following solution is proposed. actions were proposed to the PlastiCircle project:

2. DEFINITION OF THE SOLUTION FOR AUTOMATE SCALE-UP

The general idea on the proposed solution is outlined in the context of a light packaging waste plant. In this section, it is explained which possible solution could pursue a proper characterisation for many citizens without excessive resources in terms of costs and human actions.

Heading the technical solution, it must be thought that on the main feeding line, it can be found general light packaging waste collected from households which has been delivered by waste transport infrastructure, mixed with PlastiCircle bags (or general citizens' bags targeted to be characterised on a potential scale-up). In order to automate the characterization, it is proposed the creation of a smaller sub-belt loop at the beginning of plant (Figure 1) capable to read the barcode of the bag, spreading the material on the belt and performing a characterization using artificial vision techniques. This loop would consist of 3 stages:

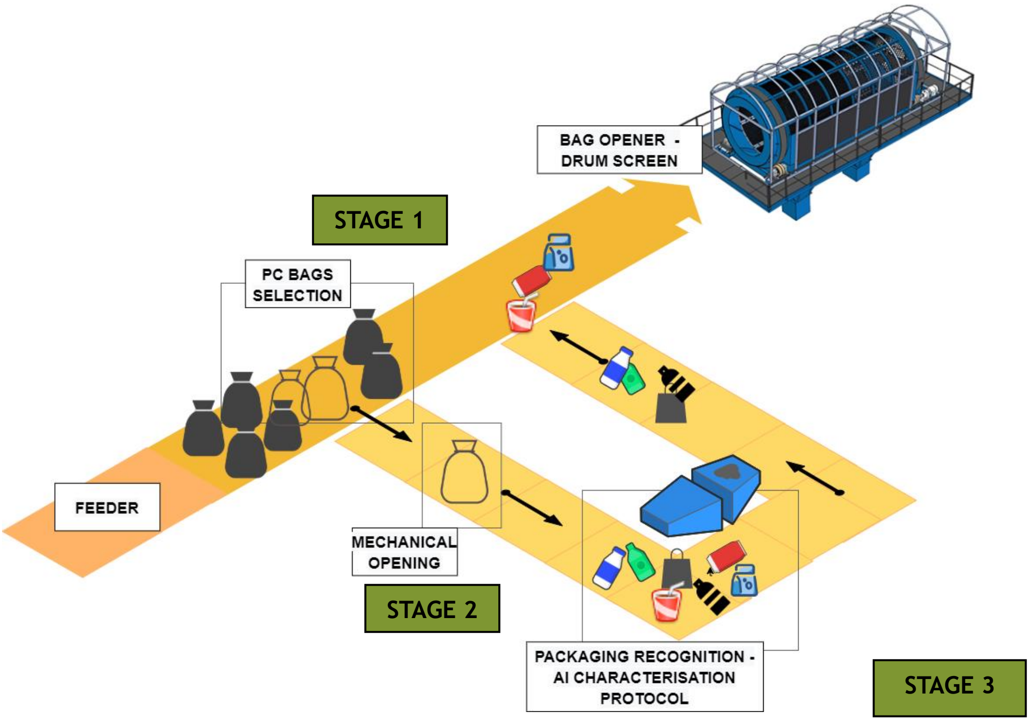

Figure 15: Schematic representation for the solution to automate the characterization protocol

STAGE 1 – PlastiCircle bags selection. From general light packaging waste lifted on the belt, it is needed to identify the target bags to be characterised. Main problem comes on how to extract the right bag from the main belt to our characterization belt. To do so, 2 alternatives are considered as a possible solution:

a) *Semi-automatic model*: An operator must extract the PLASTICIRCLE bag from the main line, read the barcode of the bag and leave it at the beginning of the loop. This label reading will relate to the rest of the process which will be automated.

b) *Totally automated model*: A robotic arm (or mechanical solution) equipped with artificial vision technologies must choose the bags marked with labels and place them on the characterisation belt. This action difficulties considerably the technical answer to the problem, in the way the system must recognize labelled bags from the waste on the line, finding a label among all the waste is quite unlikely to be effective. Therefore, PlastiCircle labels could be moved to RFID ones so that they can be detected by RFID reader infrastructure which connected to the mechanical system, could peak them from the waste flux. This alternative would imply higher cost and the introduction of electronical ink into the bags which priorly does not seem to boost sustainability.

For these last two alternatives (a and b), it is believed the **semi-automatic model is more likely to be feasible** for both technical and economical implications.

STAGE 2 -- Mechanical bag's opening. After bag has been set on the characterisation belt, this need to open via mechanical solution in order to display the different items in the bag on the belt. To spread the items on the belt, this mechanical opening could be combined with a vibration system to avoid having situations where some items cover other ones.

STAGE 3 -- Packaging Recognition – Artificial Intelligence (AI) characterisation Protocol. On this step of the loop, displayed items on the belt will be read by a system based on computer vision algorithms which works by characterising the shape and colour of objects to detect possible improprieties and types of plastics.

These algorithms are artificial intelligence techniques based on learning approaches and because of that improve their accuracy based on the number of (training) readings taken by the machine. Once the waste is characterised the machine will assign a score to the user based on the content of the bag. Subsequently, the contents of the sub-belt will be returned to the main belt with the rest of the waste.

3. TECHNOLOGICAL DESCRIPTION

This section pretends to describe, from a technical point of view, the proposed solution from above section. Consequently, main technologies to be used on this approach are detailed together with additional considerations. Main technical difficulties on the solution spin around stage 1 and 3, which are: the **selection of the bags** from main belt (on the case of the totally automated system) and on the computer vision **algorithms for the automated characterisation** protocol.

STAGE 1 -- <u>Selection of bags – Totally Automated solution</u>

In the process of bags selection, the bag would be picked from main waste line and transferred to the "characterisation loop". This could be done on two ways:

- **Manual**. Plant operator should take the bag and scan it with an RFID reader. Then it would directly go into stages 2 and 3.
- **Automatic.** This way would imply a more complex solution which is developed below:

As mentioned on previous section, for totally automating the bag selection stage, it is needed some combinations of a robotic arm/mechanical mechanism combined with artificial intelligence technology.

In the case of the robotic arm, this arm will have two technological challenges. From one side, it has to be able to detect the bags and locate it, and from the other side it has to move the arm taking into account the speed of the belt and the best way to catch it. This mechanical system will have to be combined with an image recognition software based on artificial intelligence that will be furtherly developed on STAGE 3, as the technological approach is barely the same.

There are some companies which develop technologies able to perform this work. Inside the project consortium, PICVISA has ECOPICK, a customable robot that can be adapted to identify and separate any recoverable material/item. This robotic arm belongs to ABB (https://global.abb/group/en) which is a leading supplier of industrial robots and robot software, equipment and complete application solutions. This kind of technology could be applied to pick the bag, however, in general, the fully automated model will be much more challenging that if the picking of the test bags is done by an operator due to the necessity to read the label sticked on the bag.

Figure 16: ECOPICK render from PICVISA (left) and AMP system (right)

Outside the consortium we also find other supplier which could provide similar solution on the specific sorting application, among whom we find some competitors:

- **TOMRA (EU) (link):** AUTOSORT CYBOT is a waste sorting robot on the market which combines four essential technologies at once. It achieves the highest sorting accuracy and purity levels in two steps: first objects are first detected by sensors and subsequently sorted into one of four separate target fractions by the fast picking robot arm.

- **Bulk Handling Systems (US)** (link): Max-AI is an artificial intelligence that uses machine vision to analyse and sort material streams. This robotic arm infrastructure fits more with a potential picking bag application.

- **AMP Robotics (US):** AMP has a robot arm capable of picking objects in a conveyor belt, as can be seen in this video.

STAGE 2 – Mechanical bag opening.
This stage would imply some commercial solution based on cutting/shedding the bag, letting the packaging items displayed on the conveyor to be characterized. Technologies already used on MSW/LP plants but dimensioned to this task. Suppliers of this technology could be BRT , SPR or Bianna Rec., inter alia.

STAGE 3 - Packaging Recognition – AI characterisation Protocol
Main challenge of **automatic image recognition** is a combined task that involves detection and localization of objects in a cluttered background, segmentation, normalization, recognition and verification. Depending on the nature of the application, e.g. sizes of training and testing database, clutter and variability of the background, noise, occlusion, and finally, speed requirements, some of the subtasks could be very challenging.

The algorithms may differ by the way features are computed. There are feature based methods that detect features such as corners and blobs. Descriptive vectors are then extracted around the neighbourhood of those points. These vectors are called descriptors and are usually indexed into a tree structure for fast approximate matching. Then there are machine learning approaches whereby features are learnt from training data. Raw RGB images are fed to the system and it is up to the learning algorithms to learn relevant features. A good example of such a system is a convolutional neural network (CNN) in deep learning.

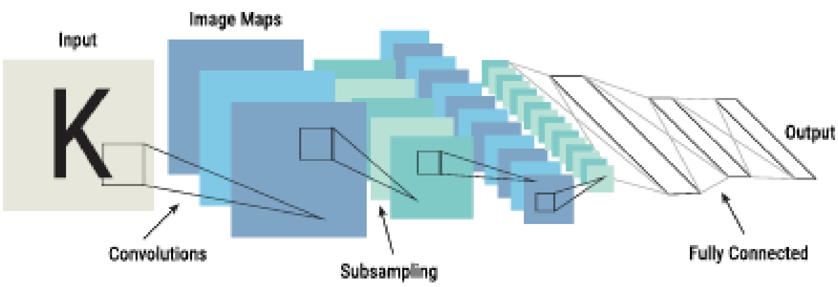

Figure 17 - Convolutional neural networks (CNN), pooling and fully connected layers in a neural network to classify and detect objects in images. Source: Lecture from Standford University

Companies mentioned on above page (i.e. TOMRA or AMP) use this automatic recognition technology based on deep learning as the input to make the robotic arm function. For the case of the automatized characterization protocol, just the deep learning integration on an artificial vision application will be enough. Adjusting the conditions and feeding the images database and clusters to train the system to evaluate the waste bags according to the characterization protocol would enable the system to perform an automatic evaluation. On Figure 4, we can see an example for the image recognition of items on light packaging waste streams. The systems recognise shape, size, colour, brands and as many variables as it is desired to feed the system, and this gives as an output:

- Material and colour
- Size
- Probability to have been identified correctly

Figure 18: Image recognition example. Source: [Seattletimes]() & [AMP]() (respectively)

4. FUTURE WORK

On this section, it is pretended to define some guidelines in case of willing to implement the arised solution trough this document. Next steps should mainly be followed:

PHASE 1 – Stakeholder sourcing. Finding out a combination of actors from the whole value chain willing to participate, from city which is interested on integrating a fully compensation system to evaluate their individual citizens behaviour; a waste manager which is disposed to implement this kind of systems on their plants and technical partners with expertise on AI application and infrastructure. Some of the partner from the consortium could meet these conditions.

PHASE 2 - Development of an integral solution for integration characterisation protocol on a fully scale-up case. We may have the case where some conditions on the model proposed by PlastiCircle might be changed to provide a fully feasible solution in a real atmosphere. This step will focus on the developments for the technical solution on the three stages mentioned in the "characterisation loop":

- **STAGE 1 (SELECTION)-** Decide between total or semi-automatic model and develop a system to identify, pick and deliver bags on the next stage.
- **STAGE 2 (OPENING)** – Build opening-bag machine together with specialized supplier.

- **STAGE 3 (CHARACTERISATION) –** Adapt current AI systems to evaluate the quality of the packaging waste.

PHASE 3 - Technical installation and development. The idea described on previous stages must be converted on a technical and physical solution. Commercial systems could give response to the necessities of the technology, so no further research-development is needed to integrate a new solution-. Just to adapt existing system to the requirements of the characterisation. In this stage, it will also be needed to build the infrastructure around the "characterization loop" on the main feeding line.

PHASE 4 – Large Scale Trials. With the required amount of feeding material obtained from citizens waste generation, large scale trial will be needed to run the system down large amount of waste. These trials will be fundamental to check potential problems with a full-scale implementation. Prior to these trials, host city should have been able to spread the characterization culture among an important percentage of their citizens. If this step is not reached, developing the technological solution will be non-effective and the feeding capacity would be too low.
Based on the results from the 4 phases, the city and different actors on these development can decide to carry on the characterisation and compensation techniques to adapt these technics as usual behaviour on the waste management system performance of the city under tests.

5. CONCLUSIONS

The potential of vision systems would allow to perform the characterization protocol analysing the content of the bags. Moreover, we have displayed different commercial solutions that nowadays offer alternatives to identify light packaging on waste plant streams. For a scaled-up in real environmental, the needed infrastructure to sort the target bags and identify its content has also been defined.

On the Review Report, one bottle neck on this idea was mentioned in regard with the compaction of waste on the transport as it could result with broken/opened bags before the characterization is performed. After the technical evaluation of a solution, there is still some uncertainty which does not allow to claim if the total automate characterisation protocol would be feasible when coexisting with compaction methods. However, in case a representative % of bags manage to get to the plant in an acceptable condition, a solution has been offered on the present report. As main conclusions, it can be stated:

- **A process for the automatic characterisation protocol** has been defined with three main stages.
- In the first stage "selection of bags", it is outlined that **a semi-automatic system could be technical and economical more feasible** than a total automatic one.
- There is **available technology to properly characterize bags when they are opened**, based on deep learning.

- Although an integral solution has been thought and proposed, **compaction techniques on trucks could still be a bottleneck** on the solution.
- A **plan for future work** has been proposed.

Considering that target bags would get from container to the plant compacted but not broken/shredded, the solution provided on this report, provides a solution for an automated scaled-up characterisation protocol, enabling PAYT PlastiCircle alternative.

5. Conclusion

The Plasticircle transport system and the technologies that formed it, have evolved from the initial developments. The technologies has been adapted to the needs and requirements of the different pilots and many changes has been implemented in order to improve them.

The IoT platform have increased their functionalities the visualization of the truck traceability in graphs based on a period of time, the implementation of questionnaries to answer by the citizens and the allocation of points are some exmaples of this functionalities.

The route optimization have been scale up from one truck to several trucks and it has avolved from the collection of 40 containers to the collection of more than 200 theoretically. In addition, an APP was developed to follow the optimized route and located the containers by the driver. Other improvement was the increasement of the frequency sending data from the filling level sensors getting more accurate routes.
The ecodriving has changed the technology used to access to the data from the truck. This change made to have direct information from the truck related to fuel connsumption, truck position without external GPS and the start and stop time. In addition, an ecodriving APP was developed in order to facilitate to the driver the alarms. This APP can be also used to route optimization.

The individual characterization protocol was designed manually, which in a real environment is not feasible to implement. A automatic solution is proposed in this deliverable in order to make the characterization protocol in the recycling plant.

In general the feedback from the pilot cities was that they would implement the PlastiCircle transport system, making links to local data platforms in order to explot the data or making improvements on the technologies like the automatization of the characterization protocol and changing the reward to the reduction of the recycling tax.

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant Agreement No. 730292.