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THESEUS

Hub4Circularity

A First of a kind Hub for circularity demonstrator for Attica and peripheral regions

Grant Agreement No 101178059

DELIVERABLE 4.8

Smart bins for Attica v1

Work Package: 4 Separation and Sorting technologies

LEAD BENEFICIARY:

Institute of Communication and Computer Systems (ICCS)

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Publishable summary

THESEUS is a Horizon Europe funded project, which develops a first-of-a-kind Hub for Circularity (H4C) in Greece, deploying systemic Industrial-Urban Symbiosis (I-US) concepts. The H4C activities are concentrated around the Attica region, which hosts the capital of Greece - Athens metropolitan area. Attica region, including the metropolitan area, almost 3,8 million inhabitants and 66 municipalities, stands out due to its political, economic, maritime and cultural importance, forming one of the major economic centers within the region, with Athens municipality in lead position within this area.

To achieve efficient municipal waste management as well as optimize waste and improve circularity-related rates within this area, several aspects should be considered from governance, authority, jurisdiction, regulations and land use to management and scheduling, logistics and fleets, treatment and storage processes and units etc.

Many waste-related plans and attempted actions within Attica's municipalities involve source separation approaches and relevant ideas related to the exploitation of Smart Sorting Points or Smart Bins. Most of them involve individual and separate actions. Therefore, the systemic approach to analyzing available relevant tools and efficiency and sustainability related criteria for their placement, is an enabling condition to multiply the impact of these technologies into the region and urban environment.

The purpose of this deliverable is to develop a placement optimization Analysis for Smart Bins in Attica Region.

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Abbreviations

Abbreviations	Full name
AI	Artificial Intelligence
CE	Circular Economy
EC	European Commission
EDSNA	Solid Waste Management Association of Municipalities in the Attica Region
EU	European Union
GA	Grant Agreement
H4C	Hub 4 Circularity
HMA	Electronic Waste Register
IS	Industrial Symbiosis
I-US	Industrial Urban Symbiosis
MFA	Material Flow Analysis
MSW	Municipal Solid Waste
PESDA	Regional Solid Waste Management Plan
PeSPKA	Regional Climate Change Adaptation Plan
PM	Project Management
PO	Project Officer
WP	Work Package

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1 Introduction

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To achieve efficient municipal waste management as well as optimize waste and improve circularity-related rates within this area, several aspects should be considered from governance, authority, jurisdiction, regulations and land use to management and scheduling, logistics and fleets, treatment and storage processes and units etc.

Many waste-related plans and attempted actions within Attica's municipalities involve source separation approaches and relevant ideas related to the exploitation of Smart Sorting Points or Smart Bins. Most of them involve individual and separate actions. Therefore, the systemic approach to analyzing available relevant tools and efficiency and sustainability related criteria for their placement, is an enabling condition to multiply the impact of these technologies into the region and urban environment.

1.1 Purpose of the deliverable

The purpose of this deliverable is to develop a placement optimization Analysis for Smart Bins in Attica Region and especially in the Athens–Piraeus Urban Complex, reflecting the work of Task 4.7. Within this framework, a data collection on waste management within Athens municipality and surrounding municipalities will be conducted. Scenarios will be developed on waste flow calculations and predictive estimation, providing valuable insight for optimal placement of smart bins, framed with IoT and automatic waste segregation enabling technologies. This document presents a baseline for this work, and it will be finalized in the two next versions:

- D4.9 Smart bins for Attica v2 in M36,
- D4.10 Smart bins for Attica final in M48.

1.2 Relation with other Tasks

This deliverable and Task 4.7 will interact with the below WPs/tasks. The exact interaction will be clarified in later stages as the relevant tools will have been developed in more detail.

- Task 2.3 Material flow analysis and 2050 projections
- Task 2.4 Regional and interregional pathways for symbiotic flows linked to EU and local regional plans
- Task 2.5 Characterization of value chains and KPIs definition
- Task 3.1 GIS tool for dynamic symbiotic maps and reverse logistics optimization
- Task 3.2 Matching frameworks and development of symbiotic models
- Task 3.4 Prediction of resource logistics
- WP4 sorting technologies developed
- Task 9.4 Roadmap for replicability to additional sites
- WP10 models
- Task 11.2 Policy recommendations and barriers.

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2 Municipal Solid Waste Management

Municipal solid waste (MSW) management is critical to modern cities, affecting their sustainability, resilience and quality of life. MSW management has several challenges in all stages, from collecting to recycling or landfill disposal, which is affected by several parameters. Regarding collection, the effectiveness and efficiency of the process are affected by different aspects related to bins infrastructure, fleet, work shifts and logistics. One of the specific aspects that is extensively discussed is how urban bins can be positioned within urban space.

There are many ways and reasons why bin locations are the way they are in cities, from almost random distribution to the result of controversy and service to individual cases. Waste bins' location problem is a computationally complex problem (Rossit & Nesmachnow, 2022). Rossit & Nesmachnow performed a comprehensive review of the waste bins' location problem, confirming that the configuration of the network of bins affects the overall efficiency of the municipal waste system, and identifying several approaches considering the trade-off between the cost and quality of service. The main criteria types identified are related to cost, user accessibility, routing collection, or other special criteria such as competing with informal or sporadic systems, the objective of maximizing the collected waste, maximizing the profit obtained from the selling price of the collected recyclable material, criteria associated with the semi-obnoxiousness nature of the bins (the NIMBY "Not In My Back Yard" phenomenon), number of users too near or too far of the bins, environmental impact of the bins or affecting the cultural heritage of a neighbourhood.

Several models have been developed to approach the bin location issue. Nevrlý (et al., 2021) developed a holistic multi-objective model based on multi-criteria approach including cost and average walking distance and claiming that a trade-off between social and economic criteria brings sustainable solutions. Bošković (et al., 2015) introduced a methodology based on a GIS handling different sets of information: street directions, spatial location of objects, number of inhabitants, location of waste bins, and radius of their coverage. Slavík, J. (et al. 2021) indicates that public space use or localisation constraints limit the optimal location of containers and concludes that changing the density of containers, walking distances from bins, and selecting container locations that respect the habits of households and demands of the collection technology significantly affect the costs. Rossit, D. & Bard, J. (2024) created a model configuring location and storage capacity to minimize network costs and required collection frequency at the same time under uncertain waste generation flows. Blazquez, C. (et al., 2025) developed a model that minimizes costs, addressing a location–allocation problem, related to travel distances to the bins aiming to provide practical implications to local authorities and waste management managers to make informed decisions with respect to recyclable household waste collection systems. Araiza-Aguilar, J.A. (et al., 2024) introduced a very usable GIS-based framework for urban positioning of collection points using a multivariate analysis technique (Grouping Analysis), generating different collection route scenarios. A location–allocation model was developed, to maximize coverage and minimize facilities, considering waste collection sectors and their characteristics and waste production sources.

3 Smart Bins

The smart bins will be modelled into a "typical smart bin" framework, that will be used to develop the scenarios in this study. A typical smart bin consists of a robust outdoor unit integrating a user interface as well as an internal material management and sorting system, multiple modular waste compartments and IoT connectivity into a central platform for collection monitoring, performance evaluation and optimization based on operational data e.g. fill levels, usage frequency, classification results and status. The system

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enables in-situ classification and separation of recyclable materials from waste, at the point of disposal. Such a unit can be designed as a large-scale urban prototype with approximate dimensions of 5.4 × 2.0 × 2.4 m, a 400 × 270–300 mm entry hatch, touchscreen for end-user interaction, 4G connectivity and AI-enabled sorting. Smart Bin typical specifications are displayed in Table 1.

Table 1 Typical Smart Bin Specifications

KPI	Suggested Target
AI classification accuracy	≥ 95% in controlled testing
Physical sorting success	≥ 85% in realistic mixed-input testing
System uptime	≥ 90–95% during pilot operation
Fill-level sensor accuracy	±5–10%
Misrouting rate	≤ 10–15% during pilot phase

Further specifications dedicated to the selected waste flow(s) will be elaborated in the next versions of the document, based on the scenarios to be analyzed.

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4 Scenarios within Attica

The objective of this study is to present the two dimensions of how Smart Bins systems can enhance MSW management within Attica, by:

- Enabling advanced sorting of materials, thus enhanced flows and improved capabilities in recycling.
- Optimizing number and location of the Smart Bins within Attica, based on regional criteria.

Several scenarios will be elaborated in the next versions of the document, in specific Attica municipalities (currently under discussion for the selection).

4.1 Technical Results of Smart Bins

Based on the available "Typical Smart Bins" described in Section 3 and the selected Municipalities as the fields to be studied, the scenarios will be developed based on technical results of the bin existence such as:

- Avoidance of landfill and incineration
- Reduction of contamination in recycling streams
- Reduction of misclassified waste
- Higher recovery of valuable recyclables
- Improved sorting at source
- Dynamic Online Monitoring, Traceable data
- Logistic Optimization
- Better user behaviour and awareness.

This will be elaborated in the next versions of the document.

4.2 Spatial Impact Considerations of one or multiple bins

There are spatial parameters that are improved by the existence of multiple bins, creating a dynamic beyond the simple addition of the results of the smart bins operation. These aspects will be also analysed and will be elaborated in the next versions of the document.

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4.3 The baseline

4.3.1 Attica Region



Figure 1 Map extract from Hellenic Cadastre, Digital Cadastral Map, area, retrieved on 9 April 2026 from https://www.ktimatologio.gr/maps

In this section, the baseline of waste management within Attica will be summarized. The Municipal waste generated is about 1.9 million tonnes per year in the region. From this amount, about 85% is landfilled and 10% recycled (mainly blue bin + printed paper). The remaining 5% is separately collected as biowaste green waste (1.615 million tonnes landfilled, 190,000 tonnes recycled per year. More specifically, as per the Regional Solid Waste Management Plan of Attica (PESDA, 2022):

- Almost all municipal solid waste (MSW) is currently sent to landfill at Fyli Municipality
- The plan sets a target for 2030 to reduce landfills to below 10%
- The plan sets targets for preparation for reuse and recycling of 55% by 2025 and 60% by 2030

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- For packaging waste, the targets are 65% by 2025 and 70% by 2030.
- Estimated quantities for Attica in 2030:
    - 420,352 tonnes/year in the brown bin (separately collected biowaste),
    - 836,858 tonnes/year in the green bin (residual mixed waste),
    - 513,976 tonnes/year of recyclable materials.

Furthermore, based on data received from Athens (the biggest municipality of Greece and therefore of Attica Region) and analyzed internally, the general conclusions below can be exported:

1. The blue recycling bin still has a high residue rate;
2. The performance efficiency of blue bin collection routes improves significantly;
3. Biowaste is a steadily growing stream;
4. Mixed municipal waste sent to landfill remains the dominant stream (this is the case for almost any Greek municipality).

These findings underline the usefulness of smart bins in supporting a more efficient waste management system and they can be utilized for the shaping of the future scenarios below.

4.4 The future Scenarios

The contribution of Smart Bin location into the waste management chain is displayed in the below figure.



Figure 2 AS-IS waste management



Figure 3 Waste Management with Smart Bins

To be able to shape future scenarios, technical and spatial parameters that will be improved by the typical smart bin when it is placed into a territory, need to be defined.

Table 2 Technical Assumptions

The basic technical assumptions:
Each Typical Smart Bin can improve … by 10%
Each Typical Smart Bin can improve … by 12%

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….

Table 3 Spatial Assumptions

The basic spatial assumptions:
Each Typical Smart Bin can improve by …% the spatial parameter …
The A set of Typical Smart Bins can improve by …% the spatial parameter …
….

These assumptions will be fully defined in the next version of the deliverable, based on the typical bin, its technical and territorial parameters, and on the territories of the future scenarios.

Based on these assumptions, we will examinate the following scenarios areas:

- 1 typical smart bin placed in different locations
- 2 typical smart bins placed in a combination of different locations within a defined territory/zone
- 5 typical smart bins placed in a combination of different locations within a defined territory/zone
- 10 typical smart bins placed in a combination of different locations within a defined territory/zone
- N typical smart bins placed in a combination of different locations within a defined territory/zone.

5 Integration of Scenarios into Theseus Digital Tools

5.1 Integration to MFA projections

To be elaborated and updated in the next versions aligned with the advances in MFA (WP3).

5.2 Prediction and Agent Based Scenarios

To be elaborated and updated in the next versions.

6 Discussion

6.1 Preliminary recommendations

To be elaborated and updated in the next versions.

6.2 Challenges encountered and strategies to address them

To be elaborated and updated in the next versions.

6.3 Next steps and strategic vision

To be elaborated and updated in the next versions.

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7 Conclusions

To be elaborated in the next versions of the deliverable.

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