The impact of logistics in cities

2022

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Index

Preface

Today more than ever we are seeing the value of undertaking research to understand our increasingly complex and changing world. Academic institutions have a responsibility not only to educate students but to create and share knowledge, especially knowledge that will be needed for the future. We recognize that our world is becoming more and more urbanized and yet each city is unique. IE Center for Sustainable Cities was founded within IE School of Architecture and Design with the mission to contribute to seeing the city as an ecosystem. Our view sees all realms of the city- physical, natural, digital, social, economic, and political environments - as intimately linked to each other. Therefore, applied research has a fundamental role in assisting us to be able to deal with the complexities that characterize cities and lay the groundwork for future research projects that will bring us one step closer to true and useful understanding.

Logistics is a crucial aspect of our cities in many ways. Yet, it is often taken for granted or we do not perceive its impacts – positive or negative. The present research, an initiative that has brought together our university with the private sector is an example of the power and necessity of collaboration in order to develop relevant and useful projects that lead to greater understanding, and we hope, to positive change.

It is with the utmost satisfaction that we present this work to our community, our city, and all others who are interested in logistics and in creating livable and sustainable cities.

Martha Thorne.
Dean of IE School of Architecture and Design.

Acknowledgements

This research project would not have been possible without the generous support of many. To the numerous people who directly and indirectly support the IE Center for Sustainable Cities and our vision and ambitions, we thank you. We recognize the ongoing work of Cristina Mateo, Ana de la Cruz and Flavio Tejada in this regard.

We especially want to acknowledge the work of Martha Thorne for her insightful comments and review of the final paper. This document would not be the same without her valuable input.
We have consulted studies, articles, and research published by many scholars, and while we have not had contact with them, we know that sharing and creating new knowledge is fundamental for academic institutions and we are pleased to be part of this endeavor.

For this study, we would like to recognize several key people with whom we have been in direct contact through the entire process. We would especially like to thank Cristian Oller and Dirk Sosef of Prologis. They were the first to see the importance of understanding more fully the field of logistics and the city. Their time, input, and ideas have made significant contributions to both the research process over the months and the final work. We would also like to recognize Laura Capdevila and Merche Izquierdo for their organizational support.

To Juan Pablo Lázaro, Manuel García, and Miriam Pérez Higuera of Sending, we thank them and the company for their support through time and insights for the field study portion of this research. Expert in city logistics, Dr. Walther Ploos Van Amstel, provided insightful commentaries that surely improved this work.

We are well aware of the collaborative nature of undertaking any research and know that many people, whom we have not listed by name, have assisted us, silently, in the background. To them our sincere thanks. We have immensely enjoyed undertaking this research project and trust that it makes a real contribution to the field. Any errors or omissions, however, rest entirely with the lead authors.

Madrid, March 2022

Manuel Pérez Romero, Ruxandra Iancu-Bratosin, Rodrigo Rubio and Alessandro Mattoccia.

A city is more than a place in space,
it is a drama in time.

Patrick Geddes, 1905

Executive Summary

Early in the morning, before dawn, a group of vans is waiting in a warehouse in the outskirts of Madrid. They are waiting to load their trunks with the packages for delivery that arrived at the warehouse the night before. Meanwhile, inside somebody is distributing the according to delivery areas for the drivers. Once the vans are filled with the goods to deliver, the race starts. The drivers proceed to the urban areas to deliver the parcels in the shortest possible time. They create an optimized circuit based on their own experience, or at best, with the help of a digital tool. In the meantime, the end clients are waiting at home tracking the orders on their smartphones. The van double-parks at the doorway of the building and the driver runs to ring the bell. Just for a second, the driver may meet the client. The driver hands over the parcel and asks for a signature. Then, he goes back to the double-parked van, hoping not to have received a parking ticket.

Every day, this picture is repeated many times in many cities throughout the world. It represents the normal process and flow of goods entering the city. It is urban logistics or the last mile of logistics. If we return to the first paragraph of this summary, we can identify a wide range of factors and stakeholders involved in the logistics flow and in turn, impacting the urban environment. The warehouse, the packages, the handling of the parcels, the van, the driver, the route, the tracking app, the street, the doorway, and the client, all form part of the logistics network. Although the difference between e-commerce and other supply networks is evaporating the picture above just showed one of the multiple types of direct deliveries.

The objective of the present research is to analyze and evaluate the impact of logistics in cities, and to propose specific strategies, actions, and planning policies to achieve a positive impact in the urban environment while maintaining the efficiency and functionality of the logistics network. Thus, this report is structured sequentially from analysis and evaluation to proposals and recommendations.

Through a review of pertinent academic studies and other literature, assembling data from many sources, and direct observation through fieldwork, we were able to proceed with the modeling and simulation (M&S) of the logistics flow at different scales ranging from the full scale of the city to the medium scale of a neighborhood. Traditionally, the study of city logistics has been approached from different disciplinary fields, but often neglecting urban planning, urban design, and architecture. In the present study, we want to include this point of view by placing the city at the center of the study. Our analysis of the impact of logistics centered on real case studies in Madrid and Barcelona.

Field Study Photographic Material

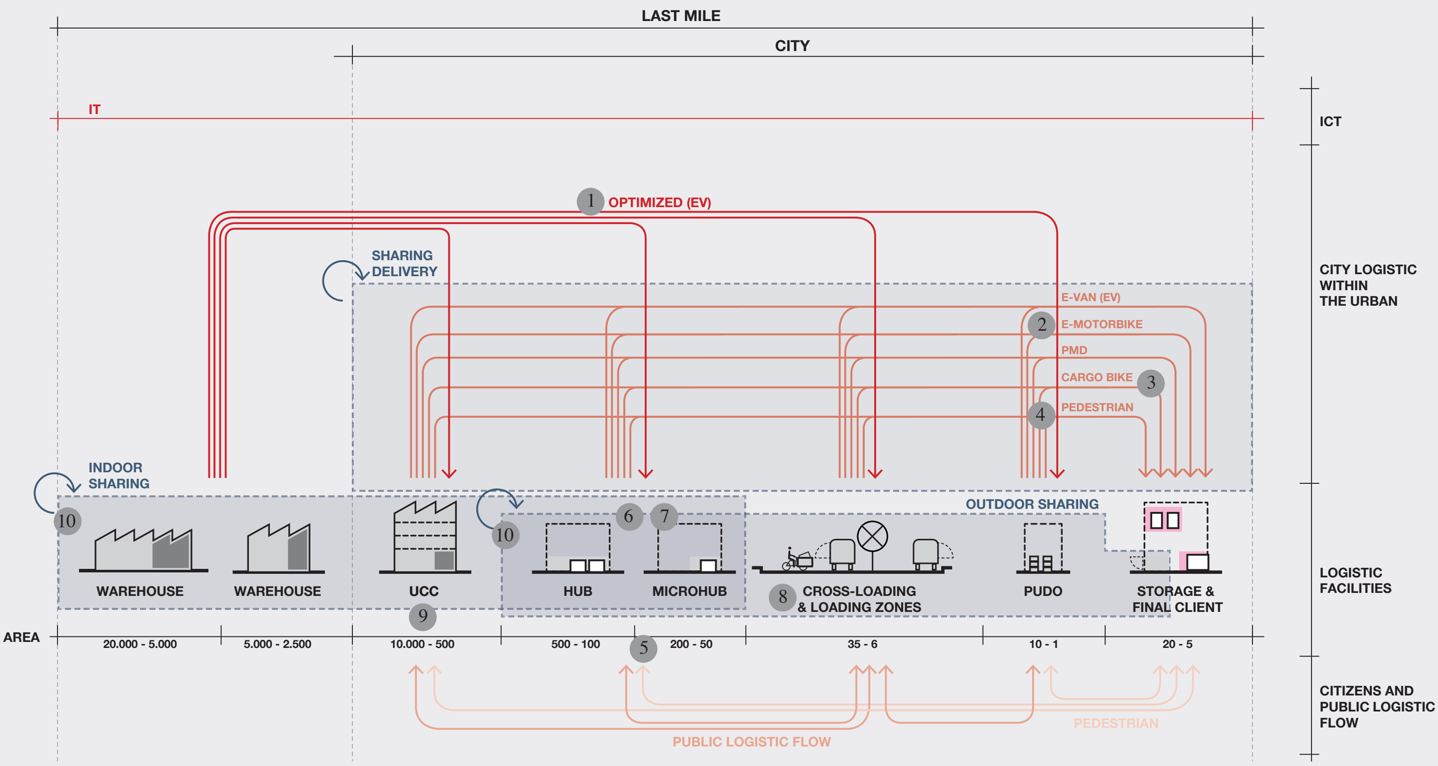
To evaluate the impact of the logistic network in the urban environment, we developed a tool that we have called the Last-Mile Logistic Index (LM-LII). This tool provides a quantitative measurement of the impact of logistics, based on environmental, functional, socioeconomic, urban, and information factors. These factors are overlayed with the stakeholders, logistic facilities, delivery vehicles, and the urban fabric to evaluate the impacts.

The results of the evaluation of the scenarios showed that current Business as Usual (BAU) models, based on a direct delivery from the last warehouse to the final client, have the highest negative impact on the environment. The normal lowering of the negative impacts of the BAU methods is by having the package pass through many different steps before final delivery and thus, requiring a network of different types of logistics facilities inside the city.

Moving forward to promote a more positive impact on the urban environment, we have defined the concept of Logistic Intensity Areas (LIA). From our research, we believe that a network of logistics facilities must be integrated within the urban structure and situated at carefully determined locations. Different types of logistic facilities, such as Urban Consolidation Centers (UCCs), Hubs and micro-Hubs, Pick-Up and Drop-Off points (PUDOs), and loading and unloading areas, are entirely possible to be located within the city but must be planned and evaluated for the appropriateness of specific places.

To aid in this understanding, evaluation, and placement of logistics facilities, we have developed the concept of Logistic Intensity Areas (LIA). The aim of the Logistic Intensity Areas (LIA) is to find a balance between the efficiency of the logistic network and the impacts on the city. We must remember that city is not just a physical commodity or land for certain types of development. The city is a complex ecosystem of the physical and non-physical. Therefore, when referring to logistics we know that the package, the delivery person, and vehicles interact with the community. The public space is the interface between urban logistics and the city and therefore, we must always understand these relationships and promote positive impacts. Adding a layer of complexity, regulations related to urban logistics must be flexible and take into account multiple factors to adapt to the changes in the network and improvements in its different components.

Finally, this paper proposes an evaluation tool and a planning policy to reduce the impact of logistics and promote a healthy urban environment. The Last-Mile Logistics Impact Index (LM-LII) helps to measure impacts, while the Logistic Impact Areas (LIA) synchronizes

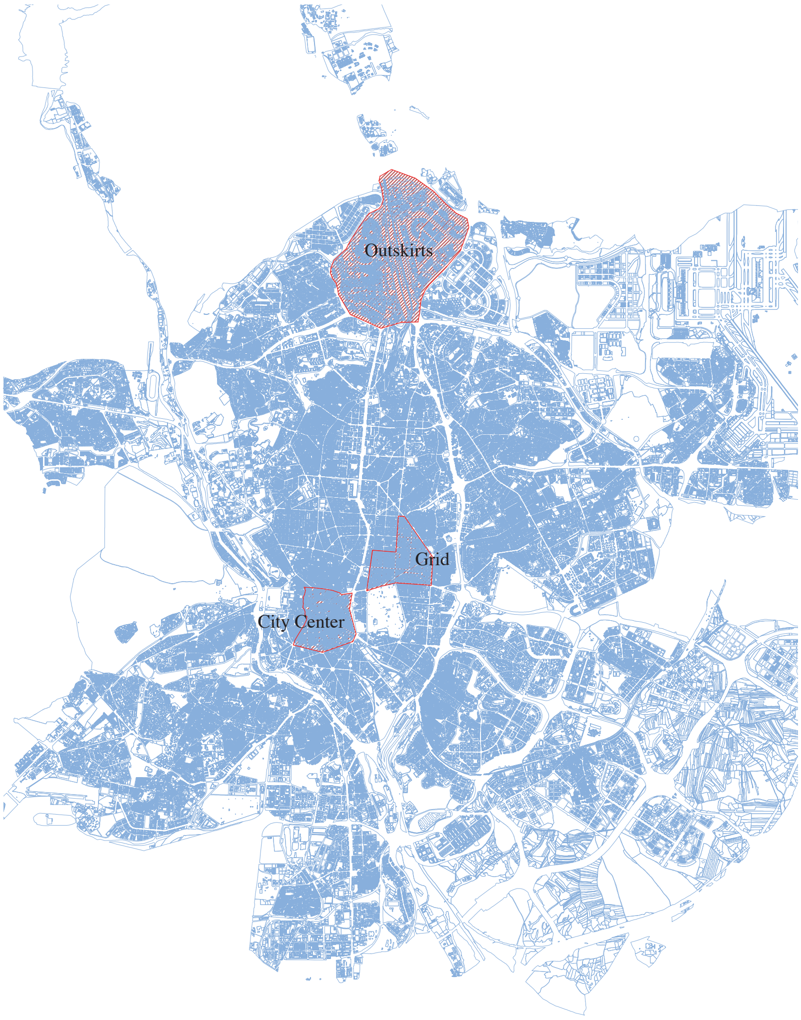


Scenarios Modeled, Simulated and Evaluated

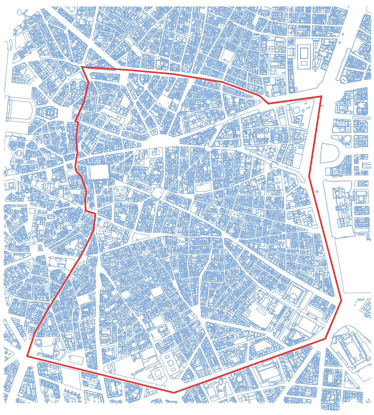
the efficiency of the logistic network, with the design of a sustainable urban ecosystem. Together they work holistically, recognizing that logistics is a complex, necessary, and fundamental part of our urban ecosystem.

The report does not pretend to be conclusive. We believe that further development of the LM-LII and the LIA must be done through collaboration with input from all the stakeholders involved in the logistics network. Representatives from the public sector at different levels (local, regional, and national), citizens associations, universities, research centers, and private companies, including logistic facilities, transportation operators, and information, communication, and technology companies must all participate. From the Center of Sustainable Cities at IE University we offer our support to the further development of a sustainable logistic network.

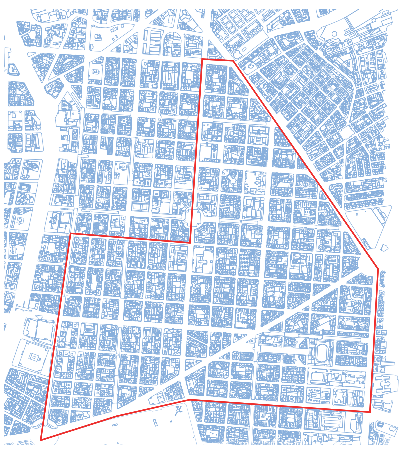
Madrid



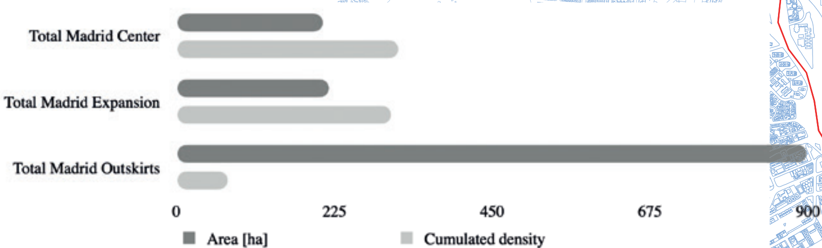
City Center



Grid

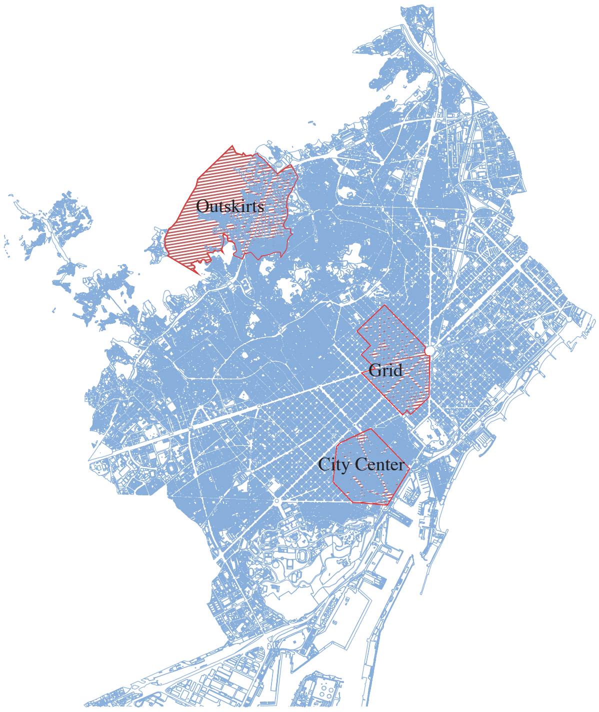


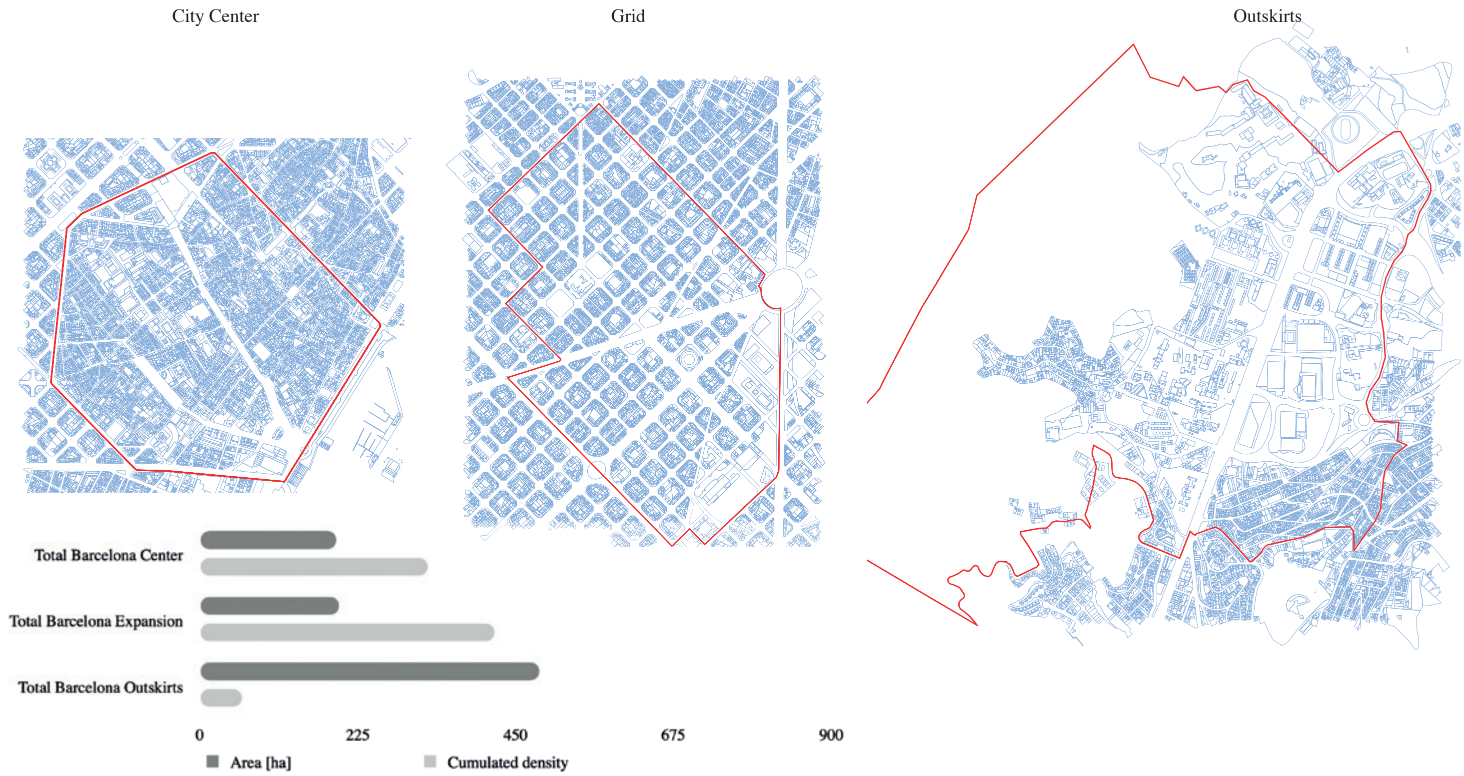
Outskirts



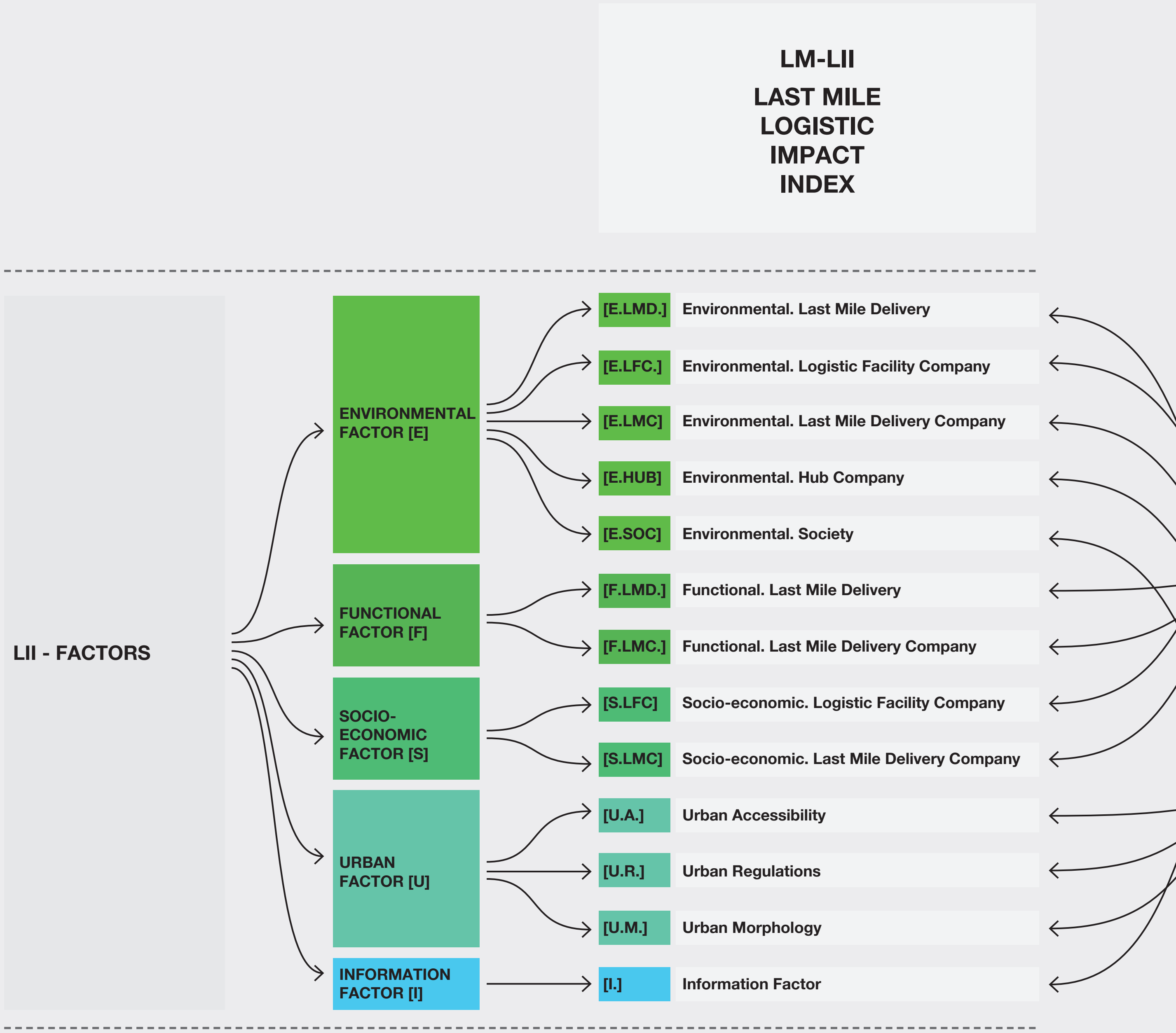
Urban Areas Selected in Madrid

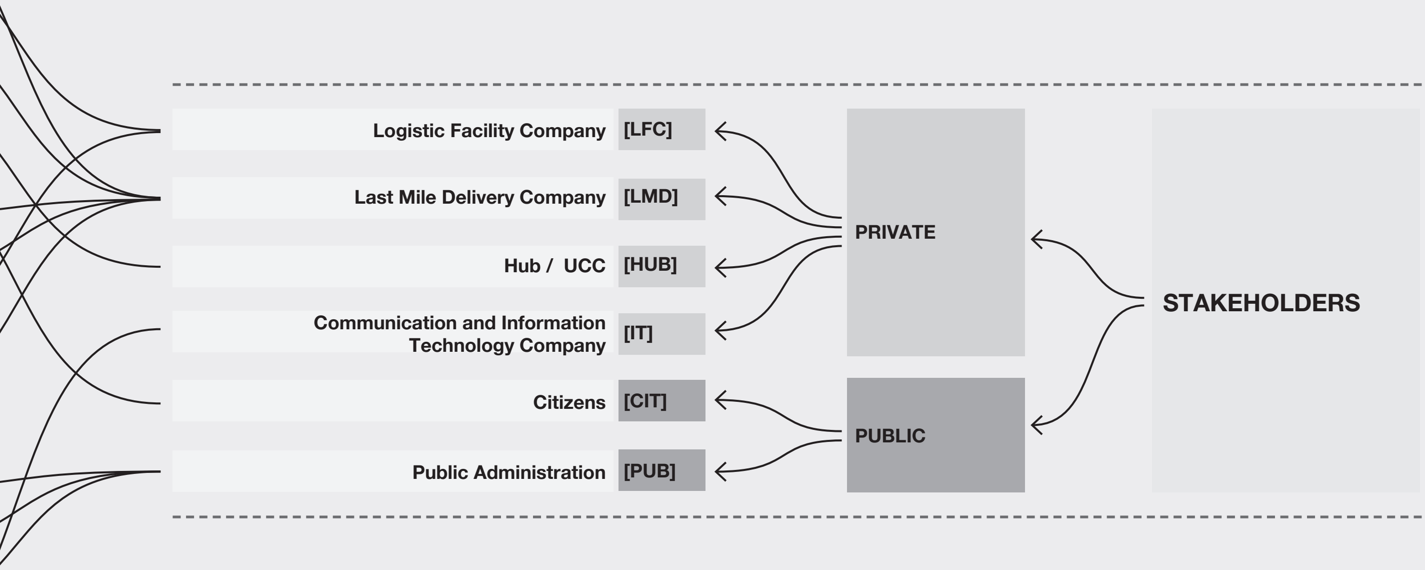
Barcelona





Urban Areas Selected in Barcelona


LM-LII
LAST MILE LOGISTIC IMPACT INDEX
LII - FACTORS
ENVIRONMENTAL FACTOR [E]
FUNCTIONAL FACTOR [F]
SOCIO-ECONOMIC FACTOR [S]
URBAN FACTOR [U]
INFORMATION FACTOR [I]
[E.LMD.] Environmental. Last Mile Delivery
[E.LFC.] Environmental. Logistic Facility Company
[E.LMC] Environmental. Last Mile Delivery Company
[E.HUB] Environmental. Hub Company
[E.SOC] Environmental. Society
[F.LMD.] Functional. Last Mile Delivery
[F.LMC.] Functional. Last Mile Delivery Company
[S.LFC] Socio-economic. Logistic Facility Company
[S.LMC] Socio-economic. Last Mile Delivery Company
[U.A.] Urban Accessibility
[U.R.] Urban Regulations
[U.M.] Urban Morphology
[I.] Information Factor


Logistic Facility Company
[LFC]
Last Mile Delivery Company
[LMD]
Hub / UCC
[HUB]
Communication and Information Technology Company
[IT]
Citizens
[CIT]
Public Administration
[PUB]
PRIVATE
PUBLIC
STAKEHOLDERS

LOGISTIC FLOW

- **FIRST DELIVERY** (from last warehouse to urban logistics)
- **SECONDARY DELIVERY** (multiple combinations)
- **PUBLIC LOGISTIC FLOW**
- **FINAL CLIENT ACTIVE ROLE** (pick-up - return)

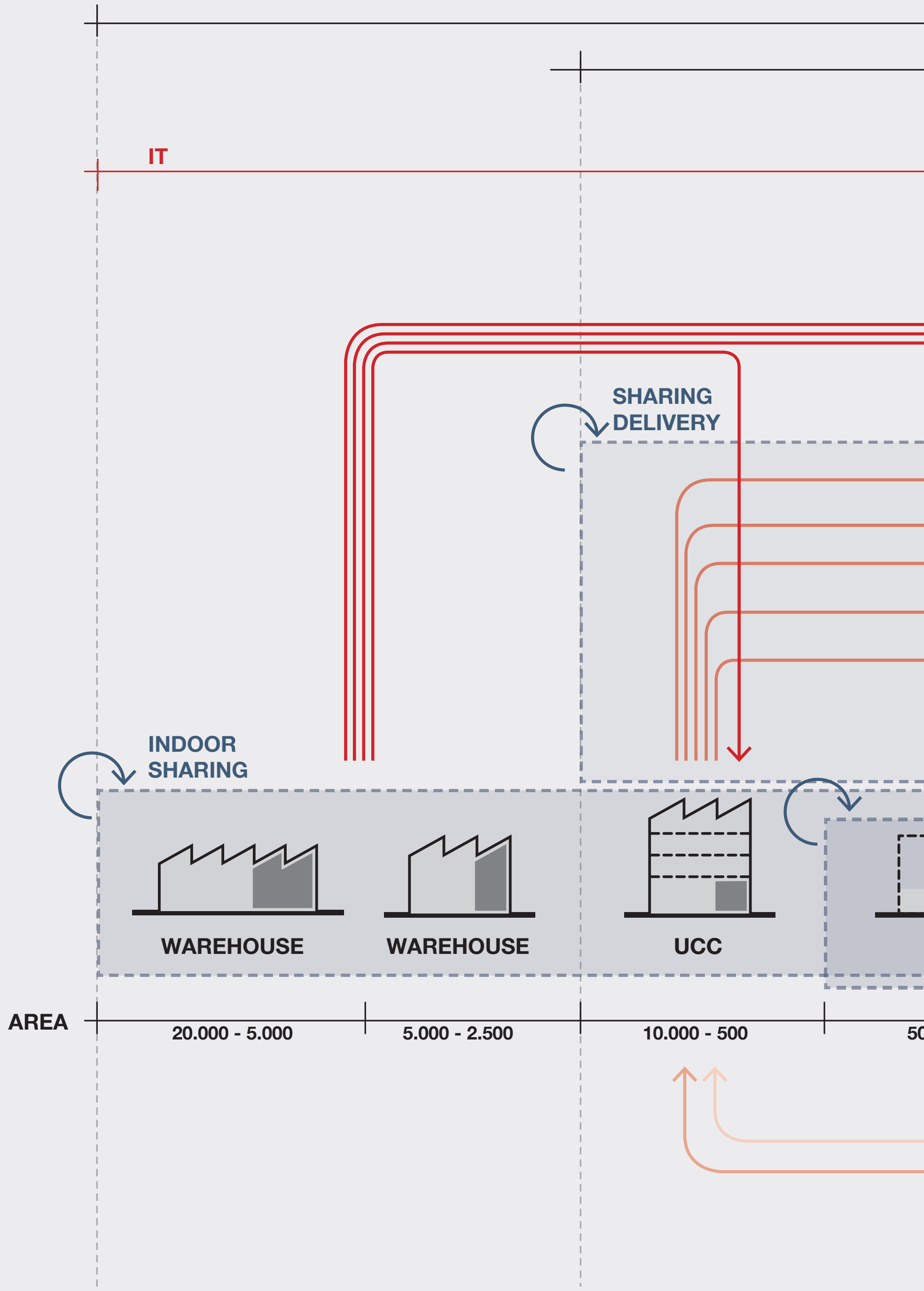
LOGISTIC FACILITIES

WAREHOUSE		20.000 - 5.000 sqm
WAREHOUSE		5.000 - 2.500 sqm
UCC CONSOLIDATION CENTER		10.000 - 5.000 sqm
HUB		500 - 100 sqm
MICROHUB		500 - 100 sqm
CROSS-LOADING & LOADING ZONES		500 - 100 sqm
PUDO		500 - 100 sqm
STORAGE & FINAL CLIENT		500 - 100 sqm

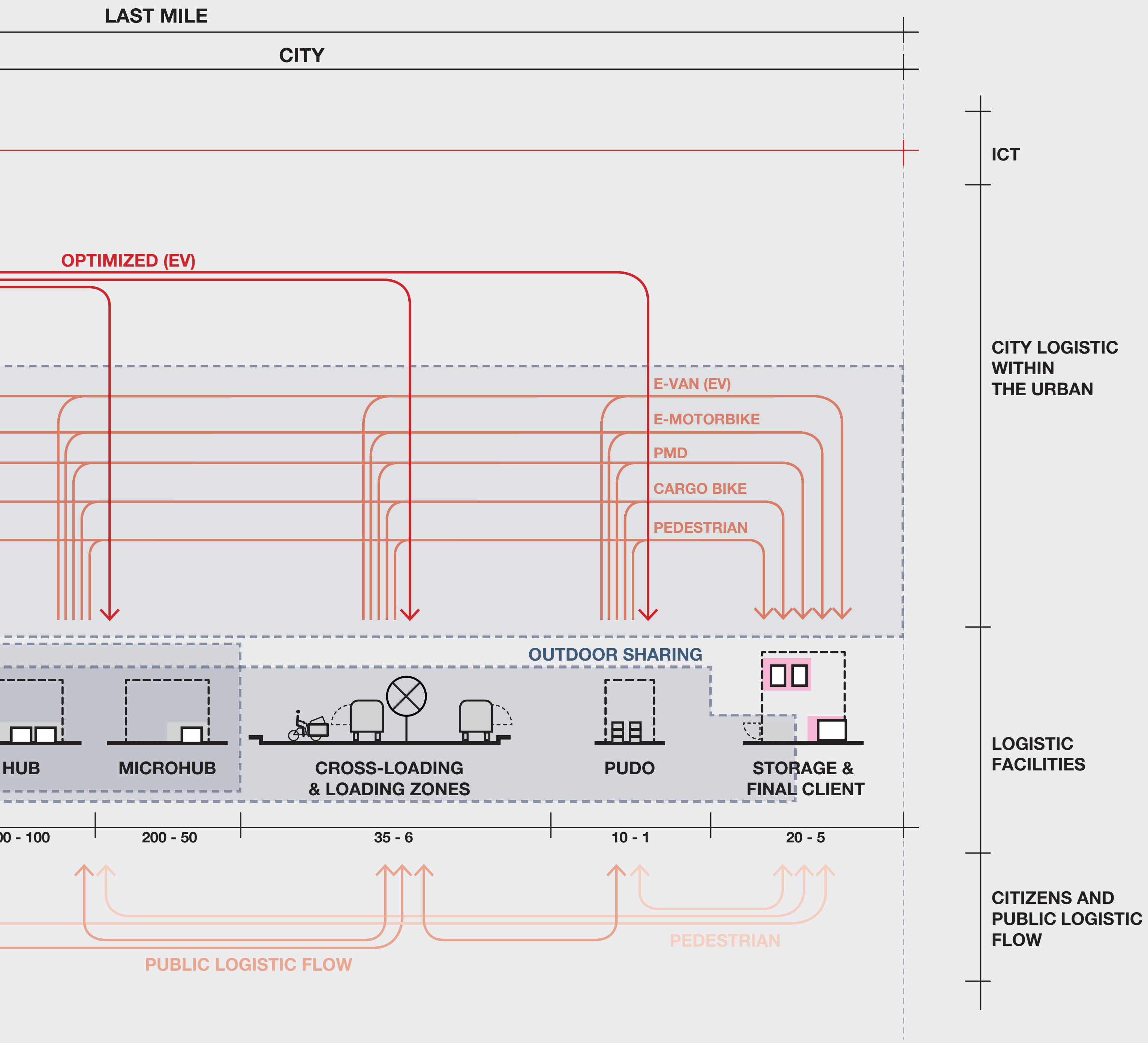
LM - LII

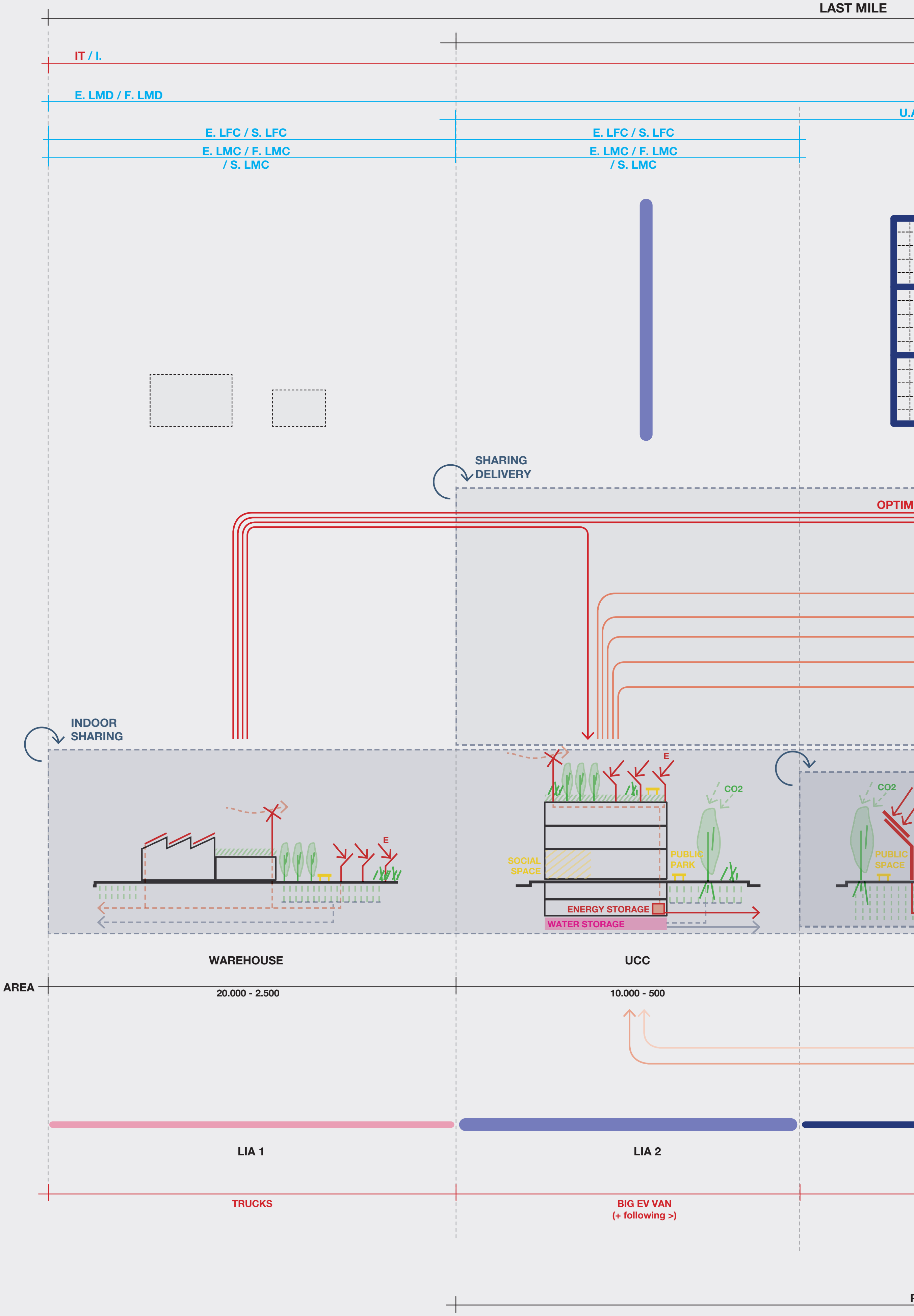
E.LMD	ENVIRONMENTAL FACTOR Last Mile Delivery
E.LFC	ENVIRONMENTAL FACTOR Logistic Facility Company
E.LMC	ENVIRONMENTAL FACTOR Last Mile Delivery Company
E.HUB	ENVIRONMENTAL FACTOR Hub Company
E.SOC	ENVIRONMENTAL FACTOR Society
F.LMD	FUNCTIONAL FACTOR Last Mile Delivery
F.LMC	FUNCTIONAL FACTOR Last Mile Delivery Company
S.LFC	SOCIO-ECONOMIC FACTOR Logistic Facility Company
S.LMC	SOCIO-ECONOMIC FACTOR Last Mile Delivery Company
U.A.	URBAN FACTOR Urban Accessibility
U.R.	URBAN FACTOR Urban Regulations
U.M.	URBAN FACTOR Urban Morphology
I.	INFORMATION FACTOR

INDOOR SHARING — SHARING & OPTIMIZATION IT PLATFORMS

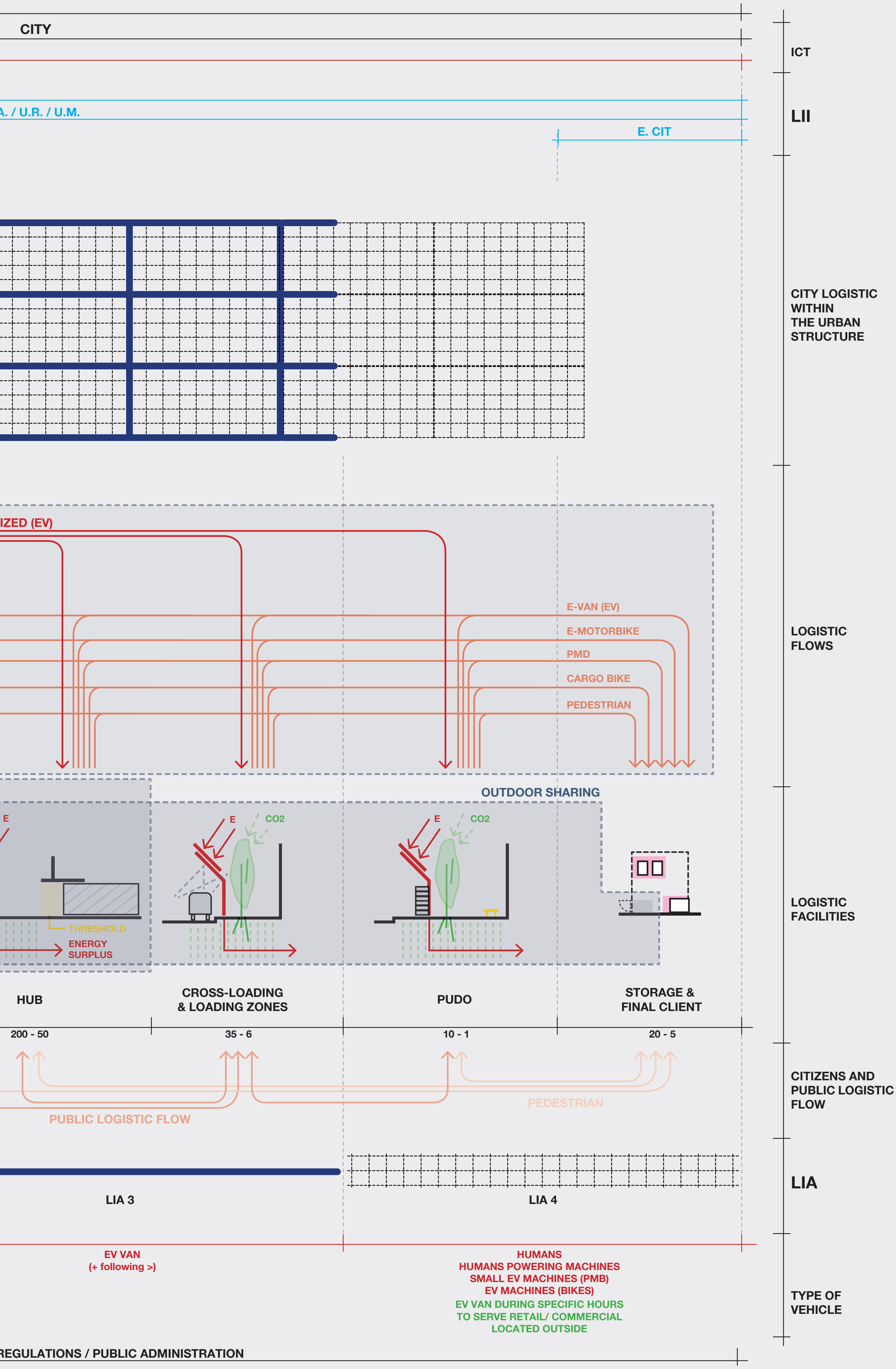


The Logistics Network


LAST MILE
CITY
ICT
OPTIMIZED (EV)
CITY LOGISTIC
WITHIN
THE URBAN
E-VAN (EV)
E-MOTORBIKE
PMD
CARGO BIKE
PEDESTRIAN
OUTDOOR SHARING
HUB
MICROHUB
CROSS-LOADING
& LOADING ZONES
PUDO
STORAGE &
FINAL CLIENT
LOGISTIC
FACILITIES
00 - 100
200 - 50
35 - 6
10 - 1
20 - 5
CITIZENS AND
PUBLIC LOGISTIC
FLOW
PEDESTRIAN
PUBLIC LOGISTIC FLOW



The Logistics Network including the Last-Mile Logistic Impact Index (LM-LII) and the Logistics Impact Areas (LIA) with the actions and strategies for enhancing positive impact.


CITY
ICT
LII
A. / U.R. / U.M.
E. CIT
CITY LOGISTIC WITHIN THE URBAN STRUCTURE
IZED (EV)
E-VAN (EV)
E-MOTORBIKE
PMD
CARGO BIKE
PEDESTRIAN
LOGISTIC FLOWS
OUTDOOR SHARING
E
CO2
THRESHOLD
ENERGY SURPLUS
LOGISTIC FACILITIES
HUB
CROSS-LOADING & LOADING ZONES
PUDO
STORAGE & FINAL CLIENT
200 - 50
35 - 6
10 - 1
20 - 5
PUBLIC LOGISTIC FLOW
PEDESTRIAN
CITIZENS AND PUBLIC LOGISTIC FLOW
LIA 3
LIA 4
LIA
EV VAN
(+ following >)
HUMANS
HUMANS POWERING MACHINES
SMALL EV MACHINES (PMB)
EV MACHINES (BIKES)
EV VAN DURING SPECIFIC HOURS
TO SERVE RETAIL/ COMMERCIAL
LOCATED OUTSIDE
TYPE OF VEHICLE
REGULATIONS / PUBLIC ADMINISTRATION

01: Introduc

ction

Cities have the capability of providing something for everybody, only because, and only when, they are created by everybody.

Jane Jacobs, 1961

> *"A few days ago, the janitor of a residential building in the center of Madrid was overwhelmed. He complained about the continuous flow of deliveries and that he couldn't handle any more packages. He said that he was not prepared for the volume of packages, and neither was the building. He even talked about the street: "Look! It is always collapsed, full of double-parked vans, and every day it is getting worse". "*

In many ways the janitor was right. Cities are not prepared for the exponential growth of deliveries. And it is not just a matter of efficiency and optimization, but also about the negative impact on the environment. Cities require an efficient flow of goods since it is a key factor to attract economic activities. (Dablanc and Rodrigue, 2014).
Nowadays, cities are facing a huge challenge. From the XS scale of the janitor to the XXXL scale of the biosphere, cities play an essential role in our planet. Two, 50, 75, and 80 are the four numbers that provide a measure of the impact of cities (Ratti, 2016). Although they only occupy 2% of the planet's surface, they accommodate more than 50% of the population, cities consume 75% of global energy and produce 80% of global CO2 emissions. The four numbers are not fixed and keep growing. Perhaps they are not accurate (Brenner and Schmid, 2013; UN, 2007), but they provide us with a precise idea of the impact of cities in the world.
The idea that humankind is living in an Urban Age (LSE Cities, 2005) is more than a manifest, a theory, or a metanarrative (Koolhaas, 2000), this viewpoint helps us to understand the huge challenges of urbanization. The relationship behind the four numbers shows even a bigger challenge. Cities are consuming land faster than they grow in population. Migration has become a strong driving force in urbanization (UN-HABITAT, 2020).
Although cities are one of humankind's oldest inventions, it was not until the end of the nineteenth century when Ildefonso Cerdà (1867) established the first principles of urbanism. Thereafter, cities have been designed from different approaches, including science, ecology, aesthetics, social sciences, or technology.

For the purpose of the present research, cities are approached as ecosystems, based on the continuous flow of materials, energy, people, and natural organisms. Unfortunately, these flows do not always move in the desired direction, and often result in waste, pollution, natural disasters, inequalities, and conflicts.
Ecosystem ecology is frequently understood as the largest organizational level in ecology which encompasses individuals, populations, and communities. It addresses the exchange of energy and matter among all organisms and their environment. (Burke and Lauenroth, 2011).
Most of the current environmental problems, such as global warming and other disruptions, can be understood from ecosystem ecology. In addition,

this approach can help us evaluate their impacts. One of the objectives of the present report is to develop tools to evaluate the environmental impact of city logistics. It is important to clarify that for the present research the term environment encompasses the interaction of three subsystems: the social, the natural, and the built environments.

Although the development of a full model to evaluate ecosystem behavior is still a challenge (Willig and Scheiner, 2011), the objective of the present paper is to provide the methodology and tools to measure the impact on urban logistics in cities. Thus, all scales must be included from the small scale of the janitor's concern to the flow of goods between cities and the surrounding territories. In other words, from the micro-scale (chemical reactions such as pollution, noise, combustion, life…) to the macro-scale (infrastructure, global warming, governance).
The concept of transport is usually referred to as the movement of persons, organisms, and goods. The Athens Charter (Le Corbusier, 1933) recognized four types of zoning and activities within the city. Movement coincided with living, working, and leisure. In some way, the role of the planner was to find a place for these four activities, in which the transport zones were designed for movement. Thus, movement was a noun (and not an action) that was designed separately by transport engineers. In the present research, we have replaced the term movement with the concept of flow, which encompasses a network in permanent transformation and evolution. (Castells, 1989; Solà-Morales, 2002; Guy et al, 2011; Batty, 2013) We cannot design a network and its content separately. The interconnection and interdependency of the nodes inside a system can help us understand its dynamics, and also to predict its future evolution and transformation.
These ideas of the city as a network in permanent change are not something new. Probably, Patrick Geddes (1915), because of his background as a biologist, was the first to establish a relationship between cities and their activities with the surrounding environment. He created a classification of cities based on thermodynamic concepts: Cacotopia and Eutopia. While the first one dissipates energy to obtain individual monetary benefits, the second conserves the energy through a positive exchange with the environment, while promoting a sustainable evolution of communities and individuals.

The concept of network adds the time dimension to the traditional spatial and physical approach of urban design. Christopher Alexander in his famous paper, "A City is Not A Tree" (1965) opposed the hierarchical structure of traditional city planning, such as zoning, in favor of an analogy of a network to describe its behavior. Cities are far more complex than any hierarchical structure. Some authors analyze cities regardless of the physical and spatial dimension, by just focusing on the network

and seeing locations as patterns of interactions (Batty, 2013). This transition from location to networks can help to understand why interactions happen, why people get together or why there is an increase in the flow of goods.
Modern cities have highly developed and complex systems of urban infrastructure. If we design cities as the interaction of complex systems, we can challenge the traditional logic of "build and supply" (Guy et al., 2011). Some authors understand the city as a big logistics system, divided into several interconnected subsystems, which include urban transportation, distribution, and information or communication subsystems (Averkyna, 2017). The question that lies behind this is, who is shaping and who will shape the urban infrastructures of the future?

1.1 City Logistics

Cities are becoming global trade nodes. The supply chain has expanded into a global network of new infrastructures such as ports, airports, railyards, and distribution centers (Dablanc and Rodrigue, 2014). This global supply chain is a complex network of production, which includes multiple stages, ranging from the extraction of raw materials to the delivery of finished goods. (Dablanc and Rodrigue, 2014). City logistics is more than the transportation of goods. Among the multiple definitions of city logistics (Giuliano, O'Brien, Dablanc, and Holliday, 2013; Taniguchi and Thompson, 2008), we focus on the interdependencies between citizens' welfare, the logistics system, and public policies for urban logistics (Cardenas, et al.,2017): "City logistics deal holistically and systemically with context, actors, norms, and operations within the city jurisdiction as well as in its relationships with neighboring cities because it is recognized that 'geographic, economic, social, and cultural circumstances affect city logistics and people's perception of critical issues related to city logistics."
In addition, city logistics includes all types of freight distribution and logistics facilities located in urban areas, together with the strategies and regulations that balance the relationship between efficiency and environmental impact. During the last decade, there has been an increasing interest in improving the efficiency of city logistics while mitigating its negative impact. (Cardenas, et al.,2017)

There are a growing number of new alternatives for city logistics, such as green logistics and collaborative logistics. The concept of urban green logistics is an aggregation of different logistical approaches. Using new technologies, green logistics aims to optimize the flow of materials, vehicles, information, energy, and resources, to reduce the negative impact on the city environment (Averkyna, 2017). The complexity of the network of city logistics is caused in part by the new ways of collaboration and sharing customers, such as crowd logistics or instant deliveries, thanks to ICTs' tools.

Urban freight distribution compared with intercity freight transport is normally more polluting because vehicles are older, vehicles transport less volume of goods per trip, and city congestion causes lower driving speeds (Dablanc and Rodrigue, 2014).

Efficient and sustainable transportation systems can reduce commuting costs and time, and lead to more inclusive cities (UN-HABITAT, 2020).

The last-mile delivery is considered as "the last leg in a supply chain to a customer's location in a city, or the first leg from a customer's location in a city back into the supply chain" (Den Boer et al., 2017). There are indications that as much as 28% of transport costs can be related to the last mile delivery or first-mile pickup (Goodman, 2005).

1.2. Challenges.

The exponential growth of city logistics in recent years has caused multiple environmental concerns. Some of the challenges facing city logistics can be summarized in low/zero-emission driving technologies and fuels, more demanding customers, connecting the physical world (IoT), robotization and automation, and a tendency towards omnichannel (Den Boer et al., 2017). The concept of omnichannel is based on the customers' demand of 'Order everywhere, deliver anywhere, and return anywhere', which will have a huge impact on the environment.

These demands are difficult to implement, as they often increase the cost to shippers (Dablanc and Rodrigue, 2014):

> *"The best city logistics strategy entails a framework that ensures coherent management of urban freight distribution, particularly assets such as trucks, logistics terminals, and parking. Incentives, regulations, and enforcement should aim at promoting better use of existing urban assets: off-peak hour deliveries, available on-site and off-site loading zones, and more full trucks."*

Some authors have proposed specific recommendations to reduce the carbon footprint of city logistics including 1) implementation of logistics platforms and hubs; 2) pooling and development of multimodal transport; 3) selection of environment-friendly means of transportation; 4) development of environmentally efficient infrastructures and logistics facilities; 5) reconfiguring the logistics network for more efficiency; 6) use of business software packages and NTICs; 7) eco-driving training; 8) reducing packaging and increasing the rate of product recyclability; 9) collaborative distribution. (Morrocan, 2016).

There is an increasing need for innovation in city logistics, to deal with GHG emissions, noise pollution, amount of freight movements, security, and infrastructure use. Innovation is happening

from all stakeholders, from vehicle manufacturers, logistic facilities, information, to communication technologies.
The challenge facing city logistics is also an opportunity to redesign the flow of goods, not only as an infrastructure but as a public service, as is the flow of people (EIT Urban Mobility, 2021). The street is not just for the movement of people and goods, it is where life happens (Gehl, 1971).

1.3. Objectives

The objectives of the present research are to analyze and evaluate the impact of the last-mile delivery in cities and recommend specific strategies and policies to seek a balance between efficiency and positive environmental impact. The work has been carried out in the cities of Madrid and Barcelona. The work is meant to be both analytical and proactive.
The analysis of the last-mile delivery has been carried out with real and empirical data to provide the basis for later evaluation. The real data has been obtained from different sources, including specific field studies to gather data about Business as Usual (BAU) models.
The multiple combinations of deliveries, logistic facilities, and ICTs provide many options for the last mile delivery. Among these possibilities, some representative scenarios have been analyzed and modeled, for later evaluation and comparison. Evaluation is one of the key findings of the present research. The Last Mile Logistics Impact Index (LM-LII) is a tool that has been developed to measure the impact of the last-mile delivery in cities. The LM-LII has been applied to the scenarios, to compare the results and to provide proactive strategies.

The results obtained from the LM-LII lead to specific recommendations and actions, for such concepts as the Logistics Intensity Areas (LIA). The LIA is a bidirectional planning policy based on a process of “giving and receiving”. It reduces the intensity of negative impacts while intensifying positive impacts. The LIA allows for specific logistics activities according to four levels of intensity areas. Furthermore, the LIA promotes positive impacts through three architectural and landscape strategies: sharing resources, naturalization, and community involvement. Thus, the LIA emerges as a dynamic collaboration tool among different stakeholders, from the public administration to citizens, to promote and enhance a more sustainable urban environment.
Being aware of the challenges and ambitions of the present research, the results and findings are opening a new path towards a fuller understanding of the impact of logistics in cities. This, we see, is just the first step.

02: Methodo

ology

2. Methodology

In recent years, the research on city logistics has been slowing down because most of the literature has not gathered historical information or empirical datasets. Neither is there a standard to work with data from available sources that could lead to a new analysis of performance or simulation methods (Perboli, et al., 2018). Thus, upon review of the literature, few research examples work with real and empirical data (CITYLAB, 2017; Perboli, et al., 2018).

The methodology followed for our current study and report was carried out through an ecosystemic approach, to understand and evaluate the interaction and interdependency of multiple factors involved in city logistics, and how they impact the urban, natural, and socio-economic environments. The ecosystemic approach gathers multiple perspectives as ecosystemic urbanism (Rueda, 2017), evolutionary urbanism (Pérez Romero, 2017), landscape ecological urbanism (Steiner, 2011), where the city is understood as an ecosystem undergoing permanent evolution and transformation. The study of the flow of production and return within a city, and between the territory and the city, helps in understanding the impact on the environment.

Although there is not a standard recipe for city logistics, a group of strategies need to be adapted to the local conditions of the urban system (Dablanc and Rodrigue, 2014), the ecosystemic approach allows the upscaling of solutions and actions that can be later applied through adaptation and evolution.

The methodology of the present research does not focus just on the optimization and mathematical modeling of the last-mile delivery. Rather, the analysis and evaluation of the impact of the last mile delivery are approached holistically from city logistics, which include a complex network of simulations with different actors and situations, based on real quantitative and qualitative data. As city logistics deal holistically and systemically with the full picture of the context, any research must include the stakeholders, regulations, operations, and the urban structure, (Cardenas, et al.,2017)

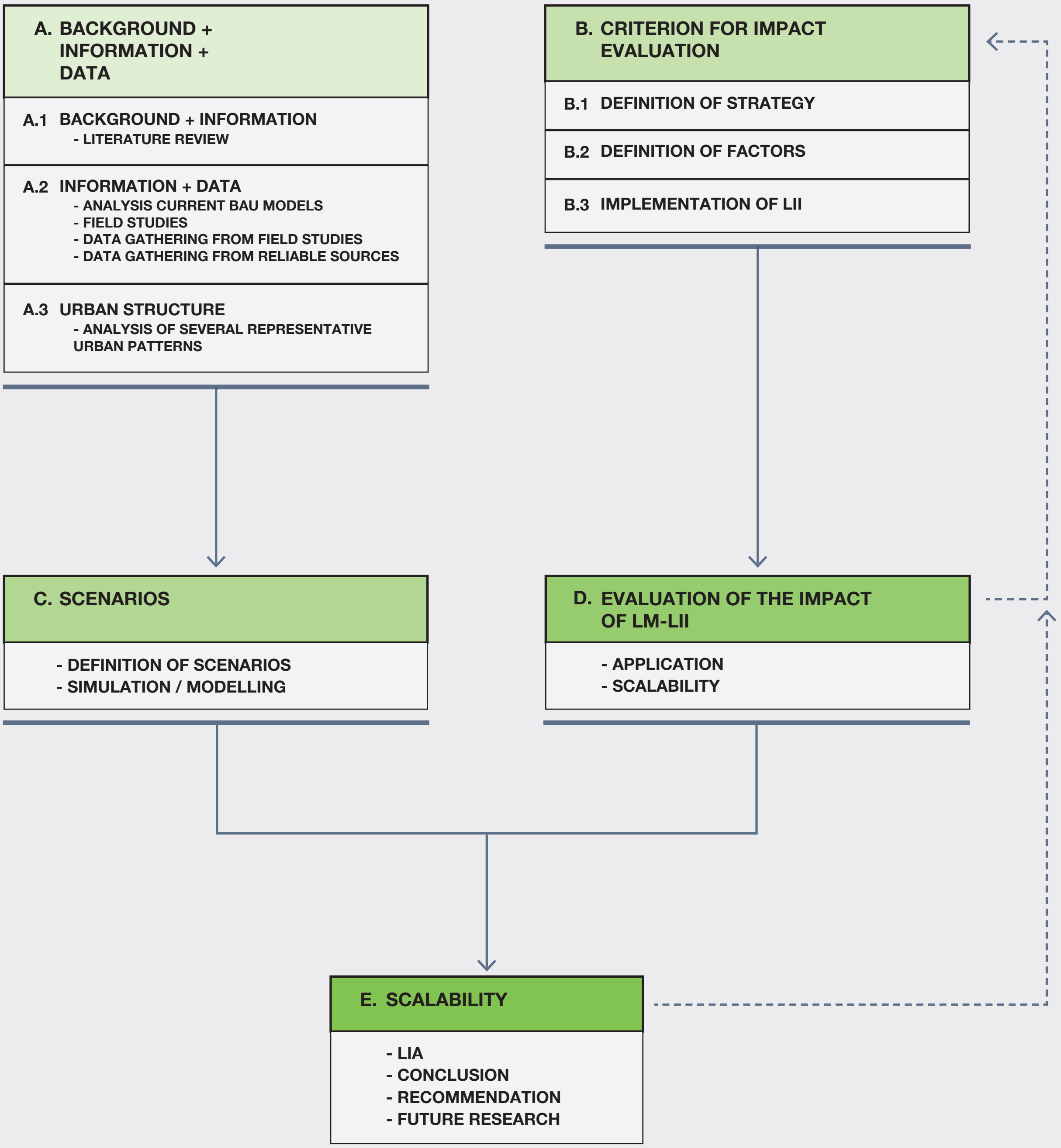
The research approach is a practice-oriented design, where the flow of knowledge that is built up with real data contributes to future proposals that could be applied in multiple situations. The objective is to provide information, tools, and strategies to improve the efficiency of the last mile delivery while reducing its impact on the urban environment.

The question that this study addresses is not just what type of currently existing last-mile delivery performs better as the combination of multiple factors, but what the stakeholders can do to make positive changes. There is something that everyone in the supply chain can do to help mitigate climate change (MIT Real Estate Innovation Lab, 2020).

Although research started with a linear methodology, it has gradually transformed into an iterative process of back and forth, where the results are affecting and encouraging us to adjust the initial criteria. Thus, the methodology for this report is based on an iterative process, which also leaves room for and encourages future research.

Basically, our study has been organized in five areas: a. Background, information, and data; b. Criteria for impact evaluation; c. Scenarios; d. Impact evaluation; e. Scalability.

Methodology followed



The background information gathers concepts, information, and data from the literature review, with emphasis on urban design, evaluation criteria, modeling of scenarios, and the interdependency between urban structure and city logistics. In addition, we specifically analyzed the classification and role of the stakeholders involved in the process. The function of the public administration was studied by consulting different transportation ordinances, planning policies, and urban regulations.

For this study, "business as usual" (BAU) models are considered as the benchmark reference or baseline measurement for the comparison of different scenarios. To obtain real data, three field studies were carried out; one concentrating on the observation of a part of the city and two from the interior of a delivery vehicle during the last mile deliveries.

The exterior field study gathered data and information of the last-mile delivery, in a specific urban area, during a full day, from early in the morning until the evening. The other two field studies were undertaken from the interior of a delivery vehicle, over two different circuits, one in the outskirts and a second in the center of Madrid. The results obtained were analyzed in relation to each other and also compared to the BAU model. Other data was gathered from reliable, public information sources related to the urban structure of Madrid and Barcelona, the geolocations of the loading and unloading areas, residential buildings, retail spaces, and traffic information. The urban areas selected for the scenarios were similar for Madrid and Barcelona (historic center, city expansion area, and outskirts) to allow for comparison and scalability.

We established the criteria for impact evaluation by first undertaking and analysis of accepted, existing sustainable certifications, and then broadening this to an ecosystemic approach. The environment is an interconnected system of natural, socioeconomic, functional, informational, and urban factors. The implementation of these factors to evaluate the scenarios was done mainly through quantitative data.

As mentioned above, the benchmark or point of comparison for the scenarios was the Business as Usual (BAU) model. The scenarios we have devised bring together both logistic facilities and vehicle deliveries in six distinct examples of urban land patterns, three for Barcelona and three for Madrid. Later, each scenario was evaluated by applying the Logistic Impact Index that we have developed. The results obtained were then compared to identify the best practices.
Finally, a specific methodology (that we call Logistic Intensity Areas) was developed that could support future planning policies using a concept of intensity areas to guide the implementation of

different combinations of logistic facilities and vehicle deliveries, all while enhancing positive impacts in the city. Compared to traditional urban planning, the Logistic Intensity Areas are a bidirectional policy involving all stakeholders, which reduces the intensity of the impact and intensifies a positive impact.

2.1. The Logistic Network Diagram (LND).

The ecosystemic approach of the present research is represented through the Logistic Network Diagram (LND). As mentioned in the previous chapter, the dynamics of logistics is not an isolated system, but part of a bigger ecosystem: the city. The Logistic Network Diagram gathers the interaction of the flow of goods within the urban environment.
The impact of logistics in the city can be explained through the LND. It is a summary of the key findings. It gathers, within one graphic representation, all of the parameters and factors studied. Thus, the holistic approach of the present research is summarized in the LND as the relationships within the logistics system, much as the relationships of an ecosystem.
In addition, the LND has guided our research. We gradually added layers of information that allowed the diagram to gain in complexity. The first layer of the diagram represents the parts of the system, formed by the stakeholders, the logistic facilities, and the urban structure.
(see LND 1)

- Stakeholders: private (logistic facilities companies, delivery companies, vehicle companies…) and public (citizens and public administration).

- Logistic facilities: buildings (warehouses, UCCs, micro-hubs, other storage spaces) and landscape spaces (loading and unloading areas, PUDOs, access to logistic facilities, other exterior spaces), organized by decreasing area dimension, as they get closer to the city center.

- Urban Structure: outskirts and city limits.

The second layer is the combination of the flow of goods across logistic facilities and stakeholders: *(see LND 2)*

- Flow of goods according to vehicle type: BAU model (ICE Van), EV Van, EV Bike, PMD, Bike and Walking.

The third layer is formed by all the factors for the Last-Mile Logistic Impact Index (LM-LII). It is the tool we have designed to help evaluate the impact of logistics in the urban environment. *(see LND 3)*

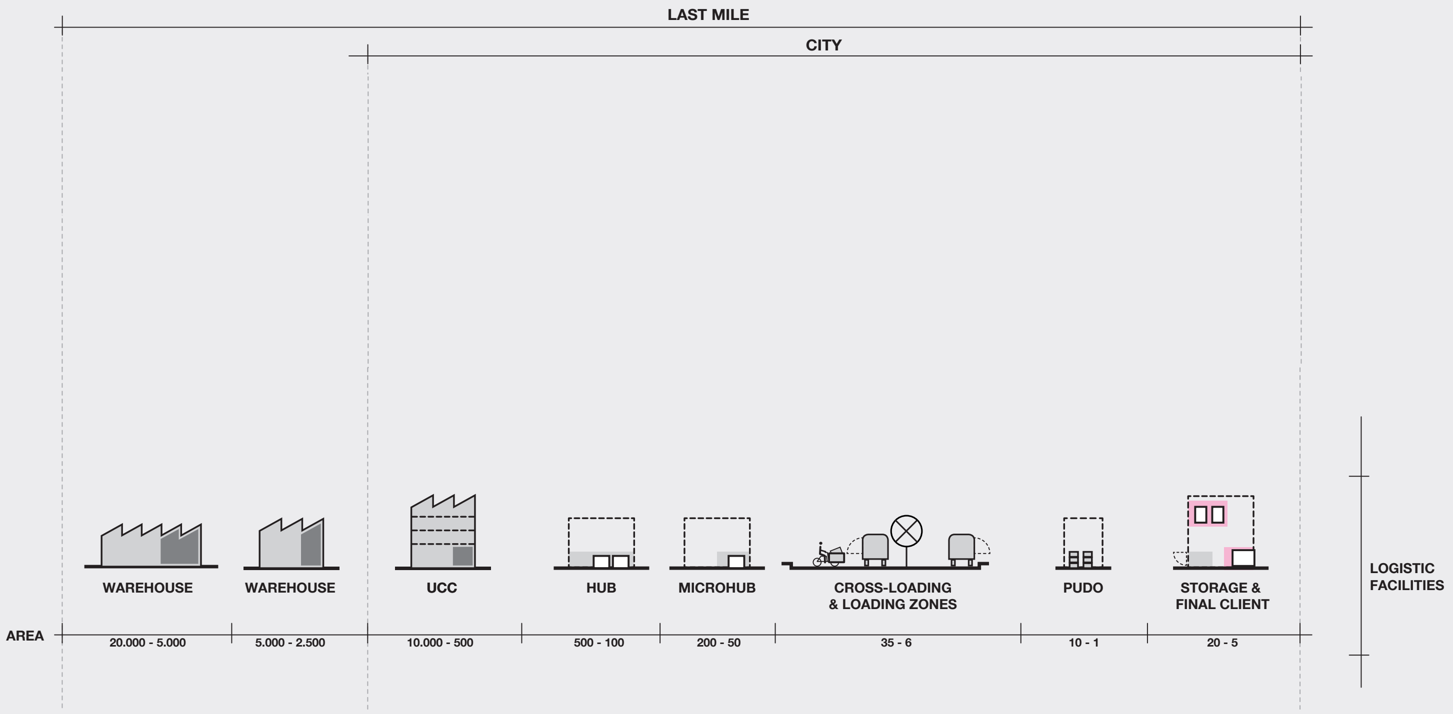
- Factors: environmental, functional, socioeconomic, urban, and ICTs.

Finally, the last layer reflects the actions and recommendations of the present research, as the Logistic Impact Areas (LIA): *(see LND 4)*

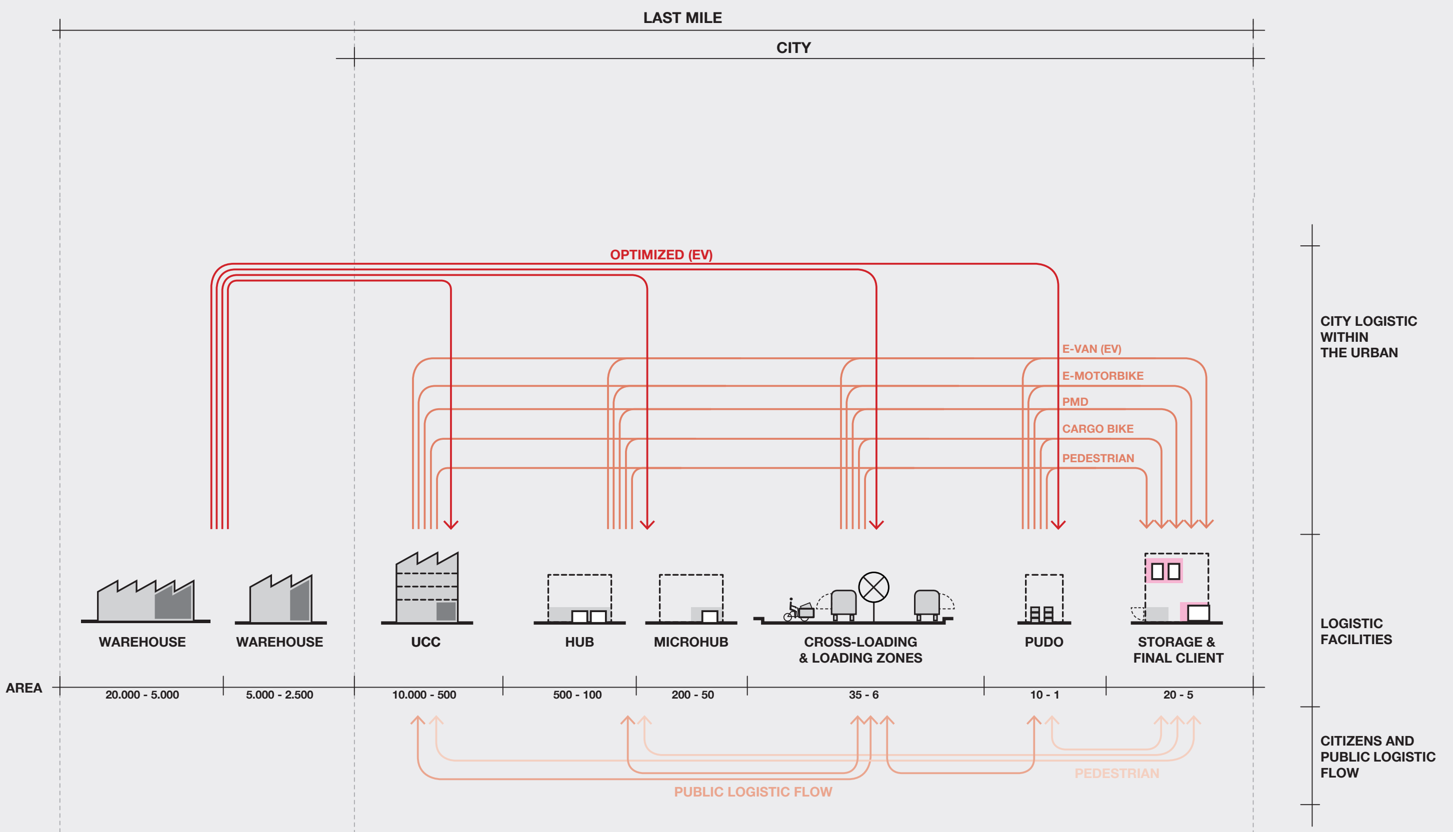
- Logistic Impact Areas. Intensification for positive impact: Sharing-Resources, Improvement of the Natural Environment and Community Involvement.

The four layers of the diagram represent the chapters and structure of present research. We have begun with observing current situations and slowly added information, concepts and complexity over time resulting in a more precise understanding of how the flow of goods interacts with and impacts the city from a holistic perspective.

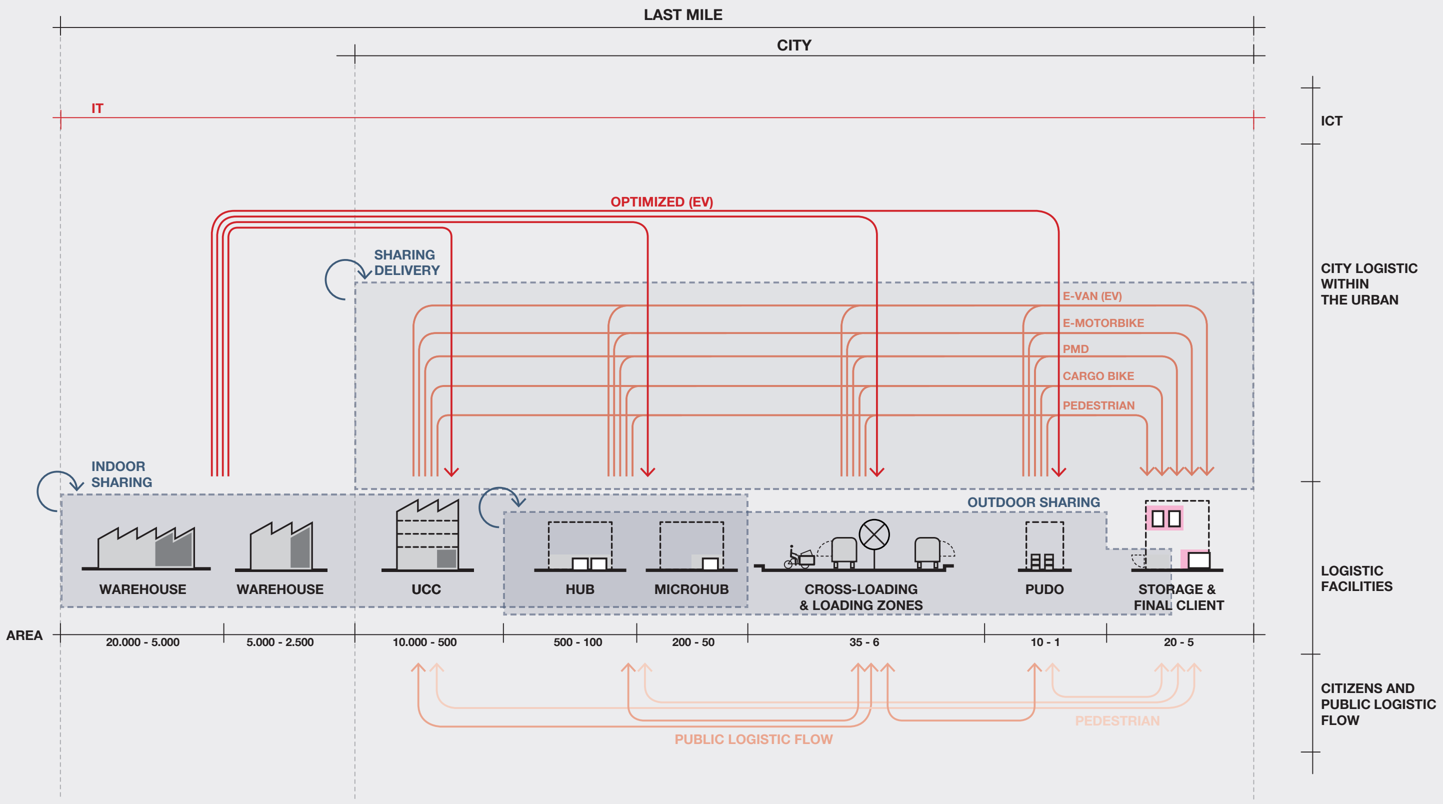
The paper opens many important paths for future research, such as the detailed development of the Last Mile Logistic Index (LM-LII) or the application of planning policies based on the Logistic Intensity Areas (LIA).



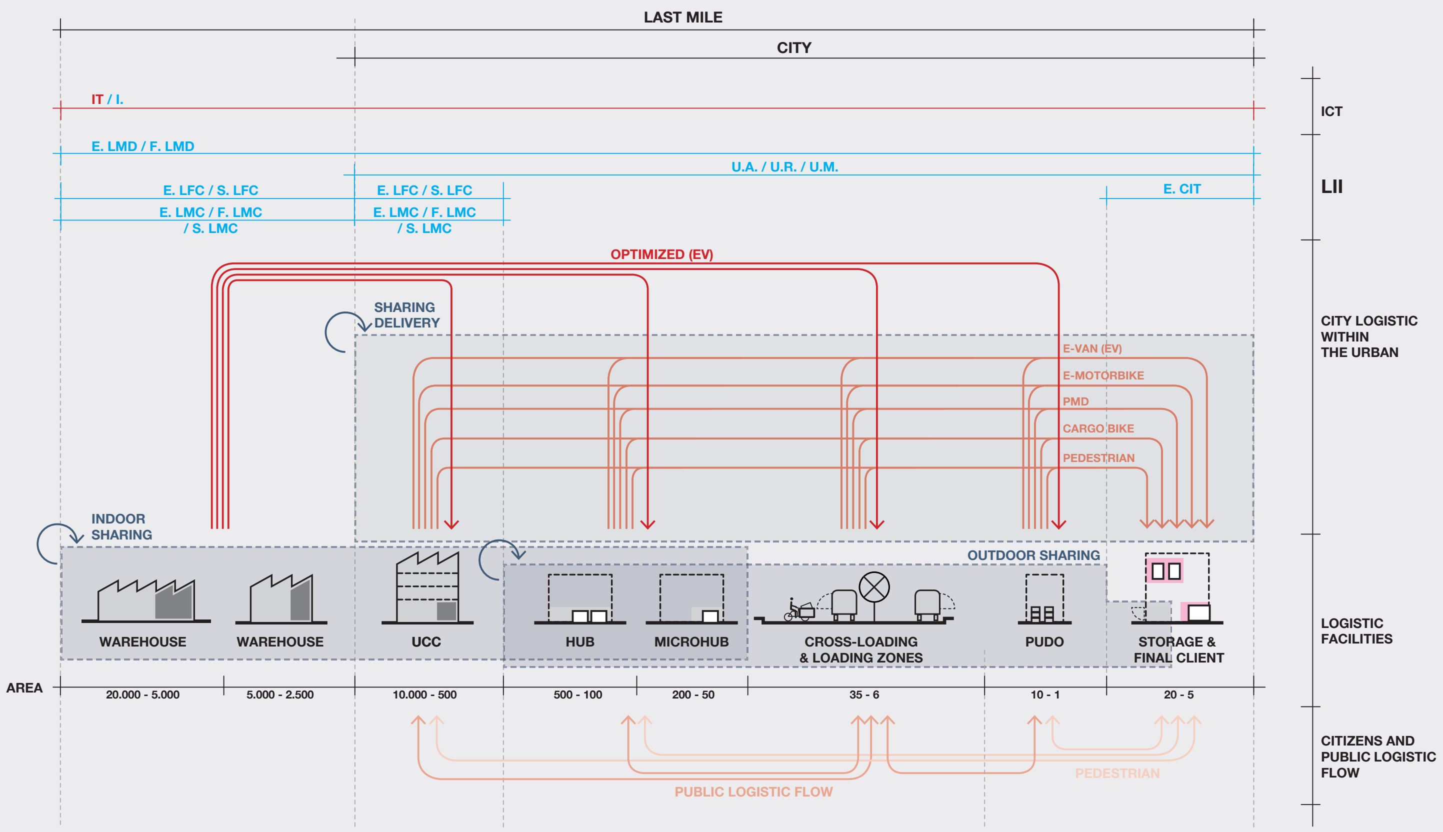
Logistic network diagram 1.



Logistic network diagram 2.



Logistic network diagram 3.



Logistic network diagram 4.

03: Logistics Ecosystem

s

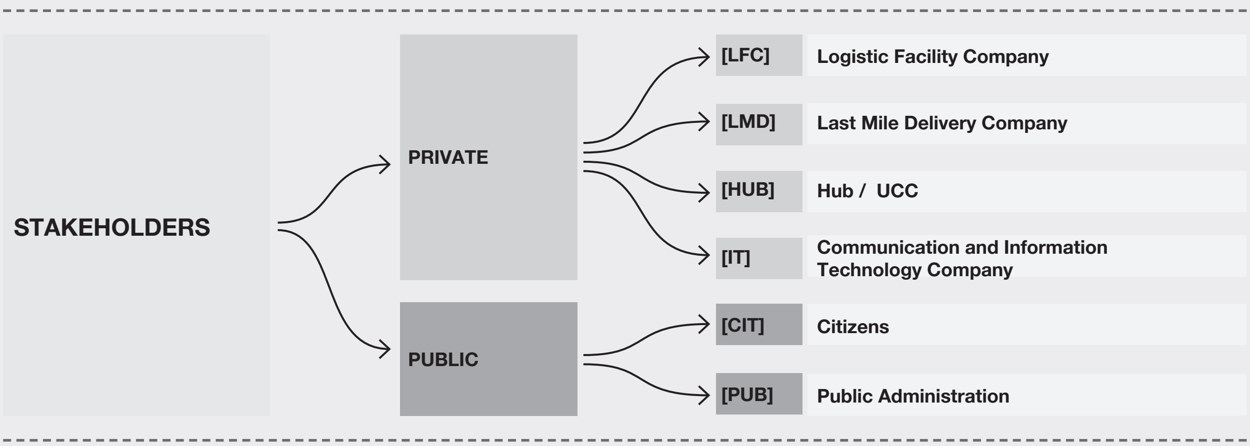
3. The Logistics ecosystem

Logistics is a multidisciplinary field. It has been approached by researchers from different backgrounds, such as computer science, applied mathematics, applied science, economic and business, transportation engineering, real estate, marketing, supply chain management, industrial engineering, environmental science, military science, and geography. Furthermore, logistics is emerging as a new disciplinary field, thanks to the transfer of knowledge from other disciplines, where city logistics is a subsystem inside the global logistic network.

The literature review carried out for the present research has confirmed this multidisciplinary approach of researchers and professionals. More than 70 authors' works have been reviewed. Within this body of research, surprising lacking were urban designers, urban planners, and architects. This can be partially explained by the artificial division between the transportation, understood as the physical movement of people and goods, and the physical infrastructure which allows the mobility. Planners, urban designers, and architects traditionally design the grid of streets and roads, while the transportation systems are implemented by engineers. Obviously, there is something that does not fit nor reflect the reality or the complexity of logistics.

In present research we have approached city logistics mainly from urban design, planning, architecture, ecology, mathematics, and logistics management. However, this division, only responds to an academic nomenclature. Historically, human knowledge has divided the world into areas of expertise or disciplines in an attempt to make it more understandable. (Wilson, 1999; Wagensberg, 2014). For us, the objective of present paper is not city logistics as an isolated phenomenon, but rather as part of the city. In fact, here city logistics is approached from an urban studies perspective, by placing the city at the center of the research. From this point of view, the ecosystem of the city is seen to include the flow of goods which interacts with the environment. Our work is to understand how these interactions happen and how can we enhance a positive relationship.

The logistics ecosystem is a network of nodes formed by the logistic facilities, which are part of the city structure, and the logistics flow formed by the delivery vehicles and the goods. The interconnection of the nodes with the logistics flow is regulated by the stakeholders and the information and communication technologies, where the urban regulations play an essential role. In the present research, the evaluation of city logistics is undertaken from multiple combinations of the nodes and the flows of the network.



Stakeholders of Last-Mile Logistics

3.1. Stakeholders.

Nowadays, it is widely accepted that urban design must integrate different stakeholders from the private sector, public administration, citizens, and social groups. The time in which decisions were made by a single person or organization are long gone. New ways of designing the city are emerging with the integration of all voices. To respond to growing inequalities and environmental concerns, designers must find new ways of engagement with citizens, activists, ecologists, artists, and the public administration (Shepard, 2017).
There is a new generation of urban designers and architects who probably started with the concept of the “open form”, at the end of the 50’s (Pérez Romero, 2017). Oskar Hansen was one of the first who introduced the idea of people participation in the design and configuration of a project. (Hansen, 1959) Later, Cedric Price, together with the psychologist and cybernetician Gordon Pask, designed the Fun Palace where the stage was a flexible space, which could be physically modified by the collaboration between the public and the actors. The Fun Palace represented the integration of people and arts through technology (Hardingham, 2016).

Later, in 1969, and as an opposition to the traditional concept of Master Plan, Cedric Price, together with writer and editor, Paul Barker, urban geographer, Peter Hall, and architecture historian, Reyner Banham, wrote the provocative manifest “Non-Plan An Experiment in Freedom” (Price, et al., 1969). The traditional Master Plan does not allow things to happen spontaneously. Rather, everything is set and controlled from the master designer through master planning documents.
Non-plan included the emerging ideas, at that time, about self-organized systems (Von Foerster, 1960), where the citizens become the designers of the city. Citizen participation and the integration of different stakeholders, from private to public organizations, has allowed a new approach to city making. Tactical urbanism (Lydon, 2015), Urban Acupuncture (Lerner, 2003), Advocacy Planning (Davidoff, 1965) Placemaking (Jacobs, 1961; Gehl, 1971), Ecosystemic Urbanism (Rueda, 2018) are just some of the terms used to describe a new methodology, which includes different voices, that traditionally have not been heard and meaningfully included in the process of city design.
In addition, participatory design puts on the table the daily activities of citizens. Philosopher and sociologist, Henri Lefebvre, in his famous work The critique of every day life (1947), argued that our habits are responsible for regulating the relationship between society and nature. From this point of view, the role of the citizens requires a proactive approach to enact a positive balance between society and nature. In fact, the right to the city (Lefebvre, 1968) is not an individual right but rather a call to co-design the city.

In 1969, Sherry Arnstein defined the Eight Rungs in a Ladder of Citizen Participation, which ranged from manipulation to citizen control. In the upper part of the ladder, there were strategies based on partnership and delegated power. (Arnstein, 1969). From 2011 to 2013, the architectural office Ecosistema Urbano designed a new public space in Hamar, Norway, based on a complex process of citizen and public participation, research, innovation, and urban actions (Ecosistema Urbano, 2014). This type of participatory urbanism has become a new paradigm, where different stakeholders are included in different ways in the process of design.

The concept of stakeholders in strategic management was first introduced by Williamson (1991), who argued that the representation of all stakeholders on boards of directors was needed. Later, and because of increasing attention to and requirements of social responsibility, stakeholders have been gradually introduced into the decision-making bodies of different type of organizations. For the objective of the present research, we have accepted the definition of a stakeholder by Edward Freeman and John McVea (2001), “Any group or individual who is affected by or can affect the achievement of an organization’s objectives”. In addition, the authors defined a difference between strategic planning and strategic management. While the first one tries to predict the future, the second one opens new paths of exploration (Freeman and McVea, 2001). From this point of view, it is possible to establish a double dichotomy between Master Planning and Strategic Planning, City Making and Strategic Management. The approach of present research in terms of stakeholder management is close to the concept of City Making and Strategic Management.

In terms of innovation, the incorporation of the ideas of external stakeholders, by encouraging firms to involve competitors, community members, and nongovernmental organizations (NGOs) could enhance innovation in city logistics towards sustainability. (Agyabeng-Mensah and Afum, 2020). In collaborative logistics, companies are able to share their customers thereby reducing transportation costs as the number of vehicles and trips are reduced and in turn, the environmental impact (Bhasker, Sarmah, Kim, 2019).

Identification of the stakeholders.

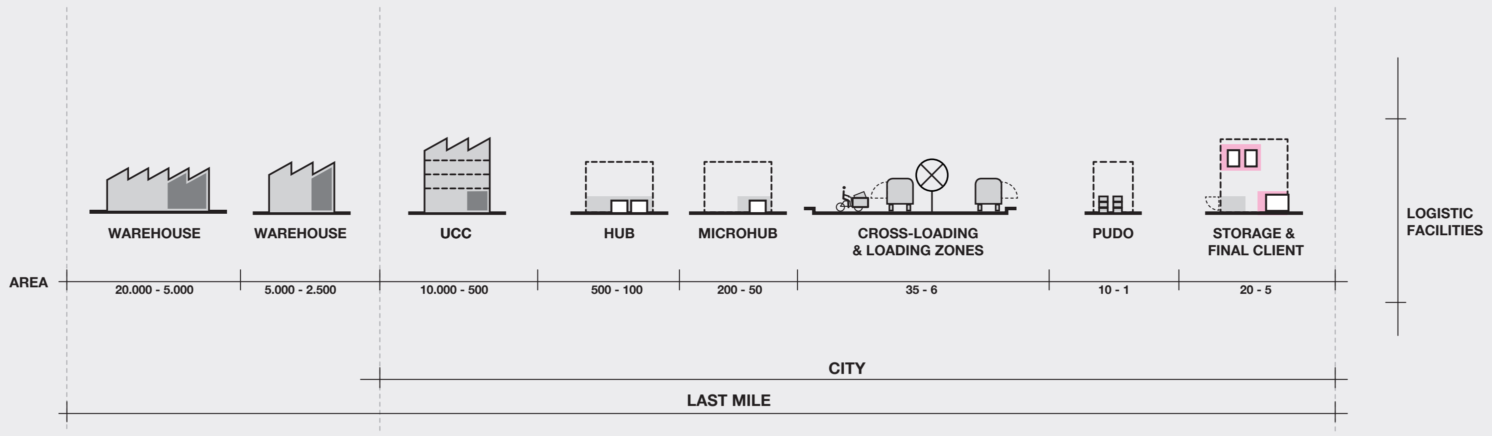
The identification of the stakeholders in the literature related to city logistics has traditionally used different approaches. There is not an accepted definition or classification of stakeholders involved in city logistics. Some authors have identified five types of stakeholders: shippers, receivers, transport operators, citizens, and shopping center owners. (CITYLAB, 2017), while others just use the categories of businesses, city dwellers, and governments. (Den Boer et al., 2017).

Beyond the identification of the stakeholders, some research focuses on the inter-dependencies between citizens' welfare, the logistics system, and the role of the public administration as related to urban logistics. (Cardenas, et al.,2017)
For the purpose of the present research, the stakeholders involved in city logistics are grouped as either public or private. The public sphere is formed by citizens, social groups, NGOs, and public administration. The private realm is comprised of logistics companies, logistics facilities, delivery companies, transportation operators, and retail businesses. We recognize that this division into public and private is just methodological, and that in reality, the separation line is a blurred limit, and that it is the relationship between both is in evolution.

Potential relationships among stakeholders.

The traditional relationship between the different stakeholders involved in city logistic seems no longer adequate to address the current situation and future evolution. New methods of collaboration and of sharing customers are being developed under different terms, such as crowdsourced delivery, which uses ordinary people (crowd) as workforce for the delivery, (Guo, at. el, 2019), crowd logistics (Frehe, Mehmann and Teuteberg, 2017) or instant deliveries (Dablanc et al. 2017). The term crowd-sourced delivery has different meanings, but for the sake of clarification, it puts more emphasis on the transport network rather than the demand side. (Dablanc et al. 2017).

Van Duin, et. al, analyzed three examples of sharing logistics that are already functioning in some cities. UZE Mobility which shares the use of electric vans for delivery, free of charge because the revenue will come from the advertising of their "mobile billboards". CargoHitching is based on deliveries which share the ride between persons and goods, where either the vehicle is mainly transporting persons or mainly transporting cargo. And finally, Stockpots is an example of the Airbnb of warehousing, or what is called pooled warehouses. Some studies show that, in general, more than 30% of some warehouses remain unused, thus providing an opportunity for sharing.



Last-Mile Logistic Facilities

3.2. Logistic Facilities.

Urban logistics can include different types of logistic facilities within the city, which can be part of an interior space, such as warehouses or urban consolidation centers, or part of exterior spaces, such as loading and unloading areas (Dablanc and Rodrigue, 2014; Deloitte, 2020). The objective of these facilities is not just to storage and cross-docking the goods, but to provide flexibility to the last-mile delivery.
As the last mile delivery approaches the center of the city, there are different types of Urban Logistic Spaces, classified from the most distant to the closest to the center of the city. These include Urban Logistic Zones (ULZ), Urban Consolidation Centers (UCC), Vehicle Reception Points (VRP), Proximity Logistics Spaces (PLS) and Urban Logistic Boxes (Trentini, Gonzalez, Malhéné, 2015).

The existing areas for loading and unloading in the streets, in Madrid and Barcelona are not enough to provide efficient stops for the last mile delivery (Deloitte, 2020). According to field studies developed for the present research, more than 90% of the last mile deliveries are carried out through illegal parking, usually double parking or in parking blocking garage and building accesses. The lack of loading and unloading areas is not the only reason why illegal parking occurs. There are a group of factors, such as independent drivers, paid on the basis of completed delivery, feel pressure to quickly make the maximum number of deliveries or the fact that there is no training in safety and courteous driving, and there is no optimization of routes, with an eye to more efficient and sustainable deliveries.
There is a severe shortage of available parking space for logistics within the city, meaning that delivery vehicles need to drive longer distances. (Quarshie, et al., 2021).

Microhubs.

A micro hub is a logistics facility where goods are bundled inside the city that serves a limited spatial range, and that allows a mode shift to low-emission vehicles or soft transportation modes (e.g., walking or cargo bikes) for last-mile deliveries.
A useful example can be seen in implementation of Citylab Living Laboratory (2017)in Amsterdam that opened seven shared micro-hubs, which are supplied by truck twice a day. The results show that:

> *“2200 out of 3500 orders are therefore no longer served by van but by bicycles from a micro-hub. The bicycles are not affected by congestion or parking which saves 13% on the average time per order. Therefore, bicycles are able to handle more orders per time compared to vans. Therefore, the amount of daily van trips is reduced by almost 100*

and the total fleet is reduced by 12 vehicles. The access and egress times from the large depot into the city center are consolidated in two trucks per day per micro hub. This saves on average 21 km and an estimated 20 minutes per van trip. Bicycles use the cycling infrastructure which results in a reduction in trip distance of 13%. The average trip distance for vans is 19.3 km and therefore 17.1 km for bicycles. Vans use about eight minutes per order while the bicycles use about seven minutes. The implementation of electric freight bicycles introduces significant operational savings. All together this saves about 60 hours of operational hours per day."

The combination of microhubs with crowd shipping shows a significant reduction in the number of vehicles and fuel consumption compared with a BAU model (Ballarea and Linb, 2019), while allowing for more personalization and adaptation of the last mile deliveries for the final receiver (Quak, Kin, 2020).

The City of Hamburg is also carrying out innovative proposals to improve the last mile delivery in terms of efficiency and environmental impact, through the use of multiple microhubs within the city limits. (HUPMOBILE, 2020)

Urban Consolidation Centers (UCC)

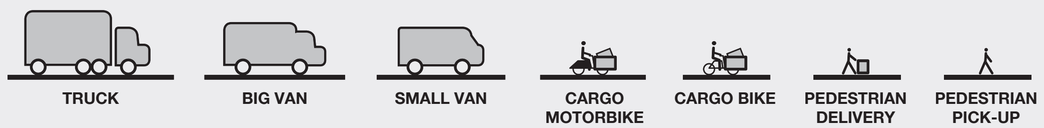
Urban Consolidation Center (UCC), also called a "logistic hotel" is an urban logistic facility located in a multi-use and multi-story building, incorporating cross-docking and warehousing facilities, as well as an interchange node. The objective of the UCCS is to avoid the delivery with non-appropriate vehicles, according to the restrictions or requirements of certain urban areas, and partially loaded vehicles. Deliveries can be consolidated at the UCCs for their later delivery with the appropriate vehicle when fully loaded. Usually, UCCs are located in or close to high density areas within the city limits. UCCs can reduce the total urban freight transport by combining deliveries and filling each truck to capacity (Dablanc and Rodrigue, 2014). Tokyo has demonstrated that UCCs are possible in dense neighborhoods, thanks to a careful selection of the urban locations and the use of zero-emissions vehicles, which help to reduce the environmental impact. (Diziain, Ripert, & Dablanc, 2012).

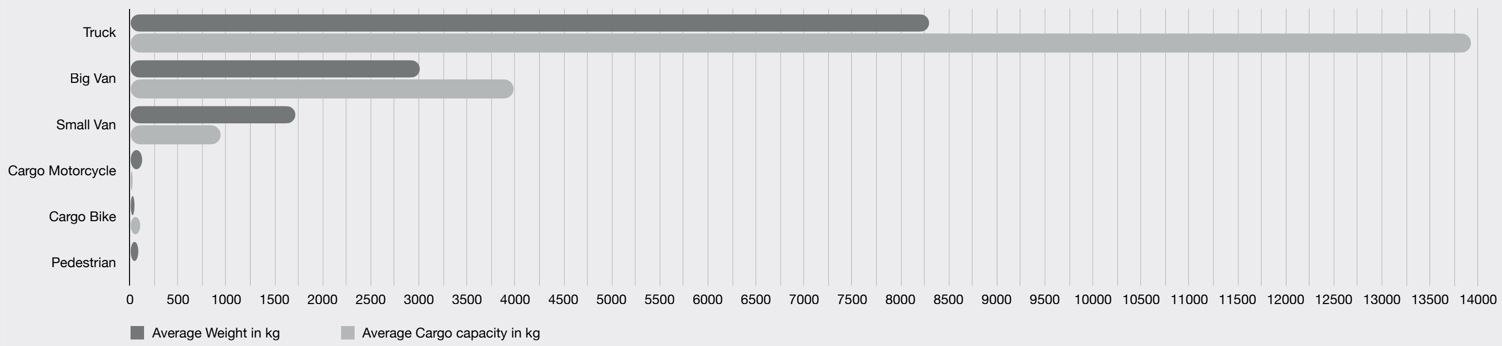
Another example comes from he CITYLAB Paris, which through implementation (2017) aims to face the negative effects of "logistics sprawl" by including within the city limits new or renewed public or private logistics infrastructure, as Urban Consolidation Centers. These are located in Urban Zones for Large Urban Services (UGSU). Eight zones for logistics within former railyards were identified: Chapelle, Court Hebert Est-Pierres, Pantin-Villette and Batignolles in the north of Paris; Bercy, Tolbiac, Les Gobelins and Vaugirard in the south. The 2016 Paris zoning plan has reinforced this policy.

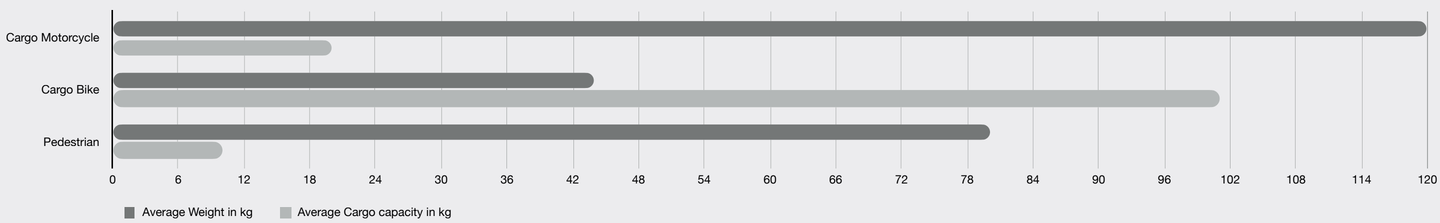
In this framework, the Chapelle International project is being built as a key element of the City of Paris' strategy to reintroduce logistics activity in the dense urban area. It will be a "logistics hotel": a multi-story, multi-user freight facility incorporating cross-docking and warehousing facilities as well as a multimodal railroad terminal.

In the case of Paris, several "logistic hotels" have been recently introduced in the planning policies and some of them have been already built. Other urban warehouses have been developed in Asian cities as Seoul or Tokyo (Dablanc et al. 2017).
In Los Angeles, USA, Amazon already has several UCC in urban locations (Silver Lake, Irvine, Santa Monica, and Manhattan Beach, as of August 2016). This type of building typology needs to be recognized in the local planning policies, to facilitate the introduction of urban warehouses within the city limits (Dablanc et al. 2017). At the same time, the architecture of this type of building must include an evaluation of the impact on the city, in terms of noise and air pollution, congestion, aesthetics, and energy consumption.

Creating a legal framework to allow for logistics hotels seems to be the next logical step. They should be officially recognized and evaluated using many impact measures. First steps have been taken in Paris which has introduced them in planning policies and in some Asian cities such as Seoul and Tokyo. (Dablanc et al. 2017).


TRUCK
BIG VAN
SMALL VAN
CARGO MOTORBIKE
CARGO BIKE
PEDESTRIAN DELIVERY
PEDESTRIAN PICK-UP


Truck
Big Van
Small Van
Cargo Motorcycle
Cargo Bike
Pedestrian
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000 8500 9000 9500 10000 10500 11000 11500 12000 12500 13000 13500 14000
Average Weight in kg
Average Cargo capacity in kg


Cargo Motorcycle
Cargo Bike
Pedestrian
0 6 12 18 24 30 36 42 48 54 60 66 72 78 84 90 96 102 108 114 120
Average Weight in kg
Average Cargo capacity in kg

3.3. Delivery Vehicles

The delivery vehicles can be classified according to different factors, such as volume, weight, energy sources, motor type, GHG emissions, noise pollutions or speed among many others. In the present research we have established a relationship between the weight of the vehicle and the weight of goods, together with the energy source. Vehicles with a positive balance means that they weigh less than the goods they can transport.

Thus, there are four types of vehicles: machines moving machines, machines moving goods, people moving machines and people moving. In the case of machines moving machines, if the weight of the vehicle is more than the goods they can transport, it means that the energy of the vehicle is mostly used to move itself. Machines moving goods means that the balance is positive when the weight of the goods is bigger than the weight of the vehicle. People moving machines include vehicles powered by humans that weight less than the goods they transport. Finally, people moving means people walking with goods.

We have set three types of energy sources: fossil fuel (ICE), electric (EV) and human powered. In addition, vehicles are ordered in volume from the biggest to the smallest.
Rather than building a classification of vehicles using absolute values, such as emissions or volume, the proposed division is based on the relationship between the weights of the vehicle and the goods and the type of energy source. This assists in the understanding of the impact on the environment and the efficiency and optimization of the transportation network. Thus, the vehicle is a machine interacting with the flow of goods inside the logistics network.

3.4. Information and Communication Technology (ICT).

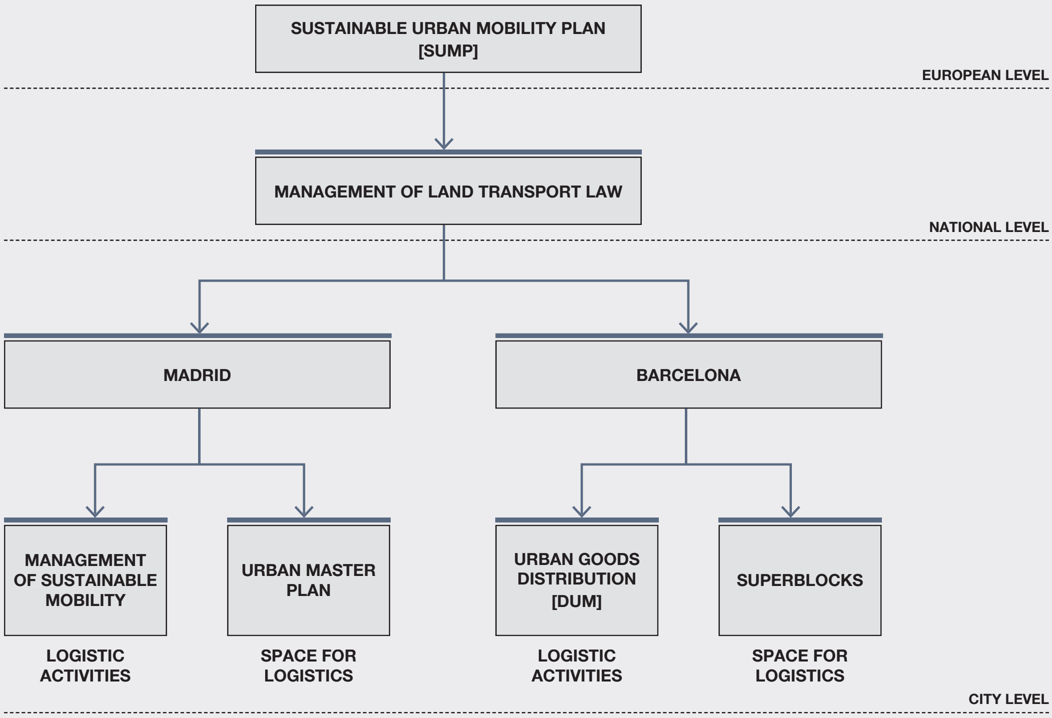
ICTs is playing an essential role in the development of city logistics. The use of ICTs is mainly focused on efficiency and optimization, along the whole logistics supply chain. The logistic facilities, the vehicles, the packages, the loading and unloading and the final client depends more and more on digital platforms. Warehouses are becoming machine landscapes, where humans are being displaced. Like a fiction movie, the future of logistics is formed by warehouses located in exclusion zones for humans. (LeCavalier, 2019), and autonomous delivery vehicles, that are just machines without humans.

In logistic facilities, the storage capacity is usually the biggest concern. The measurement unit is the volume rather than the surface area. One of the roles of technology in logistic facilities is to optimize the storage capacity and to provide the fastest pick-up. Amazon Robotics, formerly Kiva systems, has developed a technology where the shelving units (pods) are not fixed structures, while mobile ones, that are lifted by Robotic Drive Units (RDUs) and transport to the most convenient location for picking up or storing. (AWS, 2021) Rather than the employees moving to the shelves, the shelves come to the employees' workstation. The RDUs were guided by a Intend Detection System, based on machine-learning vision to move inside the warehouse and to identify where the inventory items are placed. Other systems for logistic facilities as Ocado Smart Platform (Ocadogroup, 2021), fill the warehouse with a grid of storage spaces, where RDUs collect and storage the goods, from the top, thanks to a system of orthogonal rails which allow the movement in all directions to perform the shortest and fastest circuit. Both, Amazon Robotics and Ocadogroup are two examples of how technology is optimizing the storage capacity of the logistic facilities, and how the inventory items move the fast and shortest way possible to specific locations. Compare to other technological systems for storing as conveyors belt, these two systems are fully integrated in the interior space of the warehouse.

Delivery vehicles can be guided by an algorithm that optimize the circuit in terms of distance and time. Although, this is a much simpler technology is not commonly used, since drivers trust themselves to build the most efficient circuit based on their experience. Chapter 7 gathers the modelling and simulation of different scenarios, in which the optimization of a circuit can represents more than 40% of saving time. In addition, the storage capacity of the vehicle is not neither optimize nor organize for an efficient delivery. The objective of new technologies in delivery vehicles is not to just optimize the circuit, but to implement autonomous vehicles, that can perform more efficiently in terms of distance, time, and cost.

The Pick-up and Drop-off points (PUDOs) are also logistic facilities run by a software for the storage of goods, that can later be picked-up or drop-off by the final client. In the same case, the loading and unloading areas are being regulated from the public administration by apps, that control the parking availability and time. Finally, the packages are being constantly tracked by geolocation systems. The picture above shows a fully automated logistic network, where humans are gradually being displaced. The warehouse is run by robots that collect the items to autonomous delivery vehicles, which are parked in loading and unloading areas according to a specific software run from the public administration. From there items are deliver to automatic PUDOs, that sent a message to the final client for picking-up. This automatic logistic supply chain can reduce the impact in the city but opens a new relationship between non-humans' logistics and the citizens.

As mentioned above, in chapter 3.2. Stakeholders, ICTs is promoting different ways of collaboration between stakeholders, in order to optimize the logistic network. The empty spaces of a warehouse or a delivery vehicle can be optimized by sharing logistics. Furthermore, the delivery can be performed by crowd-logistics or instant-deliveries, where ordinary people and the public transportation system can become part of the logistic flow. Thus, ICTs can help to transform the traditional direct delivery from the last warehouse to the final client, by a more flexible system with less impact in the urban environment.



Organisation of different levels of regulations of logistics and transportation of goods

Implementation and developing of SUMP objectives in present research.	
SUMP Objectives	***Research objectives.***
Plan for sustainable mobility in the entire "functional city".	The objective of the research is not just the study and analysis of city logistic, but the city itself. The research is approached holistically, understanding the city logistic as the flow of goods inside the global city ecosystem.
Cooperate across institutional boundaries.	The research proposes a collaboration through the different public administrations involve in city logistics.
Involve citizens and stakeholders.	All stakeholders, from public to private, are an integral part of present research.
Assess current and future performance.	The key findings of the research are flexible strategies that can be adapted to future requirements.
Define a long-term vision and a clear implementation plan.	The Logistic Intensity Areas propose some specific implementations, that can be gradually developed over time.
Develop all transport modes in an integrated manner.	The research leaves room for all transport modes and their multiple combinations, as part of the overall network of city logistics.
Arrange for monitoring and evaluation.	There is a specific tool for monitoring and evaluation, as the Last Mile Logistic Impact Index.
Assure equality.	The equality is assured as a balance between city logistics and its environmental impact.

Comparative chart between the SUMP objectives and the objectives of the present research

3.5. Regulations.

Surprisingly, there is little congruence or shared "best practices" found in examples of logistics and good transport policies that we reviewed. In Spain, there is not a uniform regulation about logistic and transportation of goods. There are different regulations in different cities and between cities and the territory. City councils, regional and central governments regulate the transport of goods, from different scales and territories. These measures are not usually synchronized. Moreover, an adding another layer of complexity, the European Union has set some recommendations to promote sustainable urban mobility.

In 2013, the reform of the Spanish Local Administration was carried out through the Rationalization and Sustainability Law of the Local Administration (Ley 27/2013 de Racionalización y Sostenibilidad de la Administración Local-LRSAL). Among the different objectives, there were two relevant concepts for present research:

- To clarify local competencies in order to avoid duplicities with other public administrations.
- To enhance private initiatives and to avoid disproportionate intervention from the public administration.

The first one promotes the idea of "one Public Administration, one policy", while the second supports the collaboration between the public administration and private companies or organizations. City logistics is part of the global logistics network that crosses through different countries, territories, and cities. It is desirable to find a common approach for global logistic, and specifically in the scale of the country, between the territory and the city. The global supply chain of logistics is a highly complex network.

At the upper-level regulations of city logistics is the Sustainable Urban Mobility Plan (SUMP) which started with the first Urban Mobility Package (European Commission, 2013). The SUMP is a strategic plan to make local transport more sustainable, safer and inclusive, which comprises the following objectives, to:

- Plan for sustainable mobility in the entire "functional city".
- Cooperate across institutional boundaries.
- Involve citizens and stakeholders.
- Assess current and future performance.
- Define a long-term vision and a clear implementation plan.
- Develop all transport modes in an integrated manner.
- Arrange for monitoring and evaluation.
- Assure equality.

The objectives of this Plan should be adopted by local authorities, using the guidelines for

developing and implementing the SUMP (Rupprecht Consult, 2019), which are based on a process of analysis, evaluation, implementation, and monitoring.
The chart shown in the previous pages outlines the SUMP objectives a related to the objectives of the present research.

At national level, the law for the Management of Land Transport (Ley 6/1987, de Ordenación de los Transportes Terrestres, LOTT is applicable. However, at the Madrid regional level, it is the Management of Road Transport and Accessibility. The latter puts within the local administration the responsibility to regulate urban transport and mobility.
In the case of Madrid, city logistics is partially regulated by the Management of Sustainable Mobility and the Urban Master Plan. Basically, the first regulates the logistic activities and the second the urban space for logistics.
The Management of Sustainable Mobility establishes one area of low-emissions and two areas of low-emission with special protection clauses, which seek to protect urban health and the urban environment, through the improvement of the air quality.

There is a specific regulation for the delivery of goods, which includes a digital platform for reserving loading and unloading areas. For urban logistics the law establishes (DUM- Distribución Urbana de Mercancías) two types of vehicles: less than 18 tons and more than 18 tons. The first one can deliver any time between 7:00 to 22:00 h, and the second only at night from 22:00 to 7:00, and only if they comply with noise regulations.
According to the Madrid Master Plan, the public street is divided in three areas: the street network (for the movement of people and vehicles, and for the parking), living areas (open spaces close to the street network to enhance the temporary stay of citizens) and reserved lanes (areas forming part of the public street to be used by specific modes of transport).

The Madrid Master Plan recognizes logistic facilities as a specific building typology, although a more detailed Special Plan is required before these facilities can be designed and built. The objective of the Special Plan is to analyze the impact in the traffic and in the environment. The Special plan needs to be approved by the local administration before any development can begin. To date, Urban Consolidation Centers cannot be considered a logistics typology because the buildability is low, just 1 m2/m2, and they cannot be hybridized with other activities.

In the case of Barcelona, urban logistics is regulated by the DUM (Urban Goods Distribution), which provides loading and unloading areas during weekdays from 8:00 to 20:00 h, with a time limit of 30 minutes. Telematic validation through an app is required to park in a DUM area. a. In terms of urban land-use planning, there are also regulations set by the superblocks policy, which limit the loading and unloading areas just to the exterior streets of the superblocks.

Upon review of the legal provisions, both regulations for Madrid and Barcelona, show that there is a lot of room for improvement. Basically, urban logistics regulations have a restrictive approach rather than enhancing any positive impact on the environment.

Usually, regulations are reactive and not proactive. Cooperation between the public administration and companies involved in city logistics to develop an efficient and sustainable legislation would be highly desirable and recommended. Public authorities are a key player to finding the balance between current inefficiencies of city logistics and their negative impacts on the city environment (Deloitte, 2020). In terms of urban logistics regulations, several authors have recommended some specific policy measures (Cardenas, et al.,2017). These can be classified in four areas: regulatory, market based, land use planning, and infrastructure:

Regulatory.
- Time windows and off-peak deliveries.
- Vehicle weight and size restrictions
- Low-emission zones
- Low-traffic zones
- Restrictions on vehicle type (cargo cycle, small urban freight vehicle, truck)

Market based
- Road charging
- Congestion charging
- Parking fees

Land use planning.
- Parking spaces
- Logistics zones
- Off-street loading/unloading facilities

Infrastructure.
- On-street designated loading and unloading bays
- Dedicated truck lanes
- Urban consolidation center and urban cross-docking

Most of these recommendations are not included in the current logistics regulations for Madrid and Barcelona., Current policies are not susceptible to develop them. Strategically, the rapid expansion and transformation of urban logistics requires open and flexible policies to adapt to future needs, situations, and changes.

3.6. The scales of the logistics ecosystem.

The logistics ecosystem is a complex network of flow (delivery) and nodes (logistic facilities) regulated by the stakeholders, and especially by the planning policies established by the public administration. The network has a high social and environmental impact. City logistics share the street network with citizens, where vibrant city life occurs. It is a potential place for the development of different activities, in which urban logistics is only one of them. The beauty of public space lays in its capacity to integrate citizens and activities. We have no doubt that city logistics can enhance, what Jan Gehl (1971) coined, the life between buildings.

From our research we have arrived at the need to holistically understand logistics. The fragmented concepts, laws and multiplicity of goals cannot be accommodated in a piecemeal fashion. Likewise, logistics impacts – positive and negative- do not respond to geographic limitations or other boundaries. Therefore, the only way to deal with the complexities, in our opinion, is through an ecosystem approach.

The undeniable growth of logistics is currently catching high density and complex urban areas off-guard. The first reaction to a disruptive element is usually negative, with citizens and administrations looking for culprits of said disruption. However, the cities cannot live without logistics operations. Perhaps they can “live”, but thrive, adapt, and grow would become more complicated. So rather than supporting the finger pointing and the negative perception over logistics, actions that in the end do not result in any positive change, maybe it is our responsibility now (and by our we include all layers of human activity, from private companies, public administrations, professionals, service providers and service beneficiaries) to think new strategies with what the built environment can include logistics operations in a manner that all stakeholders can thrive. If adaptability is a sign of intelligence, in a world that aims to move towards smart cities does it not make sense to design cities that can adapt to the dynamic, growing and impacting world of logistics?

Urban environments are complex metabolic systems that have intertwined layers keeping it alive, none being more important than other. It helps to understand the city in different scales, zooming in in order to get the full detailed picture, something that this paper has tried to do. We could break down a city in the following scales:

Scale 1:100.000
City level

Scale 1:10.000
Neighbourhood level

Scale 1: 1000
Street level

Scale 1:100
Building level

Scale 1:1
Human level

This break-down allows us to measure the impact of logistics on a city and also imagine strategies to manipulate what sort of impact will it be. We are recognizing here three impact categories of great importance: the environmental impact, the socio-economic impact and the functional impact. All three of them must be addressed in order to positively participate in the health of a city.

In Scale 1:100.000 - City level we understand that traditionally the logistics operations have been pushed to the outskirts, far from the eyes of residents, but also in areas that had large availability of physical space to store, sort and move packages. But with the growing demand of logistics operations from private citizens, this systems impact is sometimes failing to align with the necessities of a city. Integrating logistics facilities inside cities has obvious positive effects in all 3 categories. Less time traveled, less road presence, faster and more efficient deliveries, etc. But the idea of having logistic facilities shape the face of the city is relatively new. Bringing new services inside the city requires a certain sensibility, as it is no longer hidden from the eyes of the beneficiaries, but now part of the identity of a city. It can be designed to become a tool for placemaking and positive activation of an area. One cannot treat the design, systems, and strategies of a logistics facilities inside the city the same way one would in a space that is 20 kilometers away. But this is an opportunity more than anything else. One that can shape the future of logistics and citizens perception over these operations.

Scale 1:10.000 is the neighborhood scale, the unit to which the citizens identify most at a city scale. The quality of the neighborhood (which has many parameters that influence it, like services, infrastructure, diversity, etc) greatly impacts on the quality of life of its residents. Its residents in turn slowly build up the character and identity of a neighborhood. Seeing how the demand for packages has increased greatly in the realms of the private citizen, there are no more areas (say residential) that have a higher or lower amount of logistics operations, so all neighborhoods of all types and sizes are affected. While not so long ago only markets, commercial spaces and business saw daily logistic activity, now every single door, no matter who or what is behind it, is a potential receiver. Which means that neighborhoods themselves must adapt to this new flow and find a way to integrate logistics as a local service. As previously mentioned, a rich and diversified array of services increases the livability of an area, so it is time to understand and strategies for the insertion of logistics inside the community in a way that adds value to its surroundings. This paper explores some of the possibilities at a neighborhood scale, but more investigation can be done in order to understand the full potential of logistics operation can have at this scale.

The street level at scale 1:1000 is where urban life truly happens. There are meetings and important conversations over lunches, there's rushed passers by making their way swiftly through the static elements, doorways opening and closing allowing for all human activity to take place. For the developing of this paper, when the field study observing the behavior of the logistics operations at a street level was done, logistics came on the negative disruption end of the conclusions, with its loud, bulky and imposing presence blocking views and overpowering conversations. But on a second look, the same study opened doors for many opportunities. While the community was disgruntled by the disruption there was also a quiet acceptance of the process because it was necessary. The food shop needs to be supplied, the local business relies on daily delivery of products and every resident should be allowed to comfortably access all the wonders of e-commerce if they are so please. It was not a question of "why" all this disruption was happening, but of "how" this disruption was happening. This meant that there is an opportunity to design systems and strategies that can allow daily life to happen undisrupted but enriched by the steady flow of supplies. There are many ways to go about this and it of course depends on the context of each separate case. But the clear message is that logistics cannot be a passive actor in the evolution of a street and has the potential of becoming a positive element of change. This is also the level in which the logistics operators themselves are most exposed and where they have the potential of becoming part of the community they serve. So, while we can imagine green and beautiful loading and unloading zones that are a joy to watch in the whole picture of the street, we can also imagine the delivery person being a symbol of a good service, recognized by all the residents and whose presence is an anticipated delight.

If we bring up the freedom of access to logistics services, we must look at flexibility from both sides, the sender, and the receiver. Right now, there is a co-dependent relationship between the two while they balance timeframes in order to coincide. In some cases, they do not, and this means that the loop of that package starts again from scratch another day. Co-dependence is not always the most sustainable route. If we clearly see that there is an increase in demand for logistics services in all types of city dwellers, then it is time that the built environment be designed to support it. At a building level, the scale of which we could refer as 1:100, we see a series of micro-opportunities arise. In highly populated areas where it is customary to live in multi-story residential buildings, it sensible to think that a space of the common areas of buildings can and must be dedicated to logistics operation. As human life grows more complex and evolves it is only natural that building functions follow the trend. Designated spaces easily accessible by all parties involved in the process means that the tense moment of timelines coinciding can be completely removed from the equation. There are many ways in which one could imagine such spaces and it all of course depends on the context. They can be more or less digitalized, occupy greater or lesser space, be accessible from the street or only the inside of buildings, etc. All of this is subject to investigation in order to make the right decision, but the main take away is the larger impact a small gesture can have on the three factors we were mentioning previously. This flexibility allows for freedom or organization that in the end, has a positive impact on the quality of life of the residents, the time and efficiency of the drivers and ultimately on the environment.

At the final zoomed in map of the city we see the citizen, scale 1:1, who is one of the motors and main stakeholders in the logistics operations. Human behavior when given comfort and affordable choices with no visible consequence is easy to predict. But the currently opaque process of logistics keeps this final stakeholder in the dark about the realistic impact of their choices. There is an opportunity there to involve, inform and offer transparency and an array of better and more involved choices regarding the processes of ordering, packaging, and delivery in order to minimize the impact on the environment and even empower other aspects.

Logistics affects the city in all scales, and in this paper, we have subjected the flows to various simulations looking for opportunity to better the impact. Out of all, perhaps the most ambitious and sensible plan was the attempt to measure impact in a universally applicable and objective way through the LII. As cities grow, and with them the demand for supplies and matter, the impact of that growth is noticeable in all the layers that make up a city. A complex system that holds the processes accountable, sustainable, and adaptable is a mandatory step in the future of healthy cities. There are many such measuring systems already in place for other activities and services and some attempts to recreate those ideas in the logistics universe. However, few of them consider the soft levels of human interaction or the complex subtleties of urban typologies.

04: The stud
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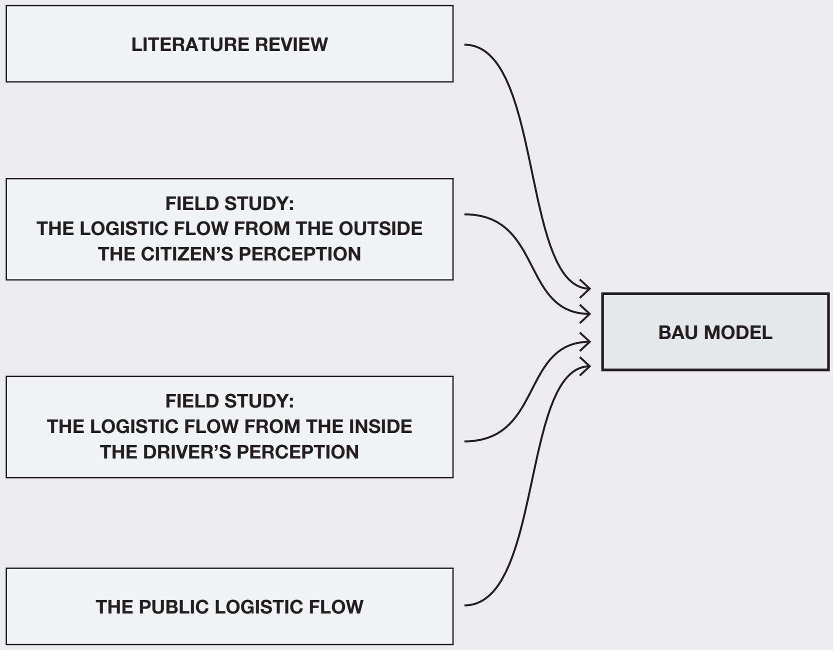
4. The study of Logistics Flow

The logistics flow, or all the movements of goods along the supply chain, is part of our daily life. Although, it has been always there, in recent years its presence has increased exponentially, especially within our cities. The flow of logistics vehicles entering the city has a clear objective. The driver, the delivery company, and the final client aim to have the delivery accomplished in the shortest time. This may sound easy to accomplish, but this model has an important impact on many aspects of the urban environment.

Most of the dynamics of BAU (Business as Usual) models are based on a direct delivery from the last warehouse to the final client. Therefore, the issue that this chapter addresses is the performance of current BAU models and their impact on the environment. Recognizing that clear and measurable information on the current city logistics network was not available, we have undertaken several field studies to support our research and conclusions. As mentioned in the methodology chapter, few research reports work with real and empirical data (CITYLAB, 2017; Perboli, et al., 2018). Our objective is not only to analyze BAU models but also to study the impact on the urban environment. BAU scenarios are considered the benchmark for future comparisons with other possible scenarios. This is the main reason why we believe that it is so important to work with real and empirical data.

Data gathering was addressed from different points of view. The objective was to include an understanding of the logistic flow from the inside and outside. In other words, both from the citizen and from the driver's point of view. These two approaches have different and sometimes opposite perspectives but are necessary to include to model current BAU scenarios.

The flow of logistics from the citizen's perspective was carried out during two full days in a specific area of the city of Madrid. Two members of the team gathered data from the logistic flow entering the neighborhood, including observing and recording such things as; parking location vs delivery point, illegal parking, loading, and unloading areas, delivery time, congestion, noise, street presence, type of vehicle, parcels to deliver, transportation system from the parking to the delivery point, among others (see Annex II). Qualitative data, as the citizen's perception, was also gathered and included. During peak hours, a complete picture of the street full of double-parked vans, unloading parcels, crossing from one side to the other was observed, and even from a cursory analysis, this situation is clearly not the nicest one. On the other hand, the flow of logistics from the driver's perception is about the impedance of the street network and all the difficulties that the driver encounters. During two different days, a member of the team joined a driver in the van, in the front passenger's seat. Two different delivery routes on



Methodology of construction of the Business As Usual (BAU) Model

the two days were carefully selected, one in the outskirts and the other in the center of Madrid, to compare how the urban fabric affects the logistics flow.
Both points of view, the citizen, and the driver must be considered when building the BAU model. The key findings of the field studies are gathered in the conclusions of the present chapter and Annex I.

Additionally, we analyzed the public logistics flow as undertaken by Correos, the Spanish National Post Office. It is an interesting model to study and compare since it has been running urban logistics for a long time. , It is currently undergoing a substantial process of transformation due to the increasing flow of logistics and the rise of many competitors.

The Post Office model has been part of the urban environment for many years. In fact, the post office courier is somebody well-known in the neighborhood, just as the baker or the doorman is. This is not a minor issue; it helps to support the identity of a neighborhood and the life between buildings. Finally, the Correos model is compared with the delivery company identified during both field studies, in terms of socioeconomics, functional, and environmental factors.

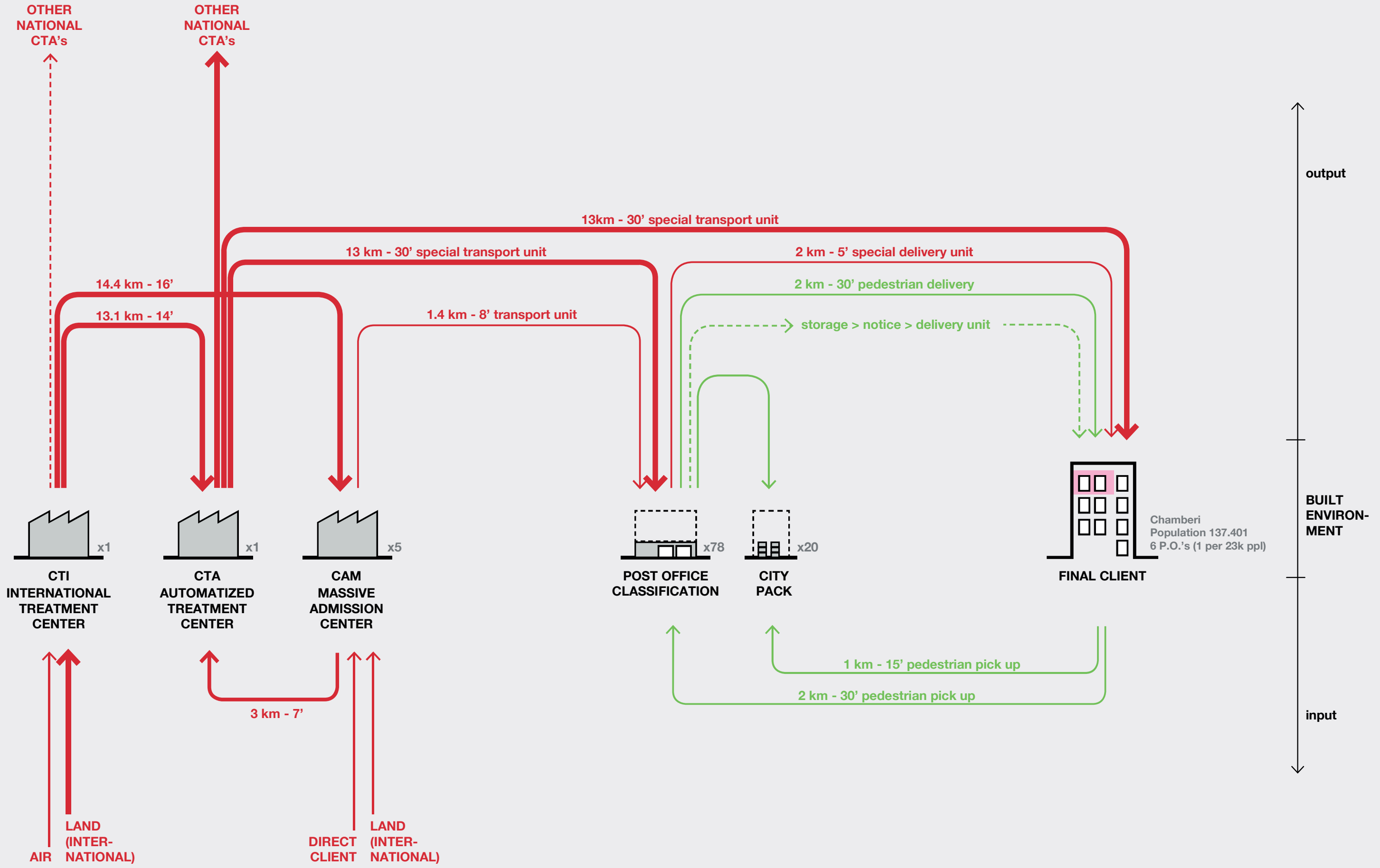
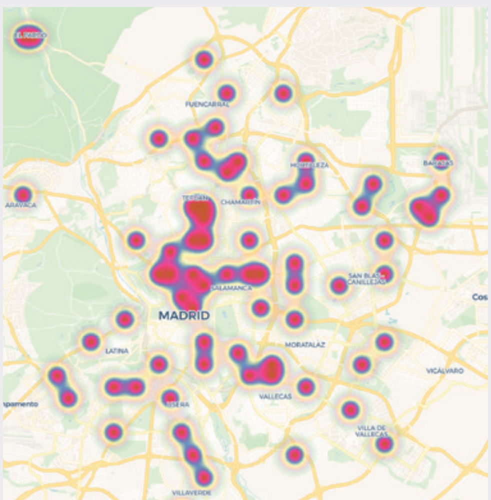
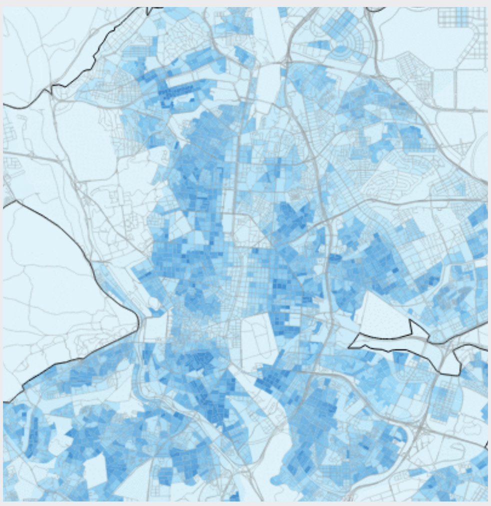
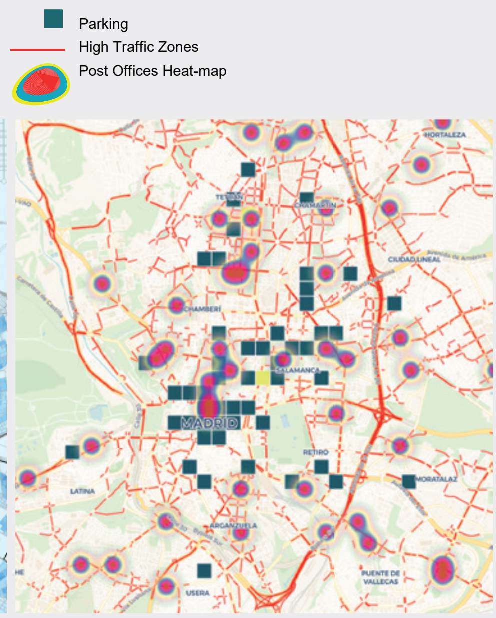


Diagram of Logistics Flow in the Correos Model



Density of Correos Hubs in Madrid


Population density in Madrid



Correos Hubs, Public parking and High Traffic roads

4.1. The logistic public flow. Analysis of the Spanish Post Office Model

An analysis of the Spanish National Post Office service, or Correos, was one of the first steps taken to jumpstart this white paper. The decision to deconstruct and analyze Correos was made based on their long-term success (founded in 1716), expansion, and integration into the urban structure. Correos is part of the everyday life of most Spanish cities. In its 306 years of activity, the 100% state-owned company has had an ongoing process of modernization, adding services to its portfolio (Express Mail in 1905, Parcel Post in 1916, Postal Express in 1981). Recently, in 2021, it has renewed its brand image (a project that started in 2016) in a successful campaign to show the world its adaptation to the digitalized world and the increasing flow of package delivery and e-commerce.

Correos is the number one company in Spain for its reach throughout all corners of Spain and land coverage. It counts with around 8.700 access points to services and more than 1.700 units of delivery. Annually, it distributes around 5.4 billion packages and letters to private homes, companies, and institutions. Correos employs about 51.000 people nationally and is a benchmark in the national postal services markets and regarded as one of the most important package delivery companies, more so in the e-commerce sector. (Sepi, 2019)
To understand the Correos model, we looked at data available within the city of Madrid in terms of the location of Correos' logistic facilities inside the capital and the relationship with the population of the area. We overlayed other available data, such as public parking areas and high traffic zones, to suggest the necessity of extra service points where high density and high traffic are present. (Ayuntamiento de Madrid, 2014)
The delivery fleet of Correos has also been analyzed from vehicle options to pedestrian delivery. Correos counts with 3.500 vans, 8.500 motorbikes (out of which 350 are electric), 41 electric vehicles, and 85 bikes. (Cuesta Nuin, 2017)
A case study of one package delivery to the center of Madrid provides a better understanding of how Correos facilities are integrated into the urban fabric, as well as the array of options for the client to choose from. As seen in the diagram below, a package delivered with Correos can change pass through five different points from the moment it enters the city borders until it reaches the final client.

In Madrid, incoming packages pass through several clarification centers that decrease in physical size as they get closer to the city center. The smallest manned centers are the post office branches themselves, of which there are 78 in Madrid. Additionally, the smallest pick-up unit is the City Pack option, of which there are 20 distributed through the city of Madrid. This expansive real estate network that Correos has built-in their years active allows them to penetrate efficiently at all scales of the cities they serve with flexibility and efficiency. It also means that they have built a trustworthy presence at a community level and strengthened a positive perception from a citizen perspective.
In this case study time and distances were calculated between all of these points to understand the scale of decentralization that Correos has achieved in the city. The case study has opened the following lines of research that helped build the scenarios for this report:

- diversification of fleet

- delivery and pick up options for packages

- capillarity of real estate, from large warehouses to consolidation centres and micro-hubs

Photographic material from the Field Study: The logistics flow from the outside, the citizens perception.

4.2. The logistic flow from outside. The citizen's perception

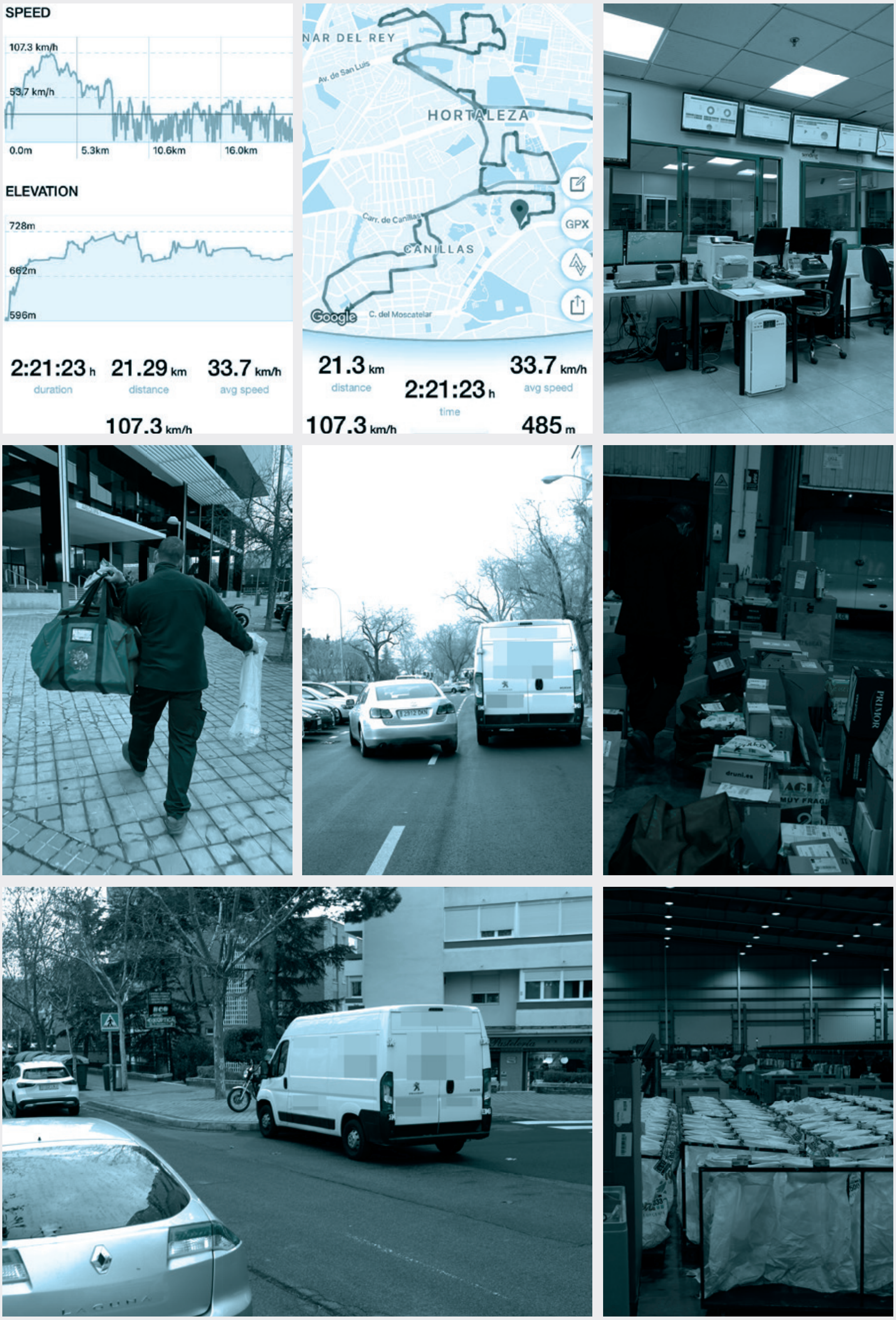
The first field study centered on a typical Madrid Street and its analysis with the goals of understanding the impact of logistics from the citizens' point of view. The data collected over two days included the number of logistics vehicles present, at what time, vehicle type, how and for how long it was parked. This information gave us insights into the logistical life of a small area on any given day. Other valuable data gathered were the photographic materials that speak about the degree that logistics occupy in a regular street and the scale it has versus pedestrians, services, and other activities. This adds to a comprehensive image of the perception that local pedestrians experience in the logistics process, which results in a noisy, disruptive, large, and pollutant vital process in the modern city.

Methodology

The streets of Espronceda and Ponzano in Madrid were documented for two days from 7 am to 8 pm. We observed that the majority of vehicles park illegally to complete their deliveries during the peak between 9 am and 11 am when the logistics intensity heightens and all loading and unloading zones are occupied. A high number of vans that parked legally in loading and unloading zones, do so for much longer than permitted, some even recorded occupying the space for longer than an hour.
The lack of available parking space forces drivers to circle up to three times in the same delivery area until giving up and parking illegally. This circling adds mileage to the trip and with that an increased ecological footprint, longer delivery times, and overall, more costly deliveries for the delivery company. Smaller vans take advantage of their size and park in pedestrian areas. We recognize a behavioral domino effect: once the first van is double-parked, all drivers queue up behind it creating a long line of double-parked vans that block the car lane.

The contrast of scales between the large delivery trucks versus the city fabric is significant, especially on narrow streets where large trucks or vans completely block the view of the pedestrians, and therefore their spatial quality is lost, and the risk of accidents is increased.

The loading and unloading zones are designed strictly for the parking of vehicles and have no provision for the loading and unloading of cargo. There is no barrier between the cargo manipulation activity and the street and sidewalk activities, which mainly consists of terraces and rest areas for locals that are living with the constant visual and audio disruptions due to logistics operations.

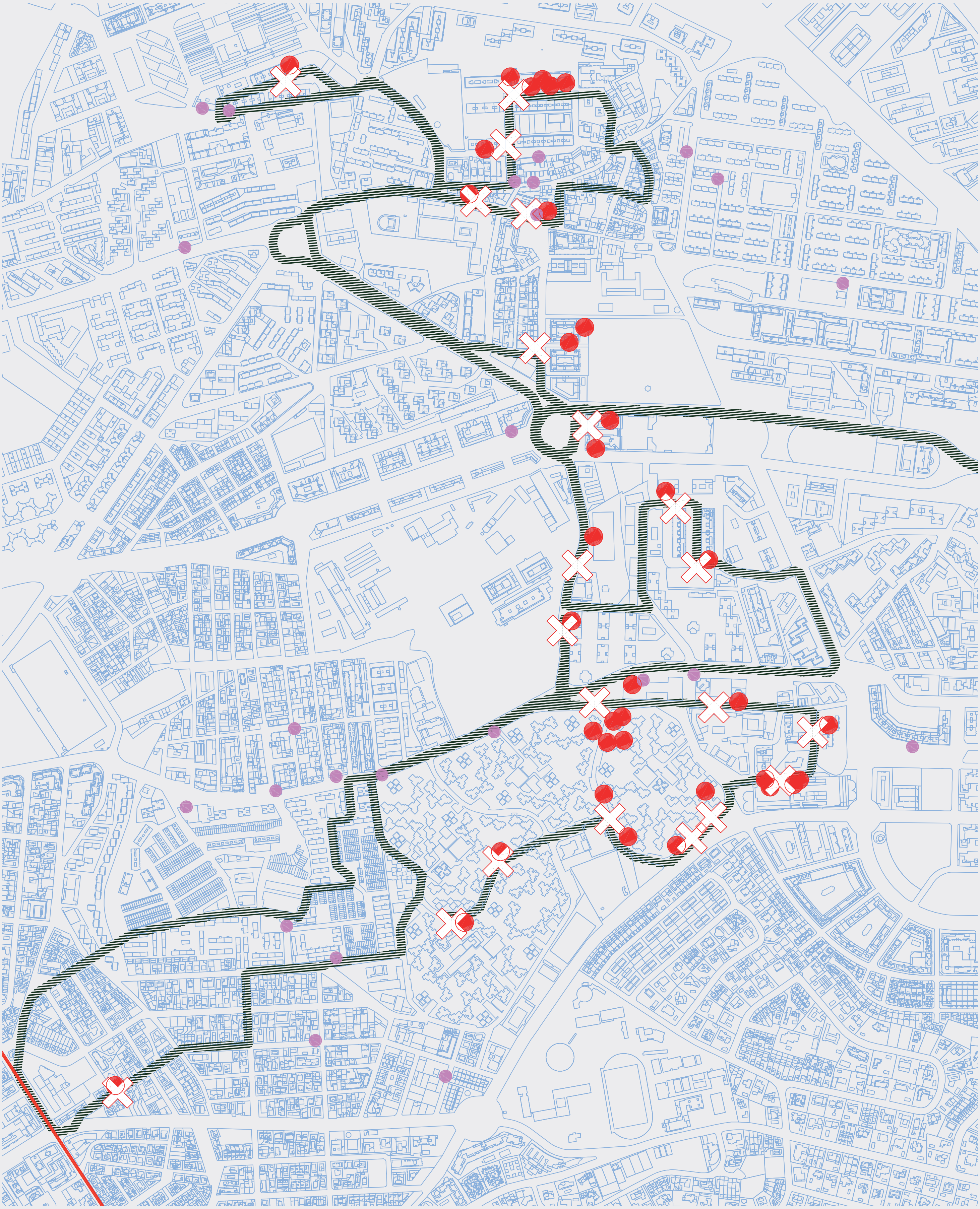


Photographic material from the Field Study: The logistic flow from inside. The driver’s perception.

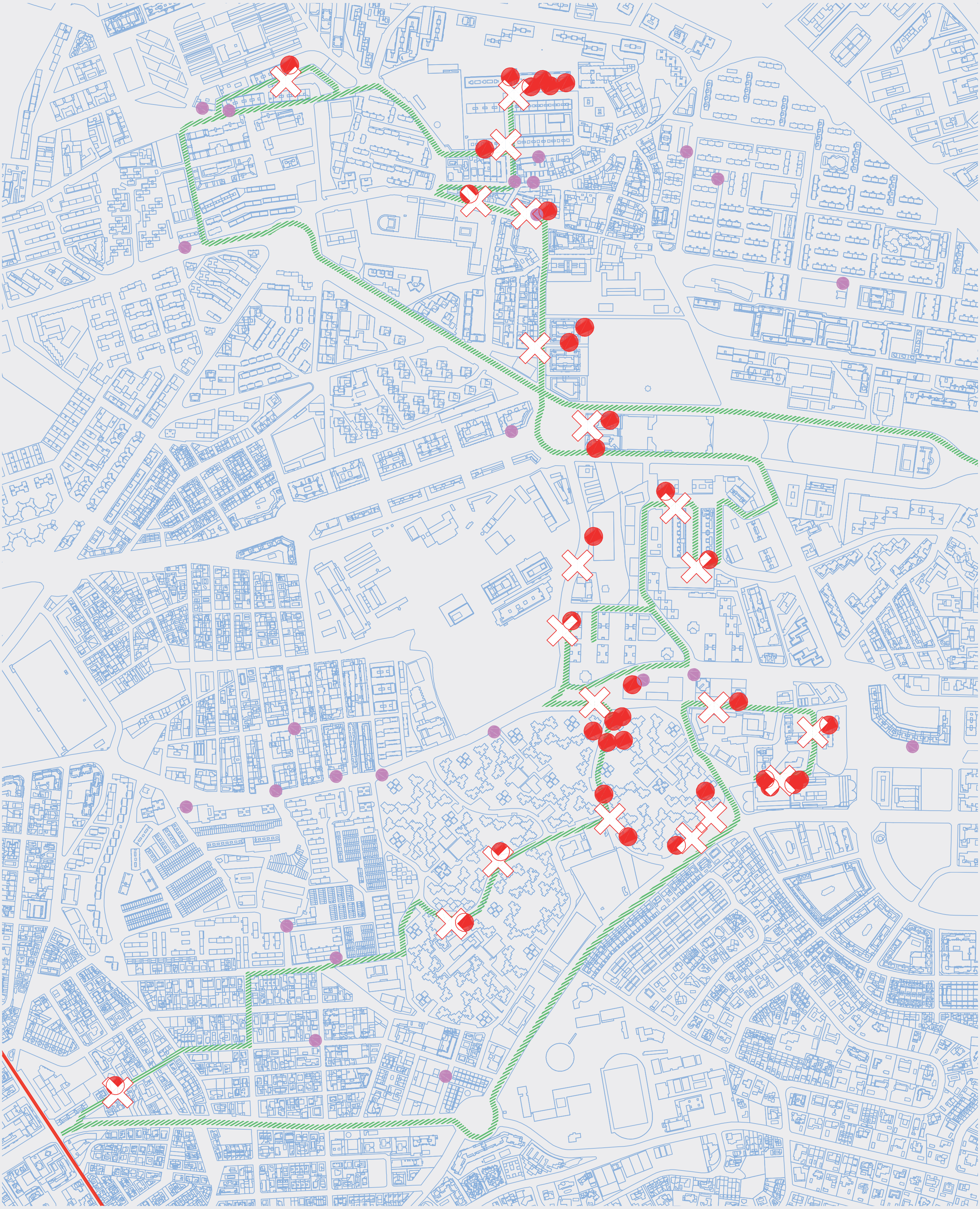
4.3. The logistic flow from inside. The driver's perception.

The case study focused on a company that is currently a tenant of logistics facilities with no vehicle fleet of their own and relies on freelance drivers to provide the vehicles they will use for the deliveries.
Typically, these drivers deal with two incoming shipments per day; one in the early morning and one at noon., This means that during the day the drivers return to the warehouse to pick up the recently arrived batch of packages. These shipments of packages arriving at the warehouse use many types of vehicles, from trucks to vans. The company in question counts with 164 ICE vans (owned by self-employed drivers), each delivering an average of 70 packages per day and having peaks of 120 packages per day in peak seasons. The facility space is prepared for 11,000 packages per day. However, with the growth of logistics, this figure has increased to an average of 15.000 packages per day and 20.000 packages in peak seasons (i.e., winter holidays). Around 70% to 80% of packages are in response to e-commerce. A significant increase in deliveries has been noted in villages that do not have access to the same commercial offerings as the cities while having access to online ordering platforms.
Most delivery companies use external software providers in order to keep track of the progress of deliveries (Malomo, 2021). The company analyzed in this field study chose Navodom for tracking the drivers and their packages in the delivery process. Navdom provides real-time data visualization about the number of packages delivered vs remaining ones, traffic information, and driver location, as well as end-of-day route data that gives the floor manager an overview of what routes need additional drivers for the next day.
All this data is gathered through a handheld device (commonly known as ´proof of delivery device´) provided to each driver and used for scanning the codes of each package to confirm delivery or failure to deliver.
The delivery company in question needs to expand the dynamic zone of incoming and outgoing packages, which results in reducing the space dedicated to long-time storage. An automated package classification belt facilitates the distribution of packages to each driver. However, this system is always in need of human supervision as it is prone to errors. The packages are classified by zones of delivery and are then handed off to the drivers who organize them in the van space according to the proposed delivery circuit. It is important to note is that most of the drivers have been delivering in the same zone for longer than a year, which gives them insights into how the urban environment will behave on any given day. The routes are decided based on experience. This method could be improved because when these routes are modeled vs optimized ones (with the help of technology) they perform poorly in terms of both time and distance.

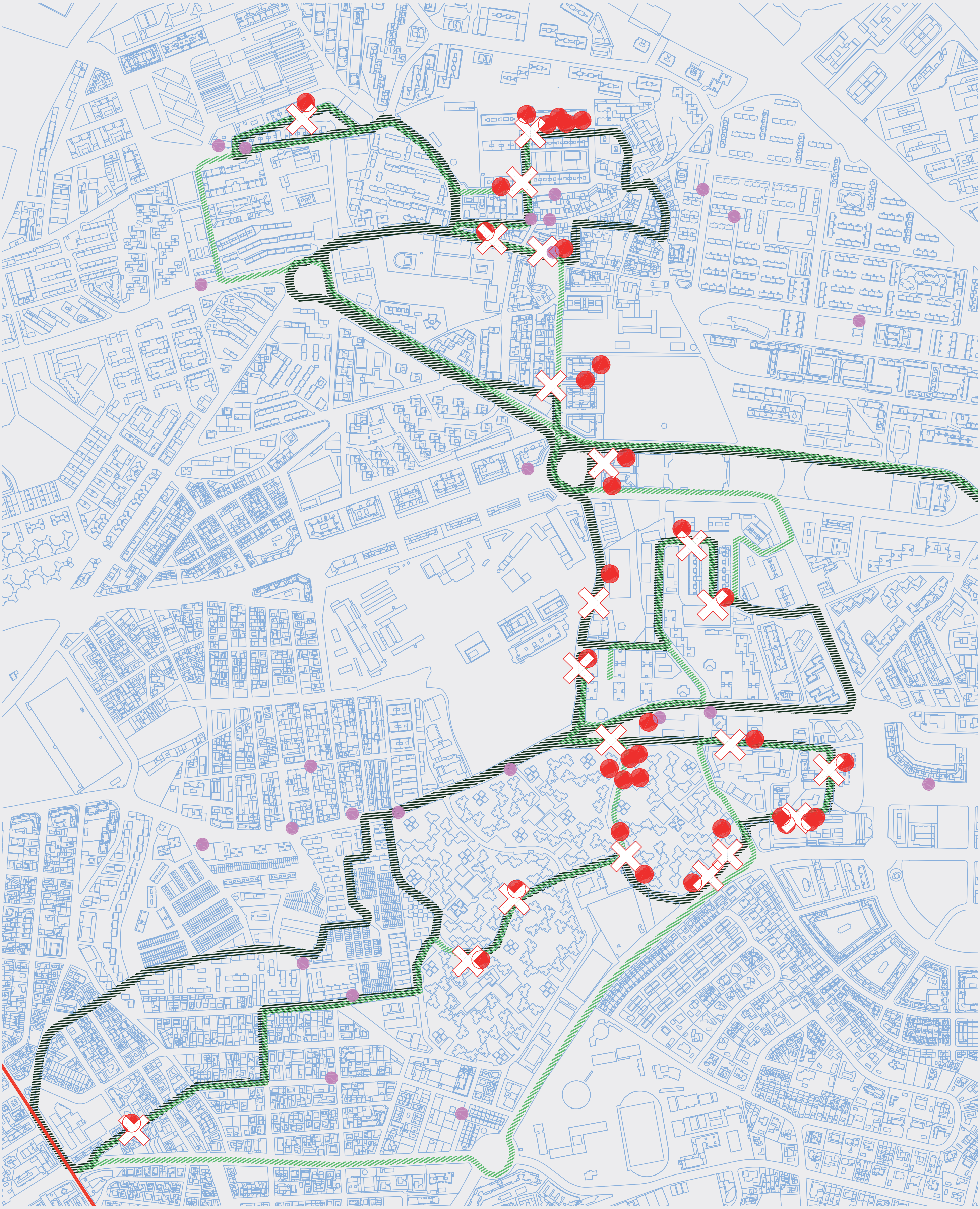
Hortaleza Madrid Field Study
scale 1:10.000

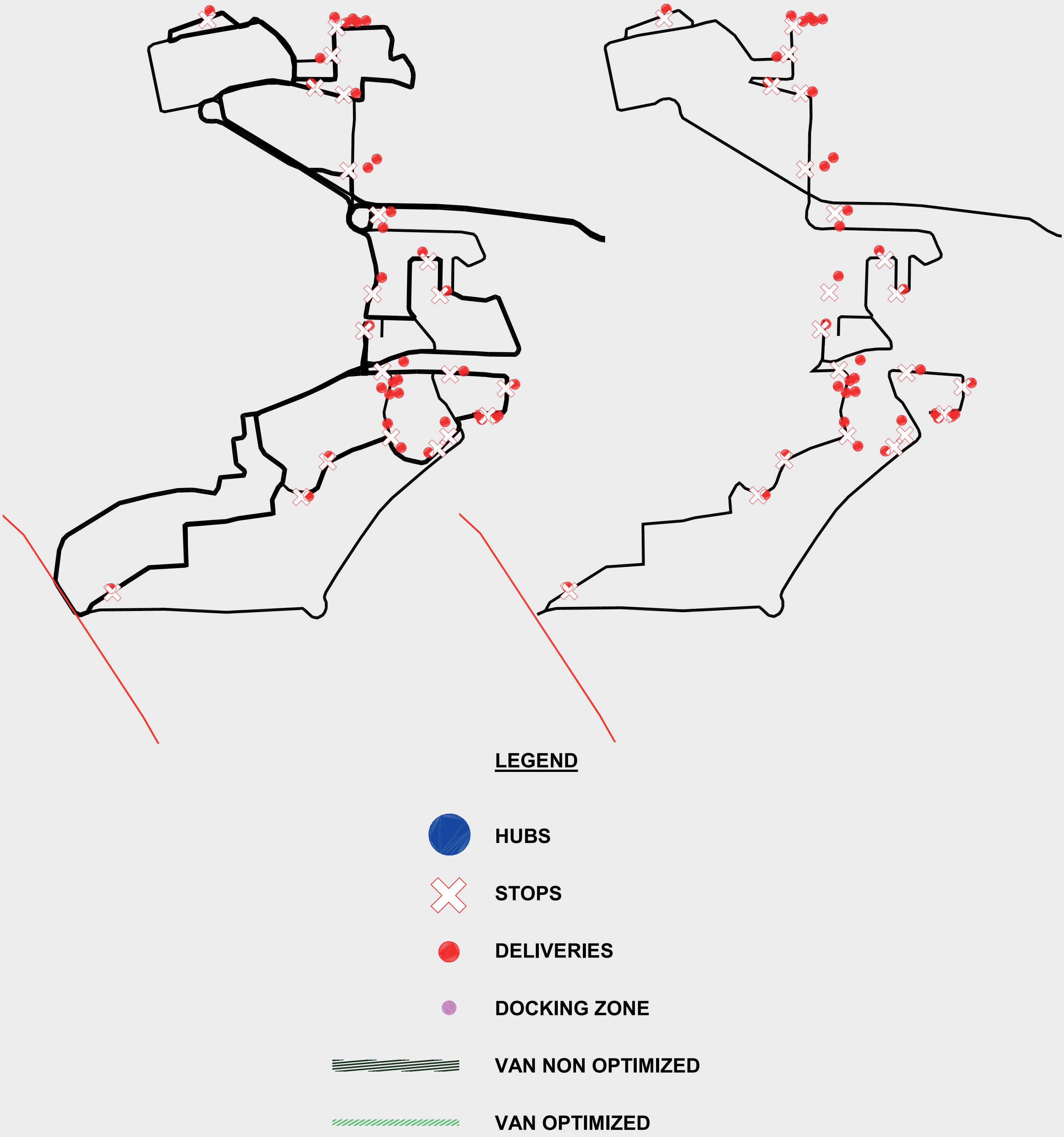


Hortaleza Madrid Field Study Optimized
scale 1:10.000

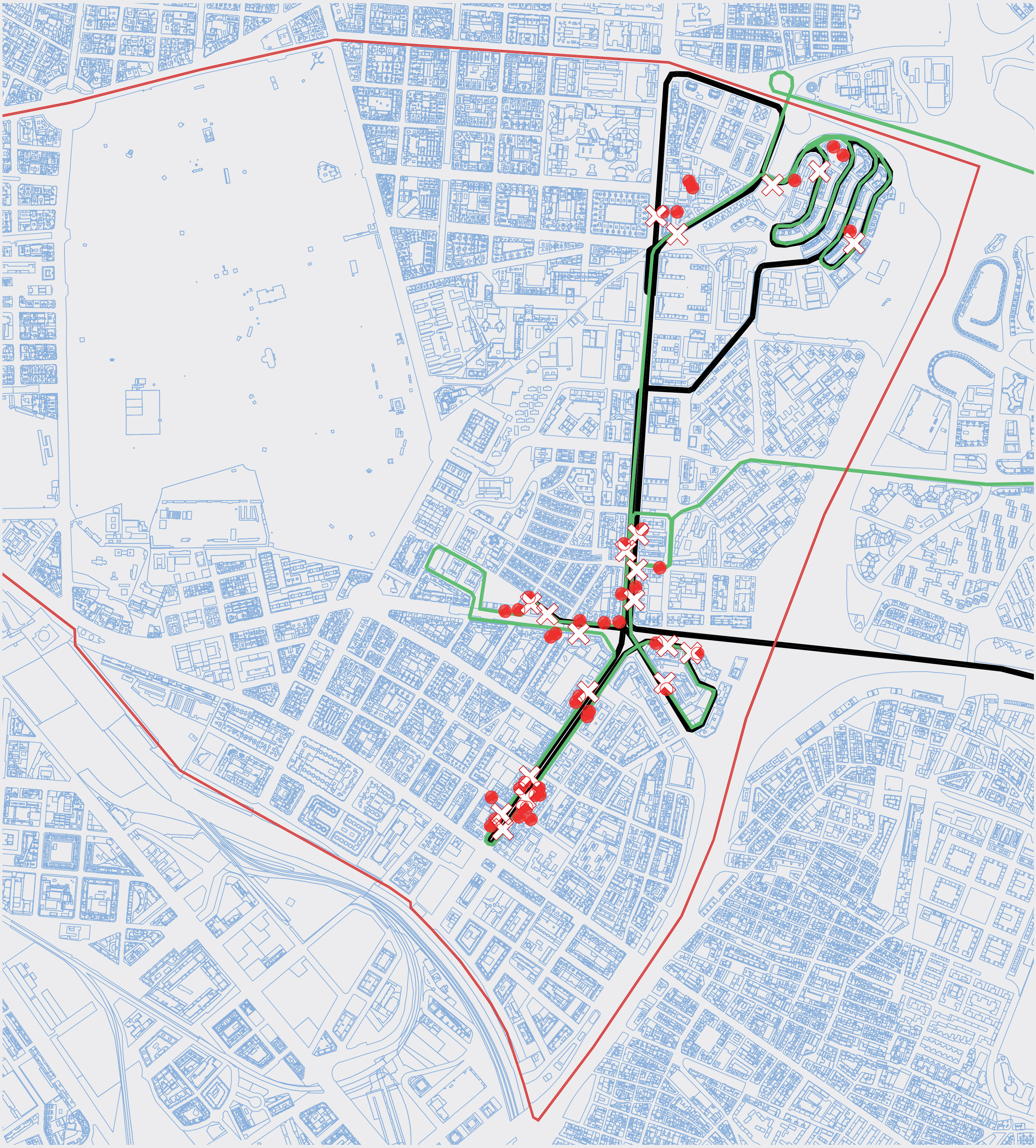


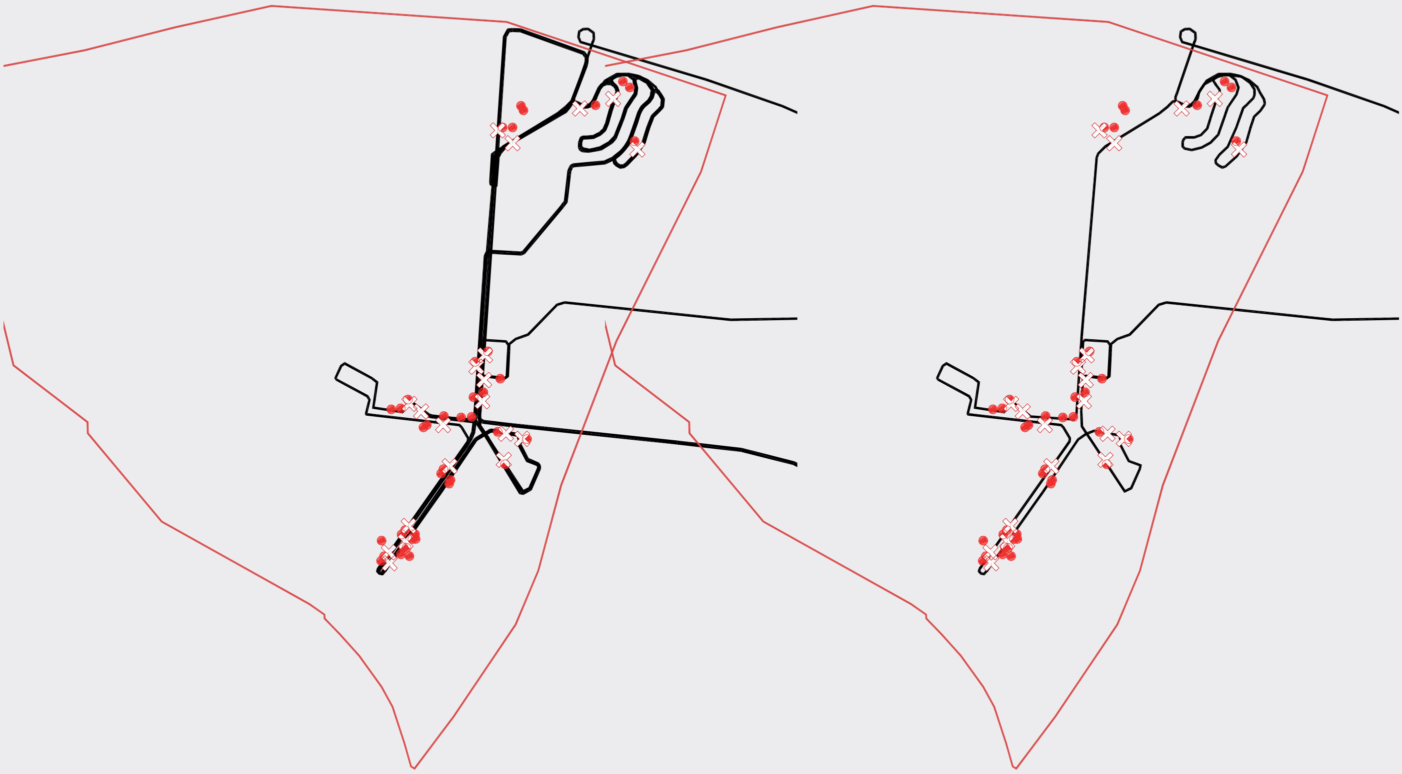
Hortaleza Madrid Field Study BAU + Optimized
scale 1:10.000



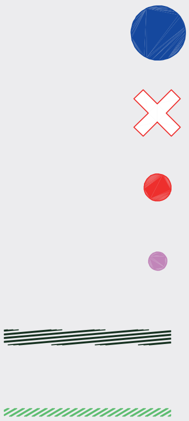

LEGEND
HUBS
STOPS
DELIVERIES
DOCKING ZONE
VAN NON OPTIMIZED
VAN OPTIMIZED

Retiro Madrid Field Study
scale 1:10.000





LEGEND



HUBS

STOPS

DELIVERIES

DOCKING ZONE

VAN NON OPTIMIZED

VAN OPTIMIZED

Comparison of data gathered from literature review and the field studies		
	Literature review	**Field Study**
Number of trips per day	150 trips / 3.500	328 trips from the warehouse to the city
Parcels per trip	23 parcels per day	70 parcels per day per vehicle
Package express delivery (% of total urban freight)	33%	unknown
Employees relationship	Temporary	Temporary
Loading and unloading zones	Lack of loading and unloading zones	Lack of loading and unloading zones
Illegal Parking	90% of stops	90% of stops
Digitalization	Lack of digitalization	Lack of optimization

4.4. Data gathered from other sources

In addition, some data has been obtained from the literature review and from other reliable sources. The quantitative data gathered from the literature review was compared with the data obtained from the field studies, in order to set a reference data for modelling the scenarios.
Following is a summary of the main data obtained from the literature review:

Number of trips per day / per trip.
About 150 trips per day were required to handle the 3500 orders. The drivers experienced a lot of stress from congestion and parking issues combined with meeting the client's specific time window. (23 parcels per trip) (CITYLAB, 2017)- Amsterdam implementation Living Laboratory.

Urban freight distribution and emissions
Package and express delivery carriage covers about one third of the urban freight transport (regarding deliveries with commercial vehicles) The average distance from the town center to the terminal ranged from 6.3 km. in 1974 to 18.1 km. in 2010. (Lukic, 2017)

On average, urban freight distribution generates one delivery (or pick-up) per week for every job. About 300 to 400 truck trips per 1000 urban residents can be counted per day. (Dablanc and Rodrigue, 2014)
In London, freight represents 15 per cent of total vehicle miles travelled in London, but 34 per cent of nitrogen oxide (NOX) and 27 per cent of fine particulate matter (PM2.5) emissions from road transport come from freight vehicles. Freight and deliveries also account for a quarter of London's total carbon emissions from transport. (Quarshie, et al., 2021)

It is estimated a stopping time of 12 minutes per delivery on average. This is high, making it even more difficult to make optimal use of the vehicle's capacity. (Quak, Kin, 2020)

Public authorities are aware that approximately 25% of the pollutant gas emissions in cities are produced by freight transport, and that this figure may be higher in cities such as Barcelona and Madrid, and as a result they have already adopted measures in relation to Last Mile logistics in an attempt to minimize the environmental risks. (Deloitte, 2020)

Loading and unloading zones.
High density areas have limited parking capacity (both on-street and off-street) to accommodate deliveries.

Delivery vehicles cope with this challenge by illegally parking in passenger car spots or double parking. Illegal parking reduces the supply of parking for cars, causing more cars to "cruise" in search of a space.
Double parking takes away traffic lanes and greatly increases local congestion. (Dablanc and Rodrigue, 2014).

There are indications that as much as 28% of transport costs can be related to the last mile delivery or first mile pickup (Goodman, 2005).

98% of stops occur in the same time slot and 40% double park. (Deloitte, 2020)

Digitalization.
9 out of every 10 distributors have not substantially digitalised their operations and 45% of the fleet of delivery trucks are more than ten years old4. As a result, Spanish benchmark distributors are 2 to 3 times less efficient than the main European and global distributors. (Deloitte, 2020)

4.5. Conclusions

Case studies and hands on Field Studies helped build the proposal for new scenarios regarding logistics in the city. Out of them important guide lines were extracted regarding what to tackle in further steps of the investigation. The guidelines can be divided into categories as follows:
Real estate, Socio-economic and Transport/ Environmental.

The Real Estate category has been informed by studying the Correos Model and the Shipping Company. The first gave an understanding about the capillarity distribution system which efficiently penetrates all levels of the city. The second provided insights with the physical necessities for storage, cross docking and handling, highlighting the need for adaptable systems on all levels.

On a Socio-Economic level, we looked at two opposing models. The Correos Model is built on stability of the workers, employing more than 50 thousand people with a rigorous training and thorough admission exams, while the analysed shipping company had very few employees and fully relied on freelancing drivers in order to complete their deliveries. This lack of stability for the drivers can have a negative impact for both the driver and the company that is collaborating with them. Drivers are paid by number of packages delivered, which puts them under high stress and in that state they are more prone to ignore regulations and their behaviour inside a community in order to reach a certain package goal for the day. Not only that, but the lack of responsibility the company has for their safety or the safety of others in relationship to the drivers behaviour on the street, leave the freelancers facing fines and repairs on their own. For the company, the freedom the driver reserves to either show up or not in the next day means that they are facing constant collaborative personnel change and leaves them vulnerable to not being able to comply with the agreements they have with their clients.

The Transport/Environmental category in these case studies mainly looks at vehicles types and diversification and one again we can see two contrasting models. The Correos model owns 100% of their fleet while the Shipping Company relies completely on the freelancers private vehicle. The diversification of the Correos fleet included electric vehicles, electric motorbikes, cargo-bicycles and parcel-carts that allowed them to adapt and enter any kind of city fabric. In contrast, the shipping company had no electric vehicles and relied solely on the driver owned ICE Vans, which are usually only loaded at 30% capacity and face mobility restrictions in more central areas of the city, and have a high environmental impact.

The Scenarios and analysis from here on were based on the findings learned from the Case studies and were developed looking to improve and positively expand the impact of these categories, exploring possibilities for change and adaptation.

05: Urban A

Areas

Urban Areas. Madrid. Barcelona

The impact of logistics in the last mile was analyzed for the cities of Madrid and Barcelona. The comparison between both, based on multiple combinations of scenarios of the last-mile delivery, helped to generate universally applicable findings and proposals.

The studies of the urban structure were undertaken in parallel, over different scales. As discussed in the first chapter, city logistics must include all points of view, from the small scale of the access to a residential building to the large scale of the metropolitan area. Thus, the analysis of the urban structure was done at different levels, which include the full scale of the city, the medium scale of a neighborhood, and the small scale of the street. A first analysis of the full structure of the city was made to visualize the scale of the last mile (1,6 km) in the city of Madrid and Barcelona, versus a comfortable 10´ walk (0.5km), and an hour delivery time by bicycle or and EV (5km). These visualization maps helped to relate different scales within the city structure. Although the concept of the last mile in logistics is commonly used, it does not refer to a precise distance, but the last leg of the supply chain from the last warehouse to the final delivery. The objective of this study was to overlap a relationship factor between distance and mobility systems to the urban structure. In fact, this approach is congruent with other models based on walking and cycling cities as the 15-minute city or “superblocks”.

Visualization maps helped to understand how the city can be structured as a sum of accessible clusters. Accessibility is a broader concept than mobility since it is not just movement from one place to another, but the quality, ease, and experience of urban spaces during commuting. This first step of visualization mapping helped to build the scenarios that will be discussed later in this document.

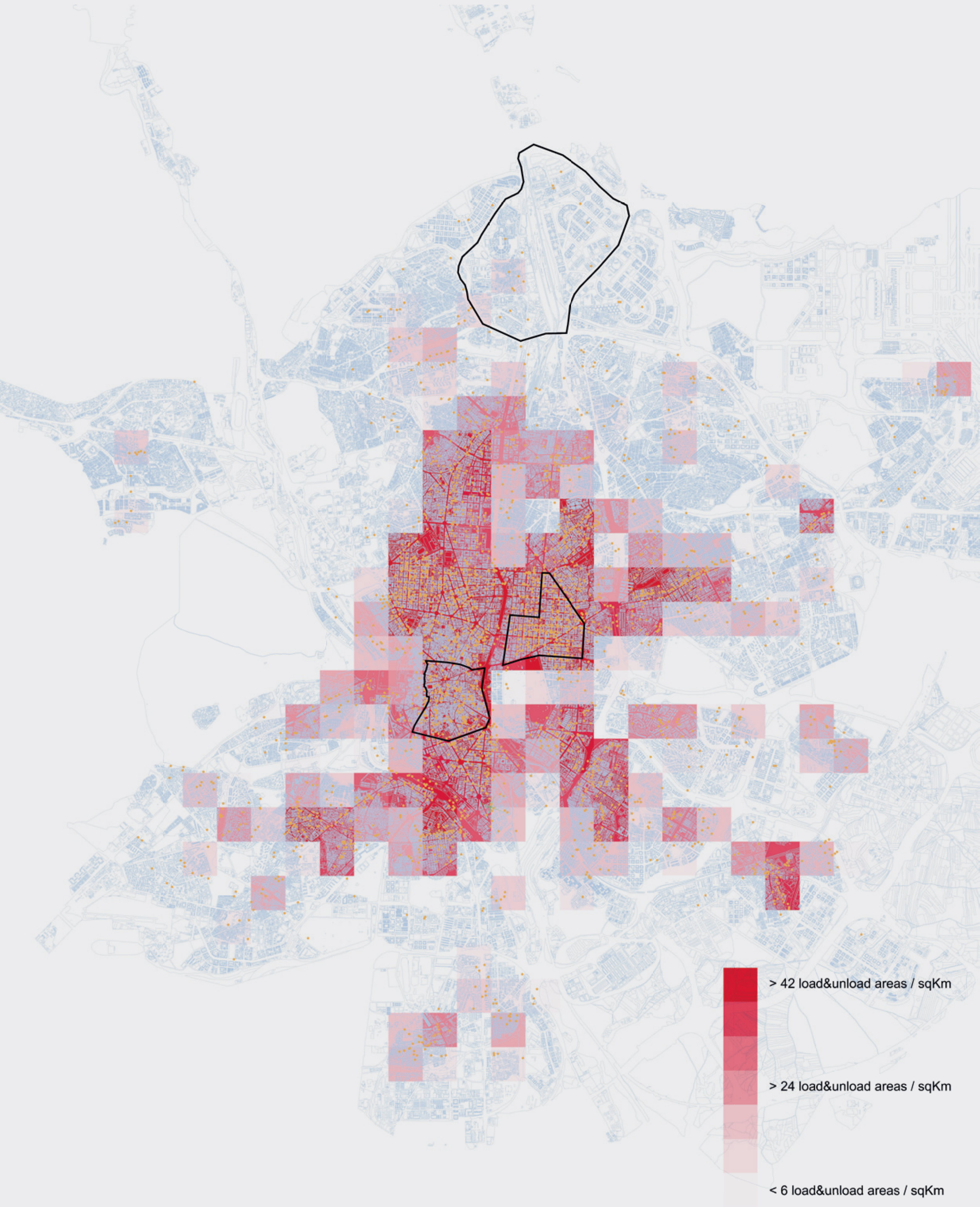
In addition, we carried out an analysis of the density and location of loading and unloading zones within the cities in question. The objective here was to identify the pattern or structure that is behind the current distribution system and its relationship with the urban structure.
Finally, the following data and relationships were analyzed at the scale of the neighborhood to provide the basis for modeling the scenarios:

- Total Area (km2)
- Total number of loading and unloading areas.
- Loading and Unloading Average Distance (m).
- Loading and Unloading Density (amount / km2)
- Total number of residential buildings
- Total number of historic buildings
- Total number of leisure and amenities.

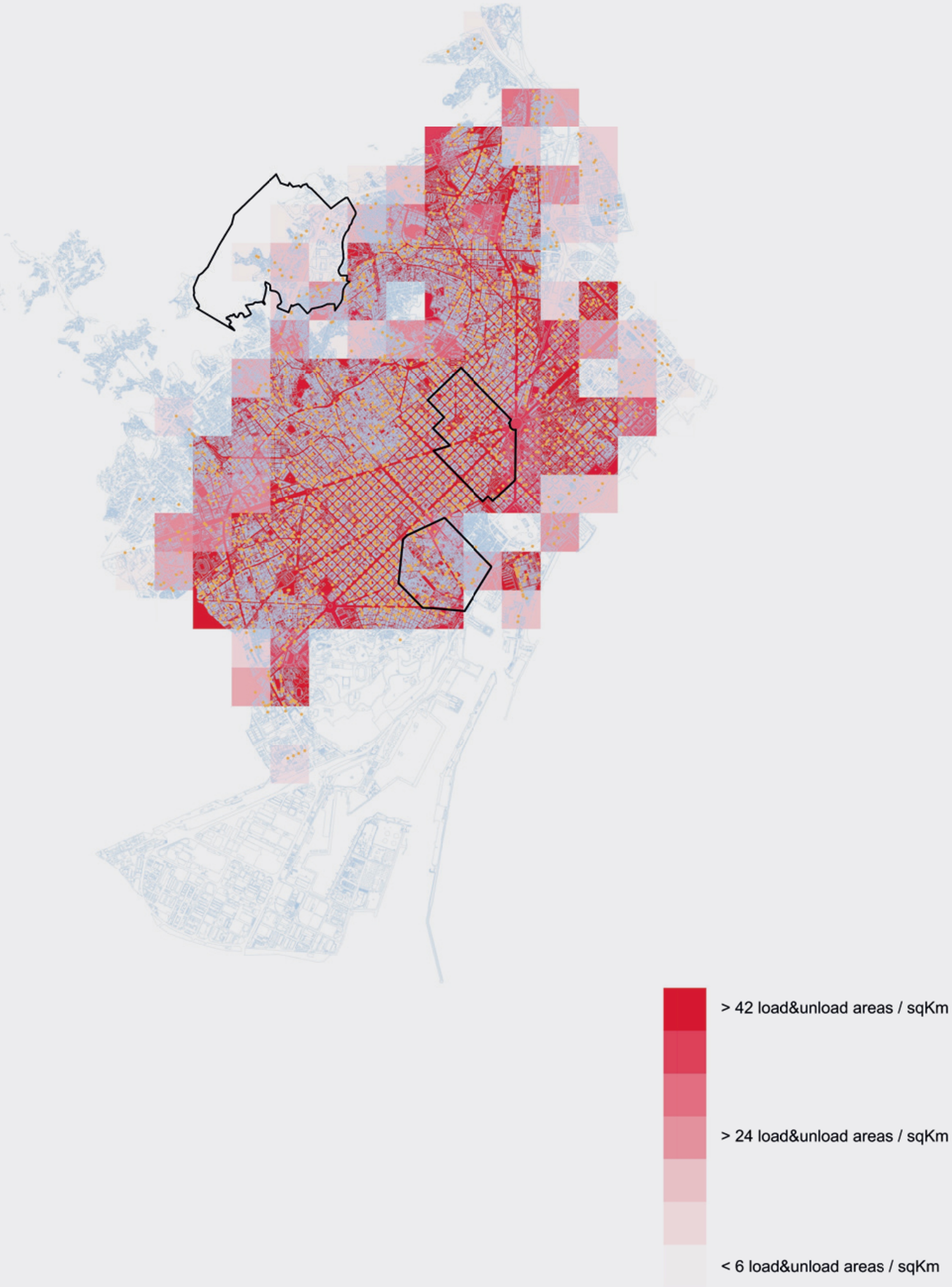
Madrid
scale 1:100.000

Barcelona
scale 1:100.000

Madrid density distribution of loading and unloading areas



Barcelona density distribution of loading and unloading areas



5.1. Criteria for the selection of the urban structures.

The criteria selection of the neighborhoods for modeling the scenarios was based on the possibility of scaling up the results. With this in mind, the urban structure of the chosen neighborhoods can be considered as a general pattern within large European cities, formed by a historical center, a city expansion, and the outskirts.

The city center represents the historical part of the city, with high density, rich in public services, and facilities and amenities. Typically, the urban structure includes a high number of pedestrian-only areas, low-emission zones, traffic restrictions, narrow streets, and lack of parking spaces and loading and unloading zones. The building typologies are compact multifamily houses with courtyards serving exclusively one building. Areas outside the traditional centers of cities where the city has expanded ("ensanches") are often organized following a grid pattern. Even though they are dense, they have wider streets less traffic impedance, and less restrictive ordinances than the city center, more parking options, and more accessible loading and unloading areas. Typically, the building typologies line the streets and enclose the blocks with big open spaces in the middle that are shared by all the buildings that form the block. The outskirts include the outer development of cities which, due to the land availability, typically has a ratio of triple surface areas with only double the population, as compared to the city center. These areas have numerous street typologies, with larger distances between buildings and entrances. In some cases, the outskirts are old villages engulfed by the growth of the city that keep the narrow street pattern with lower density. In the case of new developments, traffic is usually low, with higher vehicle speeds and more parking availability. Typically, the building typologies form enclosed blocks or are discreet linear blocks.

This paper did not include an analysis of low-density residential areas, coined the diffuse city by Francesco Indovina (2009), where low-density zones are mixed with a great number of functions and services. They reflect urban sprawl, typical of American cities, where low-density zones are spread throughout the landscape and there is a general lack of public facilities and services. The analysis of these types of settlements can be developed in future research.

For modeling the scenarios of the logistic flow, it was chosen three urban areas for Madrid and Barcelona according to previous criteria: city center, city expansion area, and the outskirts. To allow a proper comparison between them, several neighborhoods' districts were joined into a larger structure to obtain similar total population numbers.

5.2. City logistic and urban structure.

Within the areas selected of both Madrid and Barcelona, an analysis of three different types of last-mile delivery options from current logistic facilities was carried out:

- A round trip with an ICE Van during rush hours with 10 delivery stops in each neighborhood and with parking difficulties (this increased mileage).
- A round trip with an EV during the day but outside rush hours, with drop off in one singular point.
- A round trip with an EV during the night (trip starting at 11 pm), with drop off in one singular point.

Using data from the Municipality of Madrid, the Municipality of Barcelona and cross-referencing them with data from Open Street Maps, the scenarios were modeled and visualized for a better understanding of city logistics and urban structure.

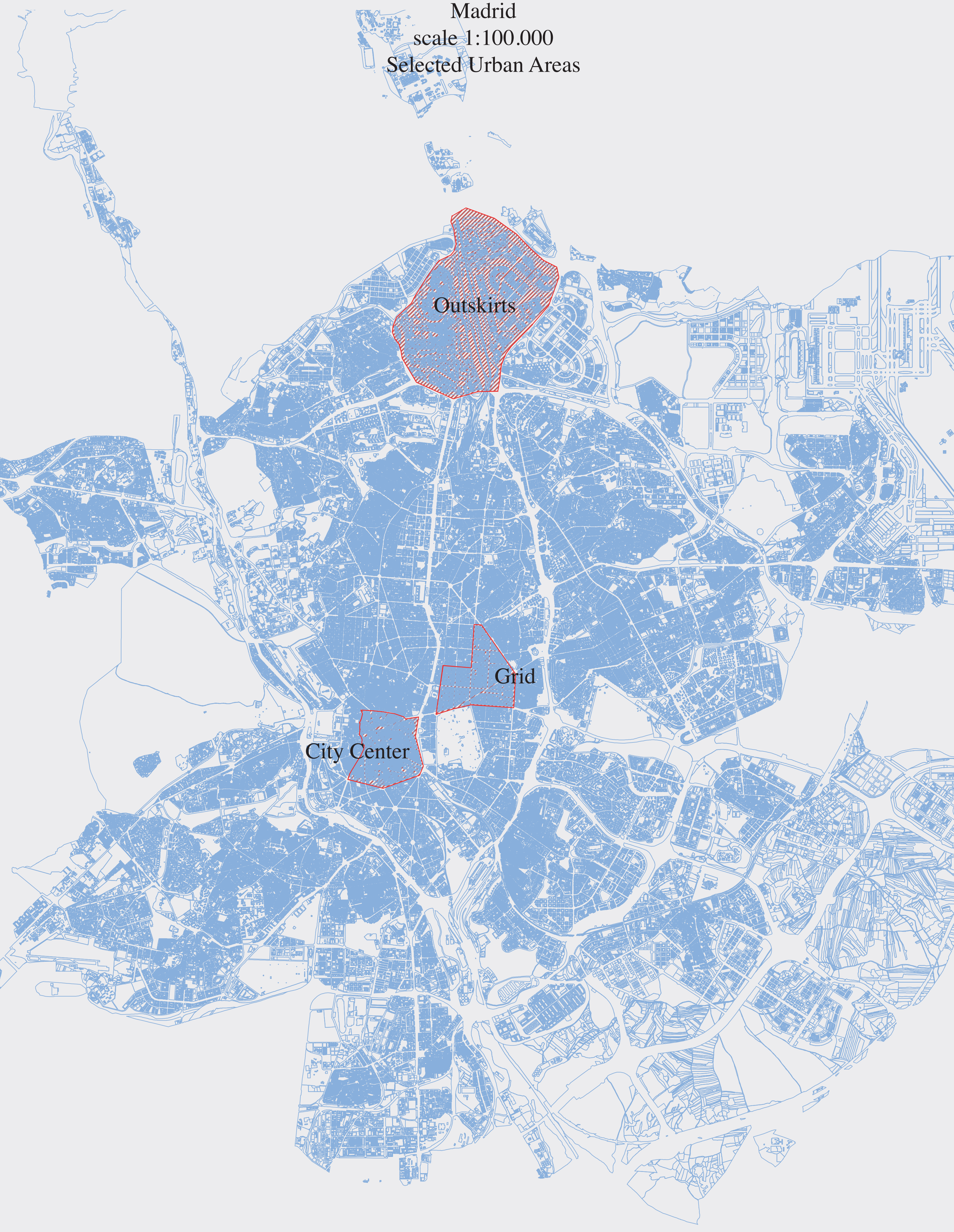
The analysis was accomplished by crossing data such as surface area, loading and unloading zones, density, the average distance between loading and unloading zones, and type of buildings (residential, historic, leisure, and amenities). This data gives rapid and comparable insights, such as the non-uniform distribution of loading and unloading zones in the three neighborhoods:

Madrid loading and unloading areas.
1. City Center: 188
2. Grid: 143
3. Outskirts: 15

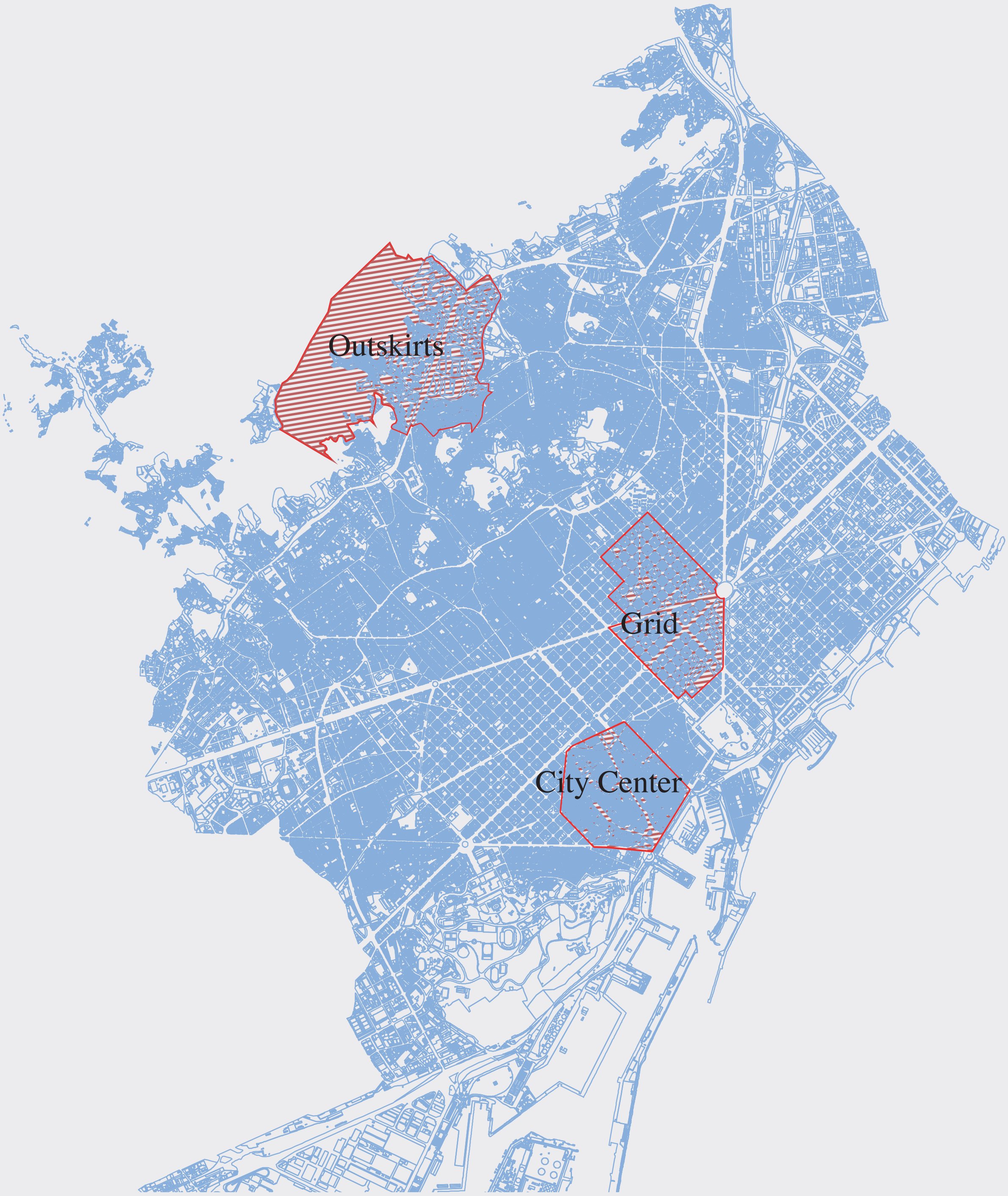
Barcelona loading and unloading areas.
1. City Center: 104
2. Grid: 166
3. Outskirts: 33.

Other maps, provided by the municipality platforms, were also analyzed, such as the availability of cycling lanes within the city, high traffic areas, and low-emissions zones.

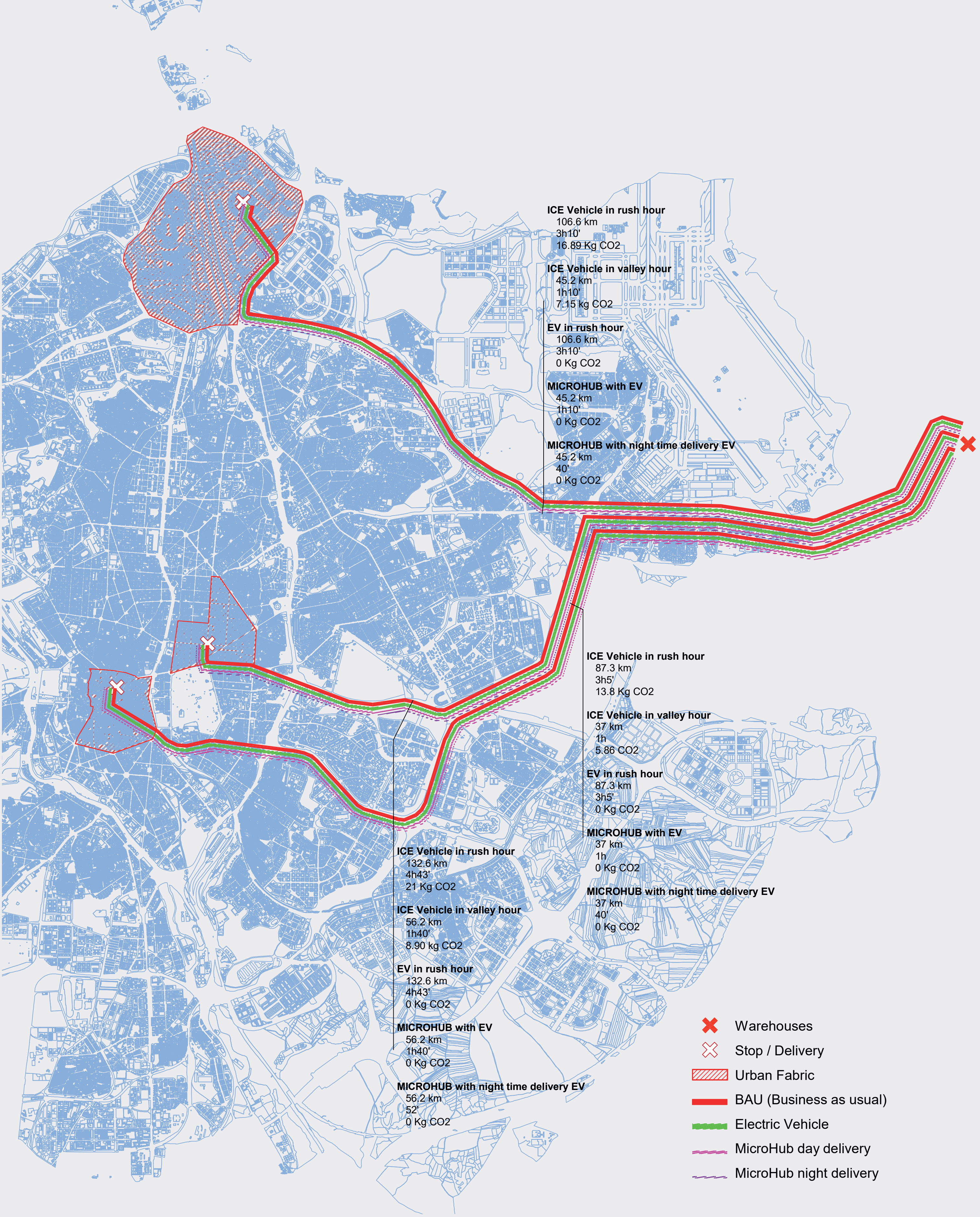
Madrid
scale 1:100.000
Selected Urban Areas



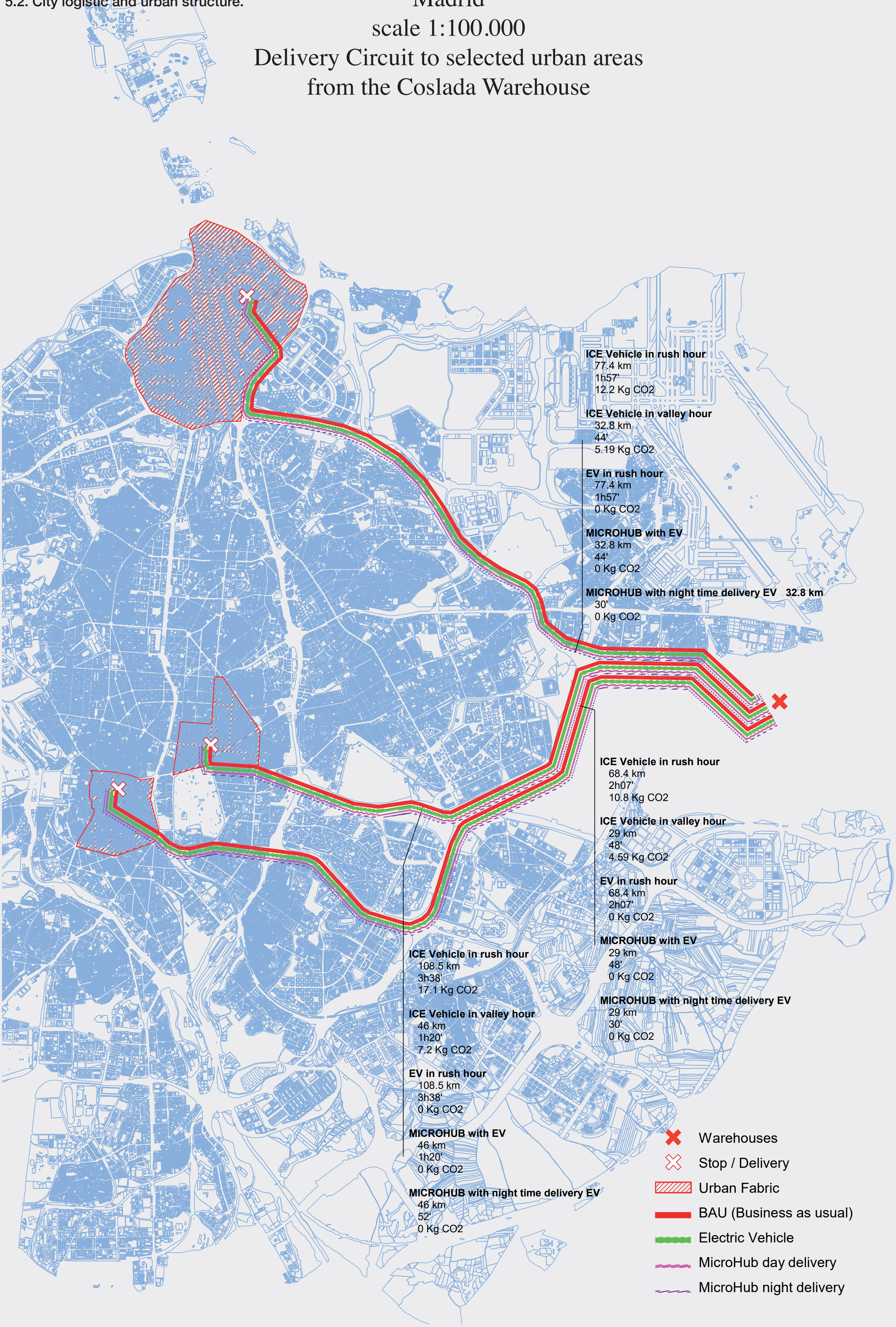
Barcelona
scale 1:100.000
Selected Urban Areas



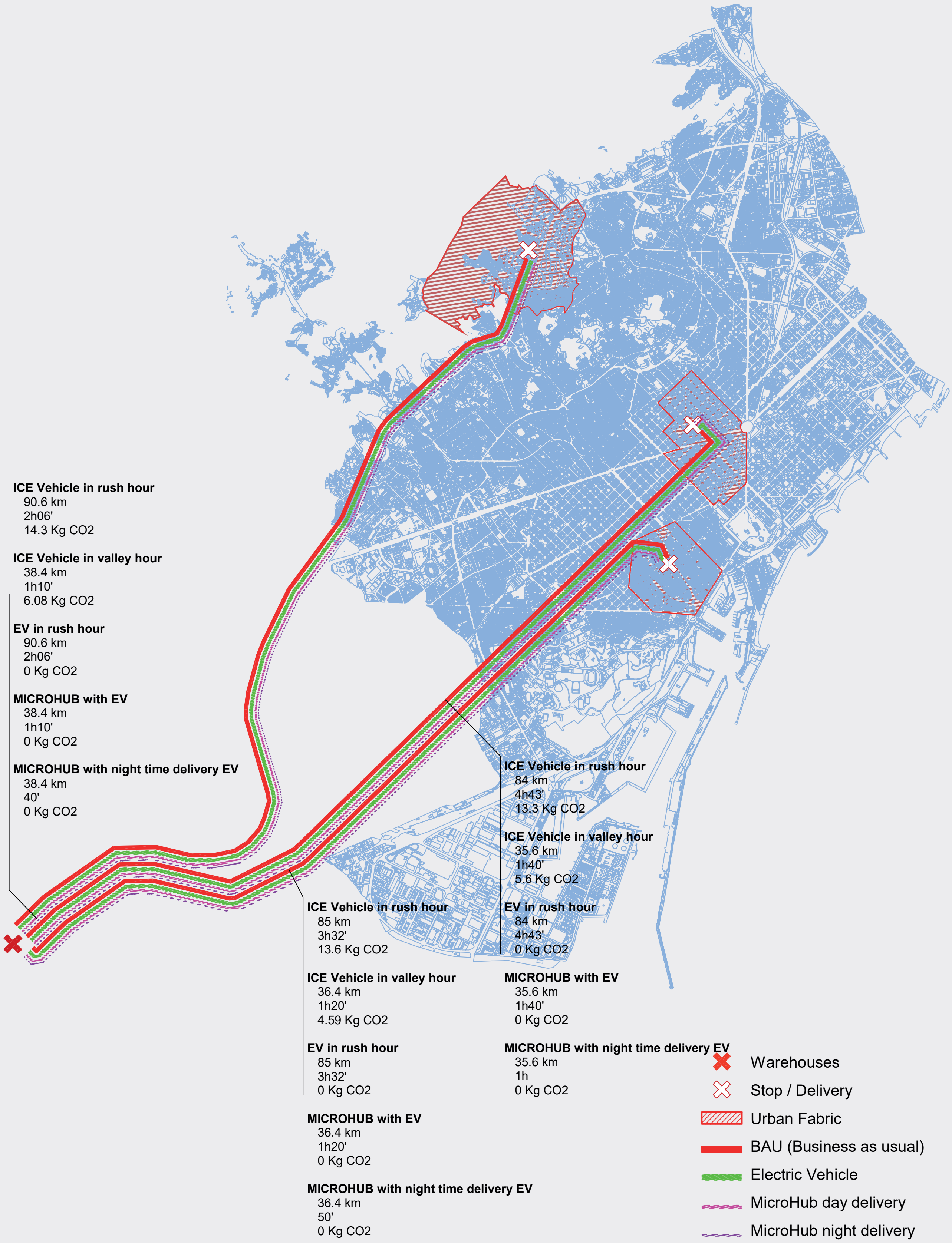
Madrid
scale 1:100.000
Delivery Circuit to selected urban areas from the San Fernando de Henares Warehouse



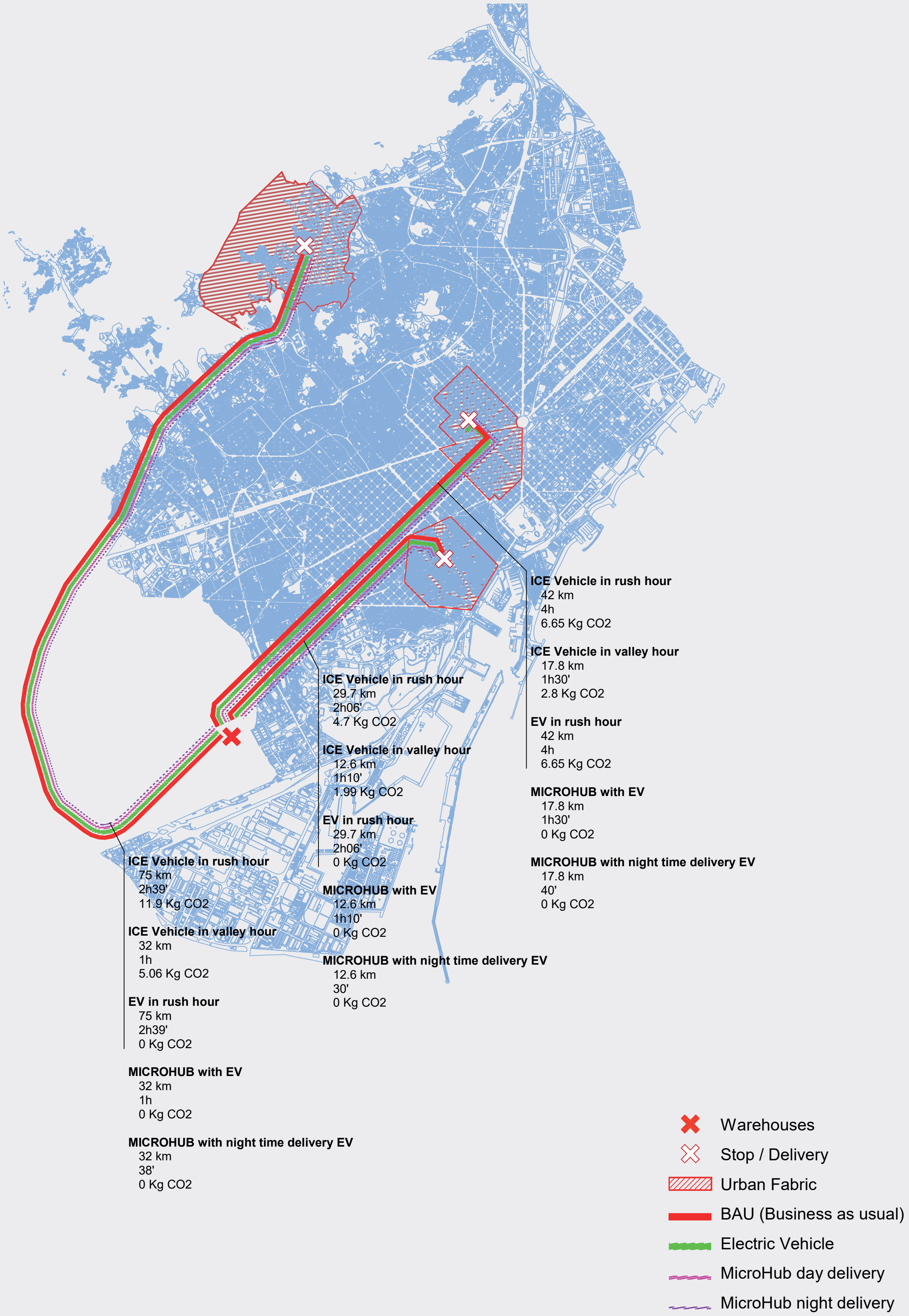
Madrid
scale 1:100.000
Delivery Circuit to selected urban areas from the Coslada Warehouse



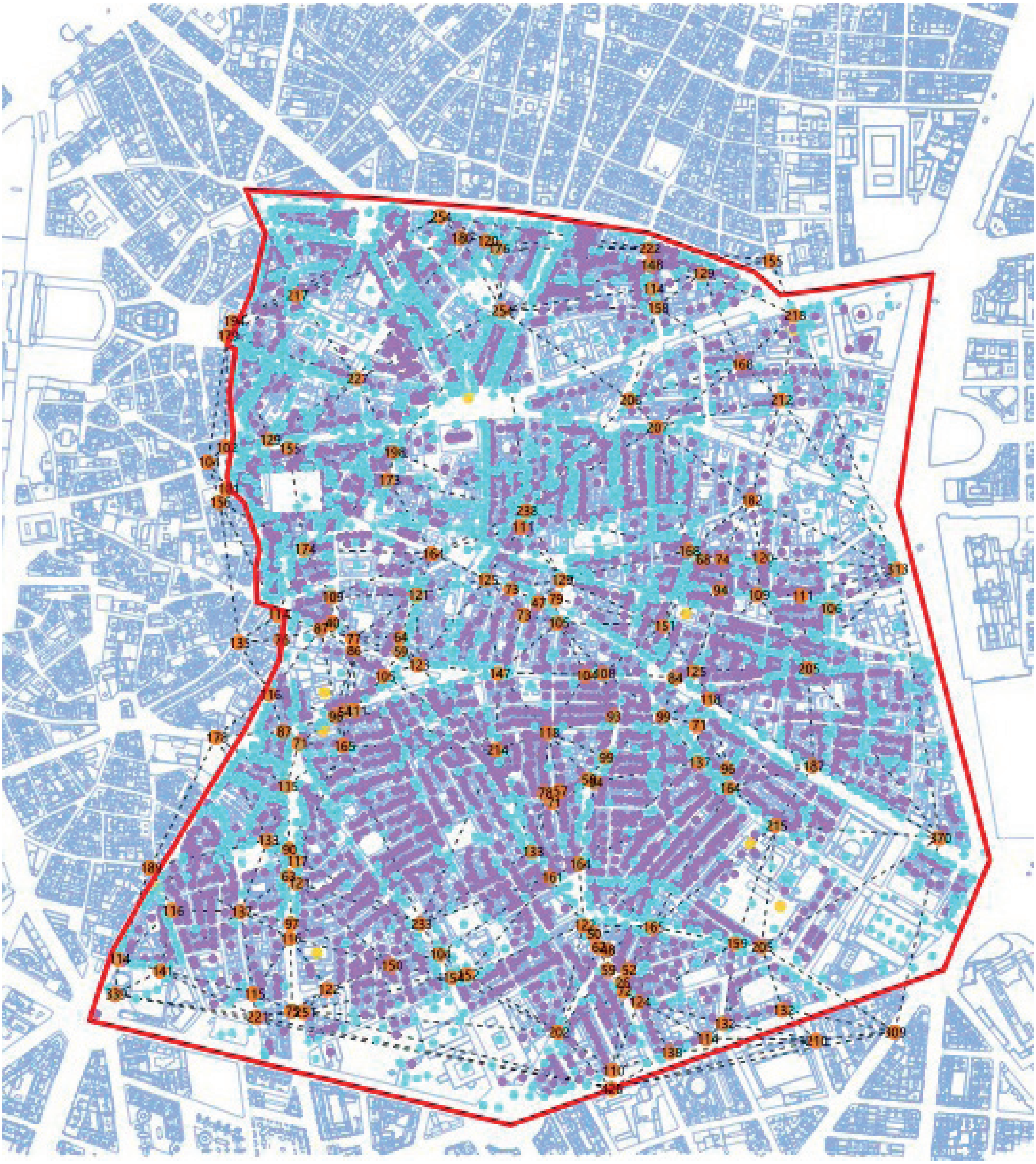
Barcelona
scale 1:100.000
Delivery Circuit to selected urban areas from the Sant Boi de Llobregat Warehouse



Barcelona
scale 1:100.000
Delivery Circuit to selected urban areas from the El Prat de Llobregat Warehouse



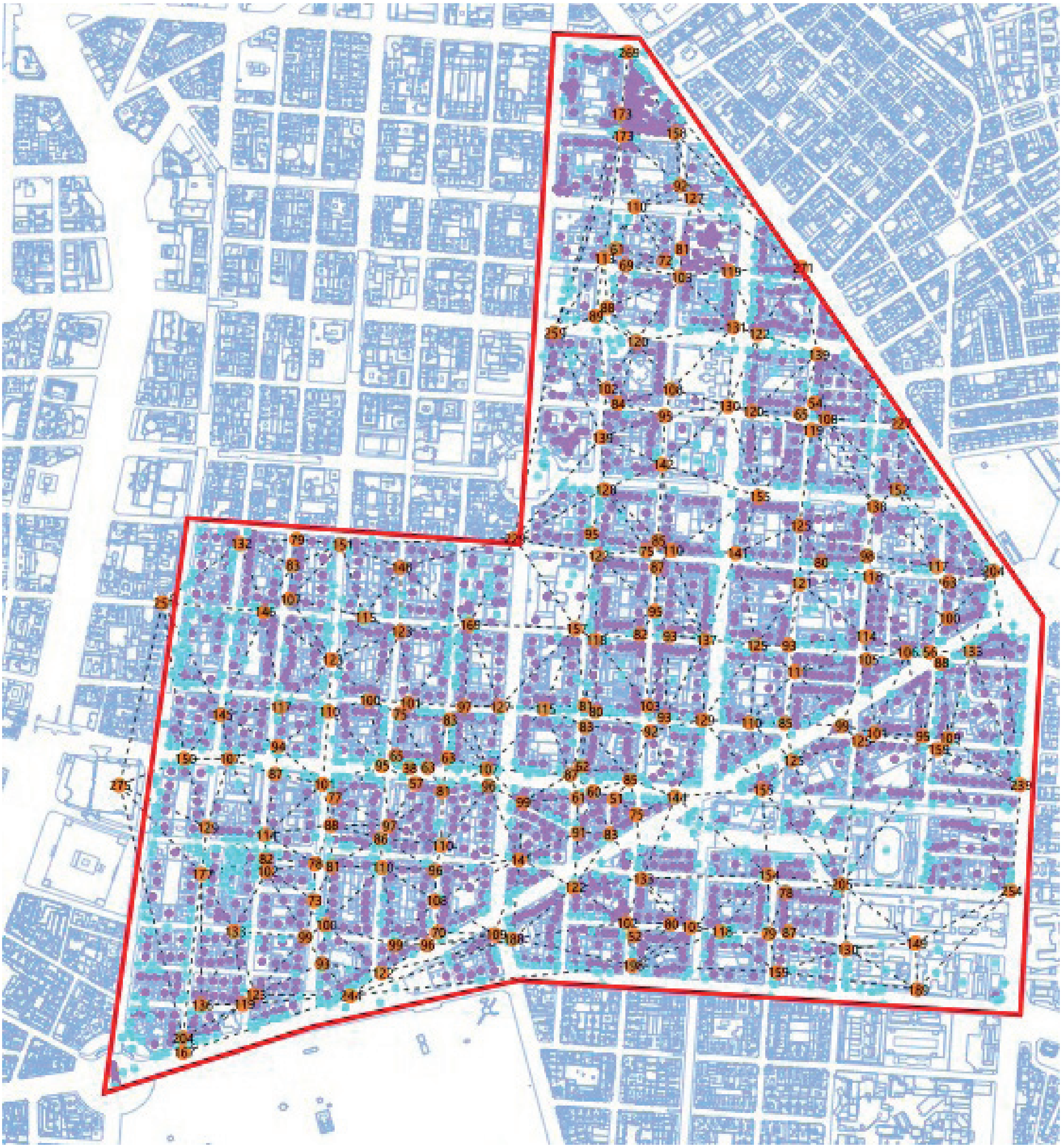
Madrid
scale 1:10.000
City Centre



CENTER

	Total Area (km2)	2.03
●	Load / Unload Amount	188
116	Load / Unload Average Distance (m)	116.83
	Load / Unload density (amount / km2)	92.81
●	Residential Buildings	3289
●	Historic Buildings	9
●	Leissure and Amenities	2241

Madrid
scale 1:10.000
Grid



GRID

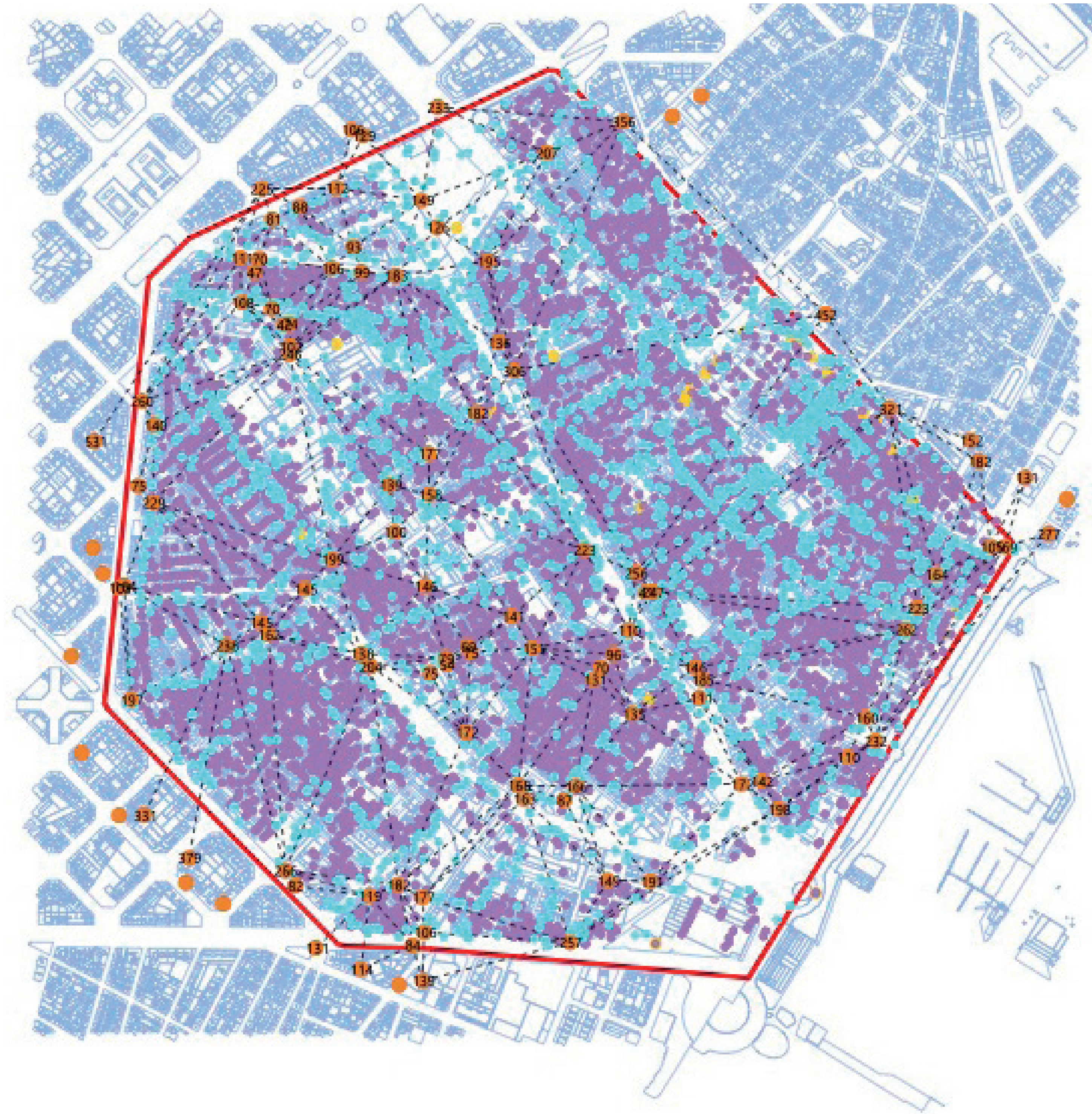
	Total Area (km2)	1.93
	Load / Unload Amount	143
137	Load / Unload Average Distance (m)	137.75
	Load / Unload density (amount / km2)	74.10
	Residential Buildings	1859
	Historic Buildings	1
	Leissure and Amenities	943

Madrid
scale 1:20.000
Outskirts

OUTSKIRTS

	Total Area (km2)	9.04
	Load / Unload Amount	15
878	Load / Unload Average Distance (m)	878.92
	Load / Unload density (amount / km2)	1.66
	Residential Buildings	2486
	Historic Buildings	3
	Leissure and Amenities	451

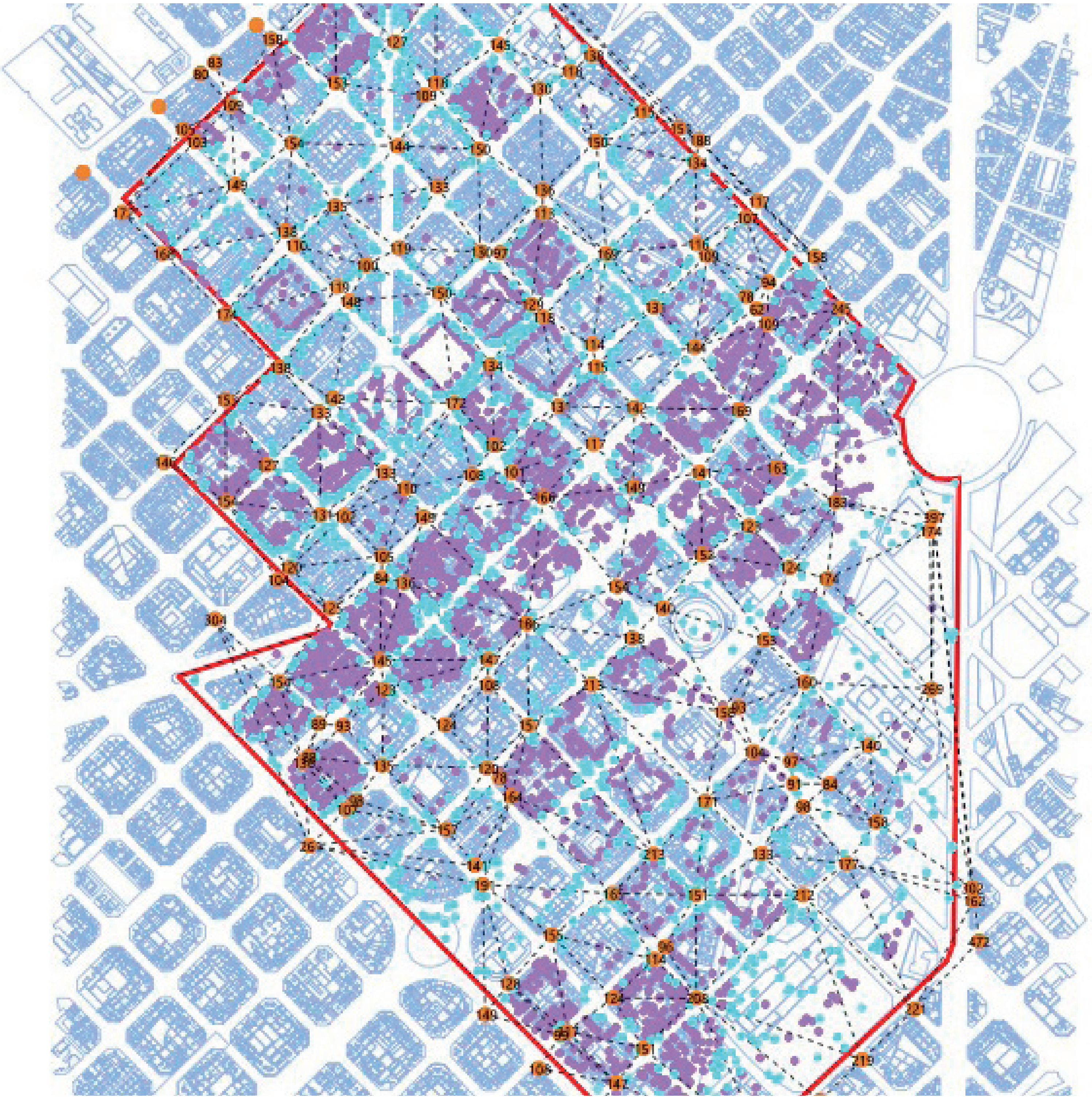
Barcelona
scale 1:10.000
City Centre



CENTER

	Total Area (km2)	1.71
	Load / Unload Amount	104
116	Load / Unload Average Distance (m)	162.92
	Load / Unload density (amount / km2)	60.70
	Residential Buildings	7242
	Historic Buildings	27
	Leissure and Amenities	1879

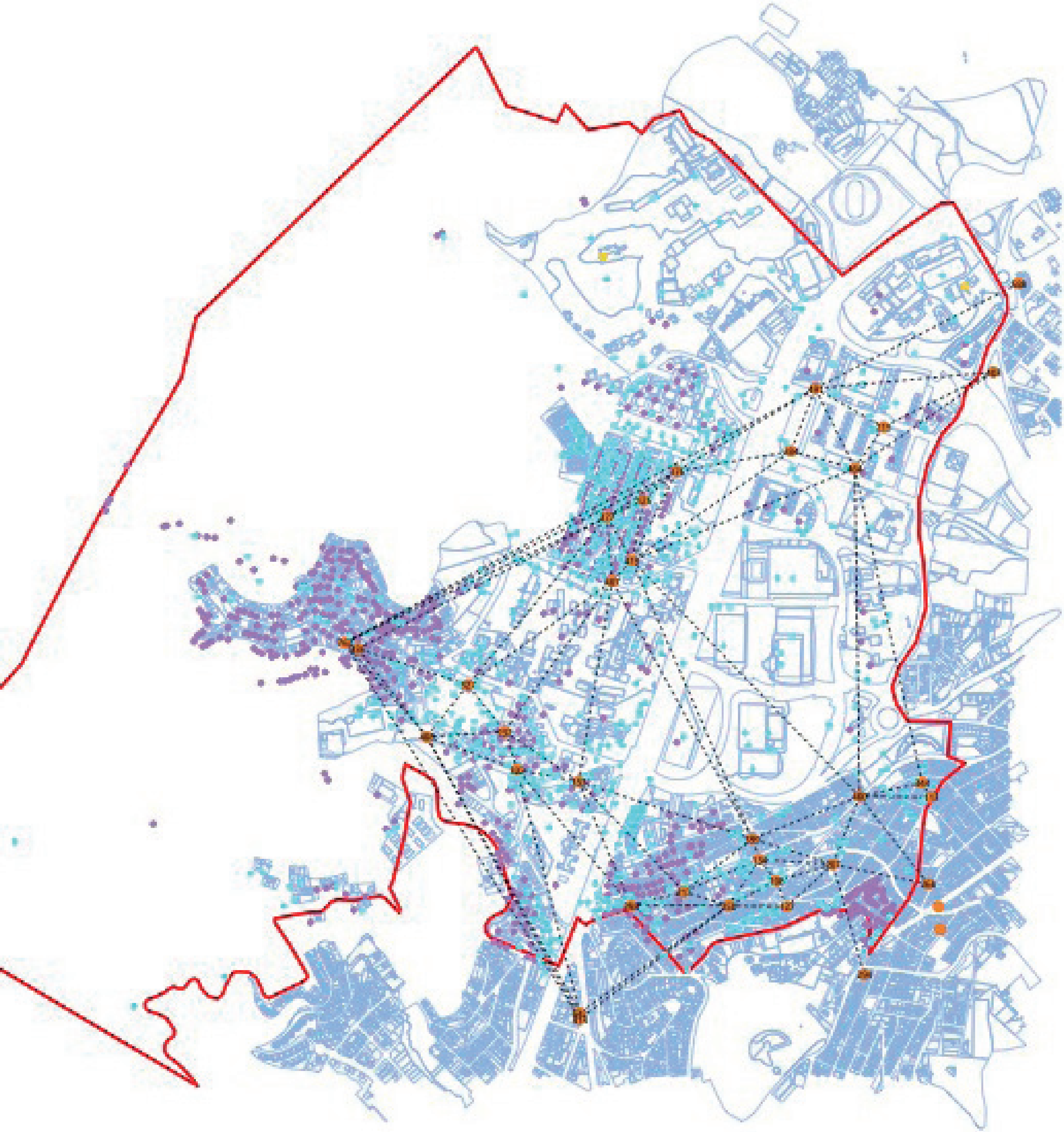
Barcelona
scale 1:10.000
Grid



GRID

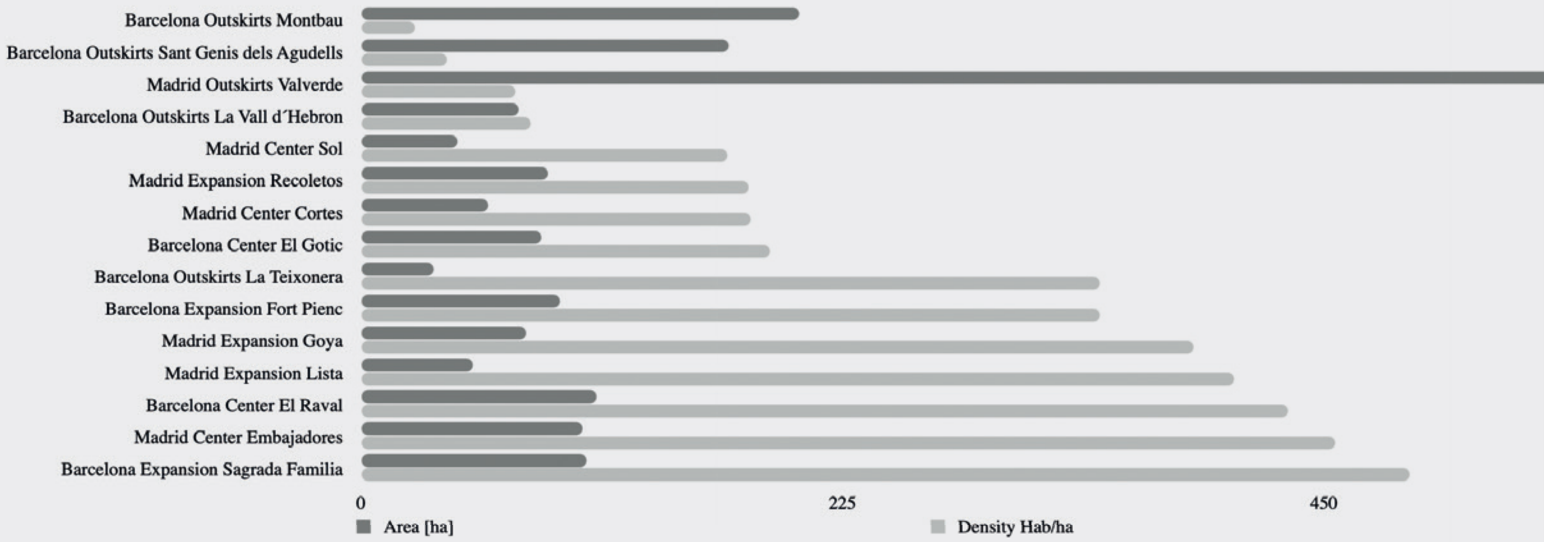
	Total Area (km2)	2.11
●	Load / Unload Amount	166
137	Load / Unload Average Distance (m)	144.86
	Load / Unload density (amount / km2)	78.50
●	Residential Buildings	3951
●	Historic Buildings	0
●	Leissure and Amenities	1361

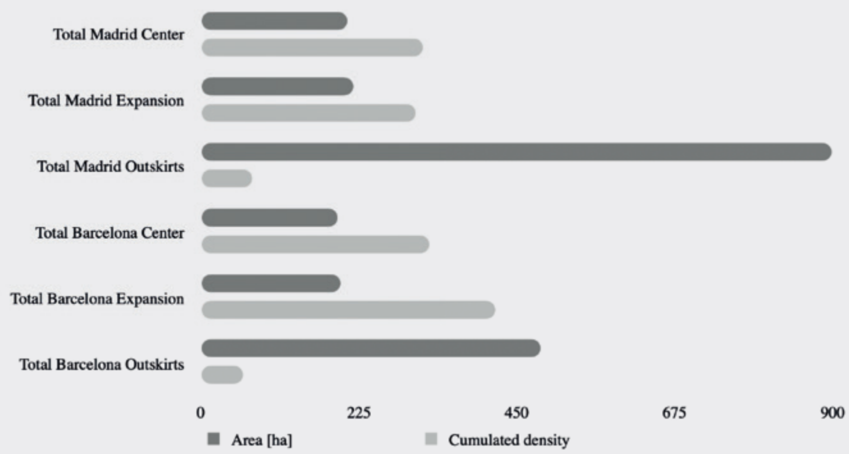
Barcelona
scale 1:15.000
Outskirts

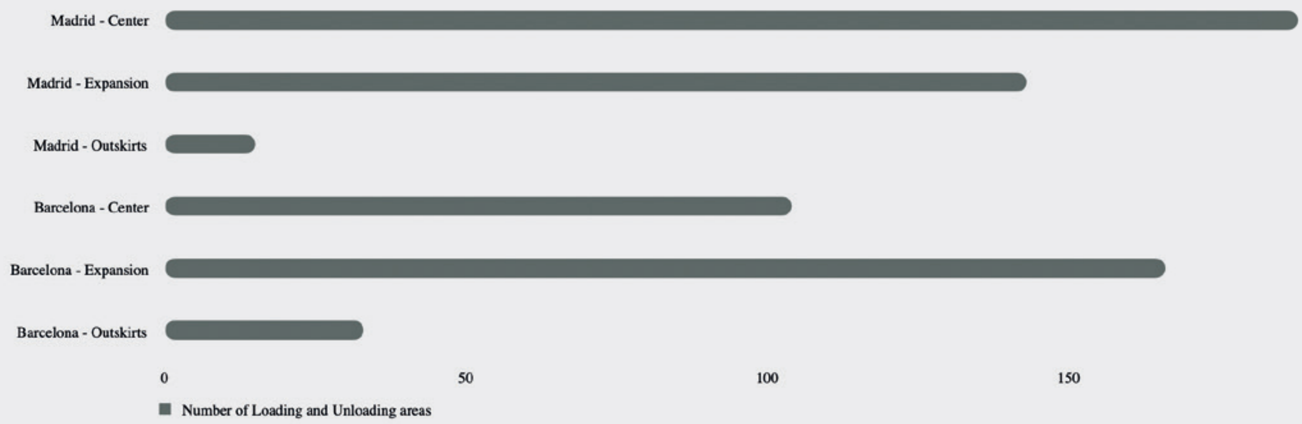


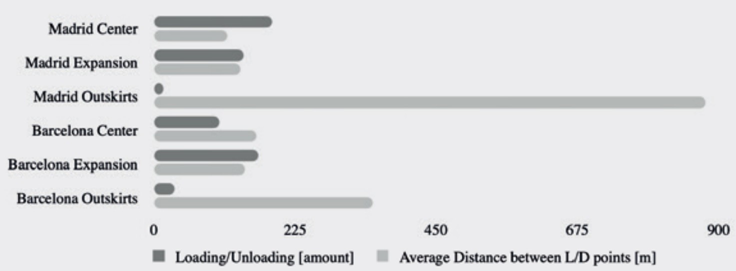
OUTSKIRTS

	Total Area (km2)	4.35
	Load / Unload Amount	33
878	Load / Unload Average Distance (m)	348.64
	Load / Unload density (amount / km2)	7.59
	Residential Buildings	685
	Historic Buildings	2
	Leissure and Amenities	296



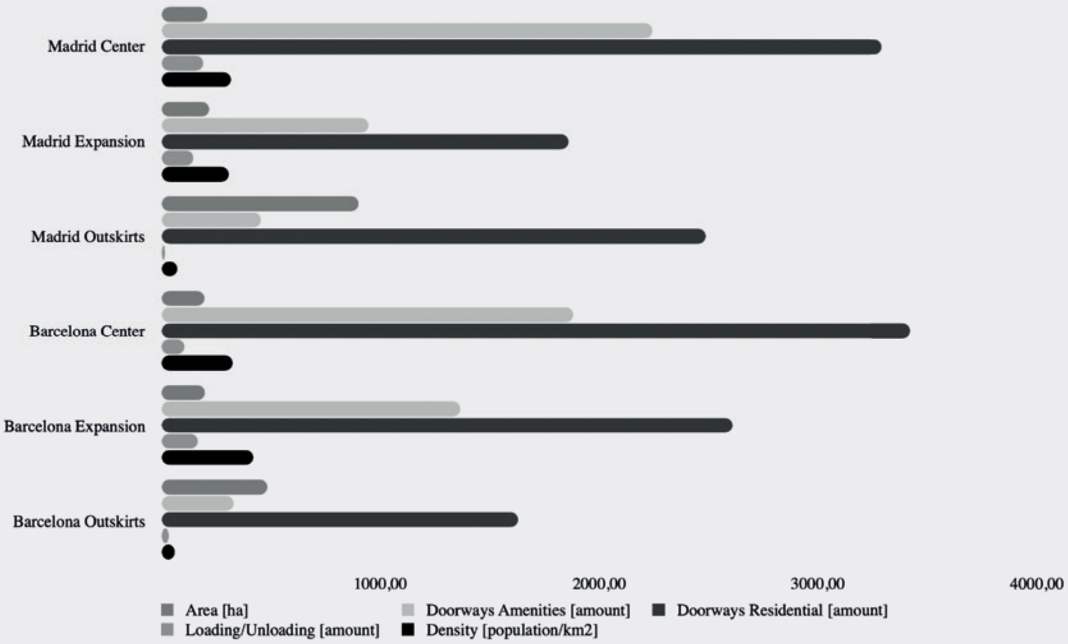


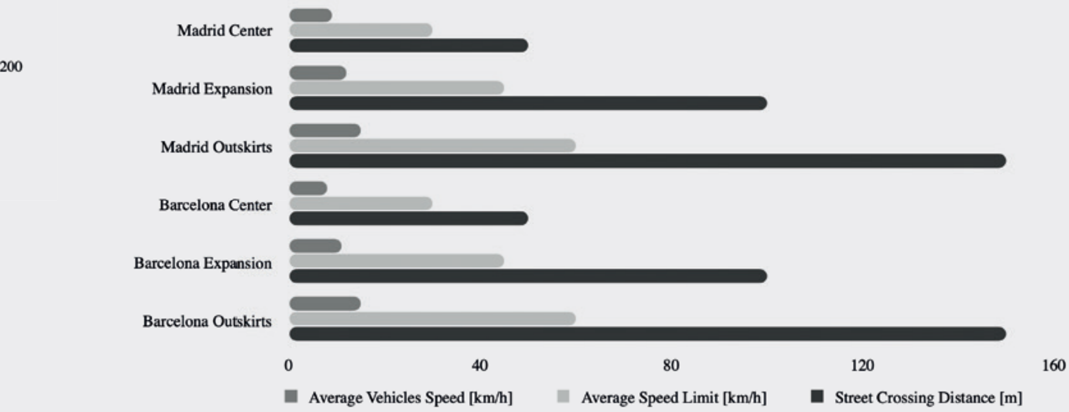




Summary of urban parameters from both Madrid and Barcelona selected urban areas.


675
900


Madrid Center
Madrid Expansion
Madrid Outskirts
Barcelona Center
Barcelona Expansion
Barcelona Outskirts
1000,00
2000,00
3000,00
4000,00
Area [ha]
Doorways Amenities [amount]
Doorways Residential [amount]
Loading/Unloading [amount]
Density [population/km2]


200
Madrid Center
Madrid Expansion
Madrid Outskirts
Barcelona Center
Barcelona Expansion
Barcelona Outskirts
0
40
80
120
160
Average Vehicles Speed [km/h]
Average Speed Limit [km/h]
Street Crossing Distance [m]

06: LII

Because man's power is still insufficient to control the overall biosphere, he is protected in his ignorance by the great stabilizing storages of the oceans and atmosphere.

Howard T. Odum, 1971

6. Last-mile Logistic Impact Index. LM-LII

6.1. Objectives

It is well-known that the concept of "last-mile" was borrowed from telecommunications networks. The Last-Mile Delivery is a highly complex system of interconnected nodes, not just a simple or uniform connection between two points. There are an increasing number of factors and stakeholders involved in the process. This complexity, of people, modes, and places, is evident in multiple combinations and possibilities which make the evaluation of the impact of the Last-Mile Delivery a challenge. Moreover, if we include the urban structure in the equation, the complexity increases even more. Cities can differ radically, not only one from another but even different areas within the same city in terms of the urban fabric, density, population, activities, infrastructure or building typologies, etc. Given this reality, the first step to evaluate the impact of the last mile in cities is to identify the parameters involved. The number and type of stakeholders, the different options for storage and delivery, the ICTs systems, together with the urban fabric define a complex network that needs a methodology for clarification and understanding. The objective is not to simplify the system, but to classify the network according to specific criteria, in order to make it more readable and understandable. This classification of network parameters will help to quantify the impacts which we will be able to measure based on real data.

City logistics cannot be managed as an independent layer of the structure of a city. It is deeply interconnected with transport networks, urban zones, urban planning, and the environment in general. (Averkyna, 2017; Paskannaya and Shaban, 2019).

6.2. Literature review

Currently, there is no tool for measuring the performance of the logistics related to urban freight at the city level (Dablanc and Rodrigue, 2014), nor a standard framework for simulating and studying the impact and optimization of city logistics (Perboli, et al., 2018).
The first works on the evaluation of urban logistics date from 1999, in the first international conference for urban logistics. The methodology proposed was based on simulations and scenario analysis. Mainly, the factors implemented were functional (distance traveled) and greenhouse emissions. The evaluation of the sustainability of urban logistics has been one of the critical reasons for the success or failure of the implementation of new practices (Gonzalez-Feliu, 2018).

The City Logistics in Living Laboratories (or CITYLAB) is a comprehensive three-year research project, funded by the European Union that includes seven CITYLAB living labs in different European Cities. The general objective of CITYLAB is to develop knowledge and solutions that result in the roll-out, up-scaling, and further implementation of cost-effective strategies, measures, and tools for emission-free city logistics in urban centers by 2030 (CITYLAB, 2017). The results were measured according to eight parameters: reduction in vehicle kilometers, reduction in CO2 emissions, reduction in logistics-associated noise and disturbance, reduction in total time spent by vehicles on roads (driving/loading/unloading), retiming of logistics operations (i.e. out of peak period), alleviation of logistics sprawl (In the sense of reducing the need for road-based stem mileage), promotion of alternatively-fueled / clean delivery vehicles and reduction in time spent by receivers on goods reception and internal logistics. Through the implementation of innovative ideas, it was expected to find a balance between the future increase in freight transport and the impact of city logistics in cities. The objective was to evaluate the effects of large-scale implementations from a social, environmental, and financial point of view. (CITYLAB, 2017). There were a set of indicators that were defined based on previous parameters which could be either quantitative or qualitative, depending on the criteria employed.

The World Bank has developed the Logistic Performance Index (LPI) which measures the freight distribution at a national level (WORLD BANK, 2018). The LPI measures global trade and supply chains, and the logistics capabilities of cities. It is a tool to interpret and categorize logistics infrastructures, which range from 1 (worst) to 5 (best), according to six factors:

1. The efficiency of customs and border management clearance.
2. The quality of trade- and transport-related infrastructure.
3. The ease of arranging competitively priced international shipments.
4. The competence and quality of logistics services.
5. The ability to track and trace consignments.
6. The frequency with which shipments reach consignees within the scheduled or expected delivery time.

Another example of evaluation of the last mile impact has been undertaken by Hans Quak and Bram Kin (2020). Based on the data of three companies, they simulated four scenarios in a metropolitan region: electrification in the largest cities only, all deliveries made with electric vans, urban consolidation centers, and micro hubs. The parameters, which measured impacts and allowed later comparisons, were the number of orders, number of available vehicles, capacity per vehicle (items), average stop time per stop (minutes), average load factor, average number of items per order, Vkm per order, Vkm per item, CO2 emissions total (kg), CO2 emissions per order (kg), and CO2 emissions per item (kg). Bhasker, Sarmah, and Kim (2019) proposed a mathematical model to evaluate fuel consumption in last-mile delivery for non-collaborative (or traditional) and collaborative last-mile delivery.

Seong-Tae Kim and Chul-Hwan Han (2011) developed a system of factors to measure the environmental logistic practice (ELPs), divided into three groups: Internal Environmental management (IEM), Environmental Sourcing and Packaging (ESP), and Environmental Process Design (EPD). The first criterion was based on how companies manage their environmental impact in terms of leadership, auditing systems, objectives, reports, and partnerships. The second criterion was more specific about the source and type of package. The last criterion was focused on the environmental design of the warehouse, recycling systems, charging facilities, and the implementation of ICT systems.

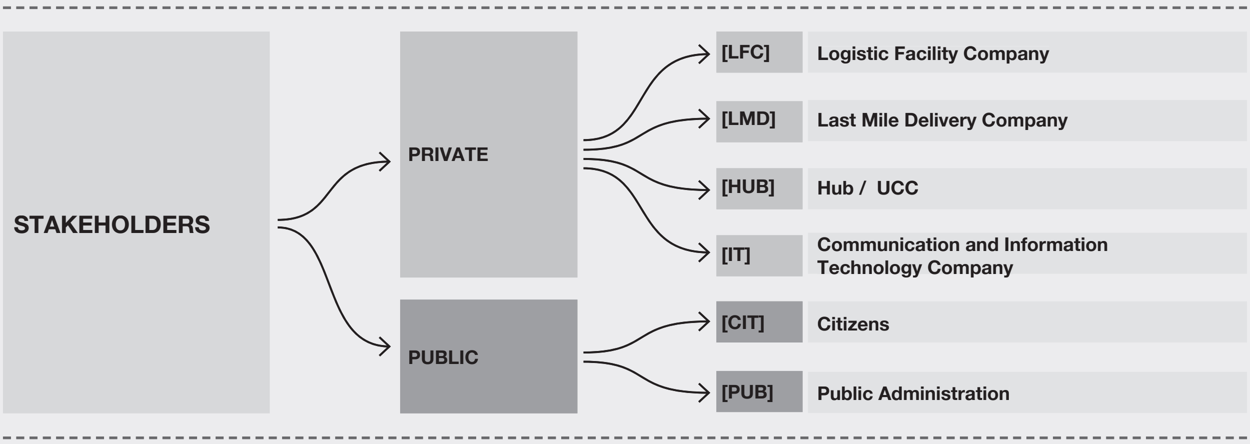
Ivan Cardenas, Joris Beckers, and Thierry Vanelslander "proposed a methodology based on the total vehicle-kilometers traveled to calculate the external costs per parcel at the national level." (2017). Van specifications, the location of distribution centers, and the number of deliveries per zip code were introduced to calculate the number of kilometers traveled (VKT). The objective was to analyze how externalities such as accidents, air pollution, noise, and climate change, influence deliveries at an urban, semi-urban, and rural scale.

Green Logistics Management Practices (GLMPS), Logistic Ecocentricity (LEC), and Supply Chain Traceability (SCT) can enhance the sustainable performance of city logistics through the prevention of environmental pollution, improvement of energy efficiency and conservation, and proper management of waste. (Agyabeng-Mensah and Afum, 2020)

Most of the literature that evaluates city logistics is focused on environmental and functional concerns, such as carbon emissions or the number of kilometers per delivery. Apart from this approach, some research studies are partially focusing on factors such as the influence of the urban structure, labor, road safety, or information systems.

The built and regulatory environments have a strong influence on the last mile delivery. In fact, the potential transportation network impedance has been analyzed as a feature of the roads and streets network as well as in relation to urban regulations. (Ewedairo, Chhetri and Jie, 2018) At the metropolitan scale of a region, the urban structure together with spatial planning policies and freight hub characteristics are the key factors for avoiding logistics sprawl. Sprawl causes a reduction in the efficiency of logistics and has a high impact on the environment. (Dablanc and Tavasszy, 2017)

In recent years, there is an increase in jobs carried out by external contractors and self-employed



Last-mile stakeholders' classification according to private and public division, and its possibilities of hybridization.

workers within the logistics ecosystem. This can be seen in the increase of eternal contractors for the implementation of digital platforms. This process also includes the of “uberization of jobs” and is happening especially in the last-mile delivery. The criticism of this approach relates to the precarious conditions of the jobs, since self-employed and temporary workers do not have the right to unionize, and do not receive health insurance or retirement benefits from the company with which they are collaborating. In addition, they are paid by the number of deliveries accomplished, which can lead to dangerous driving and behavior (Dablanc, et al., 2017).

Road safety is a major concern in city logistics and can be affected by the labor condition of the self-employed drivers often known as “gig workers.” Freight vehicles, and especially HGVs, can create a significant risk to the safety of other road users and pedestrians (Quarshie, et al., 2021). Notwithstanding the above, there is no specific literature about bicycle couriers and road safety (Dablanc, et al., 2017).

New technologies are being already implemented in the last mile delivery, such as geolocation services, mass storage, and management of information, smart lockers, electric scooters, or robotization. In addition, new and upcoming technologies are starting to be used as mobility platforms and reusable packaging for e-commerce., Future technology such as drones, or autonomous vehicles are being discussed and proposed for logistics (Deloitte, 2020).

The literature review shows that there is a growing interest in measuring the impact of city logistics. Yet no index evaluates the city logistic system as a whole with a special focus on the interconnections and interdependencies of the nodes in this complex system.

6.3. Stakeholders.

A first general classification of stakeholders (those listed in Chapter 3) as either public or private has been established. The public stakeholders are citizens (CIT) and the public administration (PUB). Citizens (CIT) includes not only the final client but also all the different groups and social structures that are part of a city. The public administration, from local to national level governments and bodies, encompasses their actions and initiatives, codes and regulations, and governance mechanisms.
The private stakeholders include the Logistic Facility (LF), the Last-Mile Delivery (LMD), Hubs (HUB), Urban Consolidation Centers (UCCs), and the ICTs (ICT). The Logistic Facility refers to the warehouses located within the last mile. Hubs are small-scale storage systems, such as micro-hubs or PUDO systems. The Last-Mile Delivery refers to

Last-mile's delivery stakeholders			
Public		Private	
Citizens	CIT	Logistic Facility	LF
Public Administration	PUB	HUB	HUB
		UCC	UCC
		Last-mile Delivery	LMD
		ICTs	ICT
Public-Private Hybridization / Partnership			
Delivery			CIT + PUB + LMD
Storage			CIT + PUB + LF + HUB
ICTs			CIT + PUB + ICT

Last-mile stakeholders' classification according to private and public division, and its possibilities of hybridization.

the different systems of the transportation of goods including, vehicle type classified according to their energy source. Finally, the ICTs refer to all digital platforms for information and communication involved in the last mile.

Once this first division between public and private is established, it opens a wide range of possibilities of hybridization and partnerships. The public sector and society may take on some of the roles previously assigned to private companies, such as delivery, storage, or ICT. The following chart reflects the first step of the division between private and public, and the second step of hybridization possibilities among them.

The evaluation of the impact of the last mile in cities must include all previous stakeholders and possibilities of hybridization. The result is a complex network formed by many different combinations, connections, and options.

The built and landscape environment of city logistics.	
Storage + cross docking	
	Warehouse (the last warehouse within the last-mile)
	Urban Consolidation Center (UCC)
	Hubs and micro-hubs
	Smart Lockers- PUDO (Pick-up and Drop-Off)
Loading + Unloading	
	Loading / unloading areas
Final Client	
	Single housing
	Multi-housing building
	Retail (ground level)
	Office building

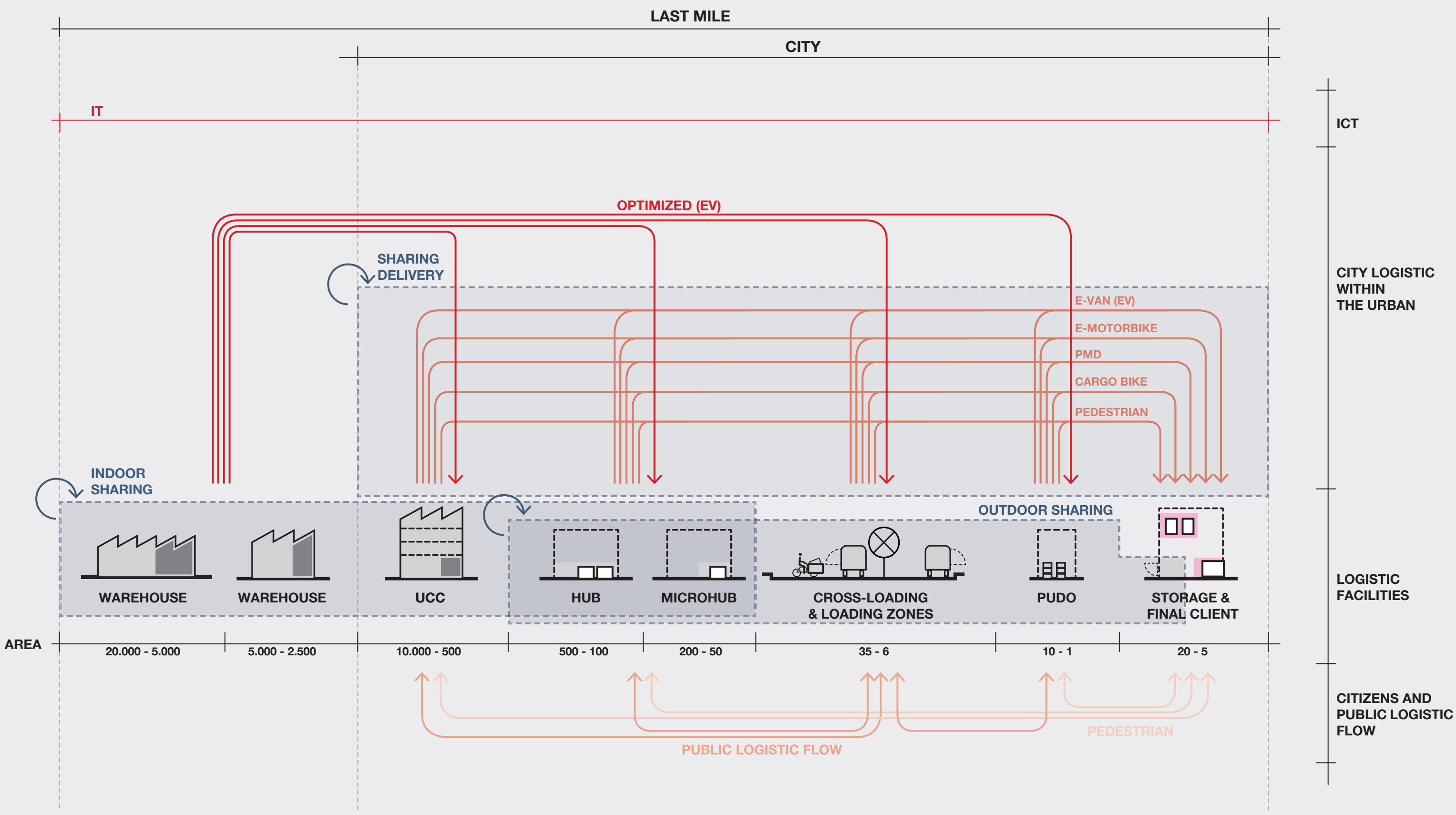
The built and landscape environment of city logistics
divided according to storage and cross-docking.

6.4. The built environment of city logistics.

The built environment of city logistics, as reflected in chapter 3, is formed by a wide range of buildings and infrastructures. We have divided these into storage facilities, loading and unloading places, and the final client. While the first one includes mostly buildings, such as warehouses, UCCs, or hubs, the second usually happens in open spaces, located on streets or in parking areas. Additionally, storage facilities usually provide cross-docking services and vehicles can also provide storage space.
The final client can be located a dwelling in a multi-family housing building, a retail establishment at ground level, or an office complex, among others. These different building typologies and activities impact the last-mile delivery in terms of time and efficiency.

Basically, the built environment of city logistics has been divided according to: the left chart.
The presence and location of these spaces within the city represent an important factor when determining the impact of last-mile delivery.
Some of these spaces, such as the loading and unloading areas on public streets, are part of the public infrastructure of the city, while others are private spaces located inside buildings. Loading and unloading areas are considered special parking spaces, and these public spaces, with different time schedules and surface areas, are regulated by the local administration Most of the cross-docking is located inside warehouses or Urban Consolidation Centers.

The distance from the last stop to the final client as well as the building typology and its services are important factors in determining the impact and efficiency of the delivery. If there is a doorperson or receptionist for the building that can receive the goods, or if there is a specific storage room, these services will provide more efficient delivery. They are also part of the environment of city logistics.



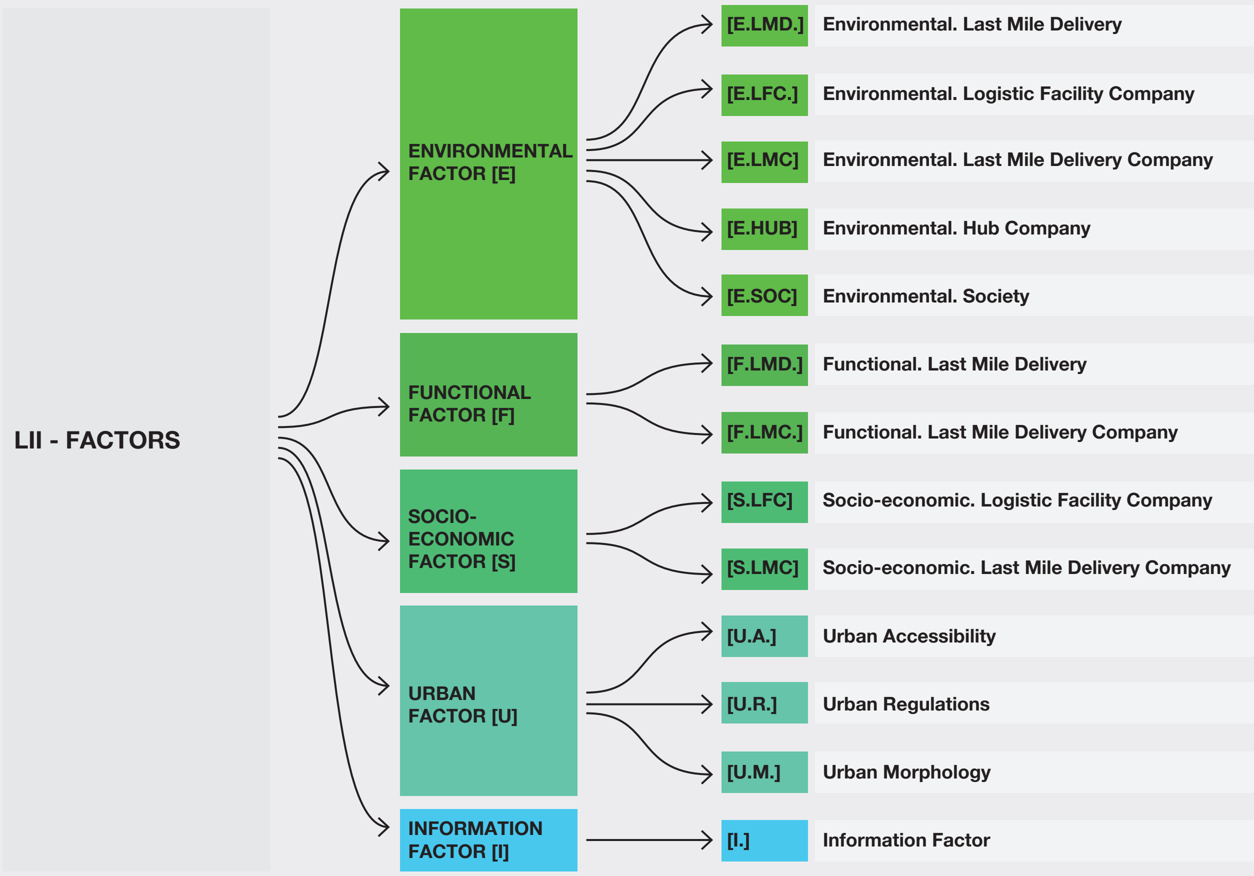
Last-Mile Ecosystem

6.5. The last-mile ecosystem

The last-mile ecosystem is formed by the flow of goods from the last warehouse to the final client, interacting with different stakeholders and logistic facilities. The transportation of any good throughout this complex network provides a huge range of options. The multiple combinations of stakeholders and delivery modes, together with the built environment of city logistics, offer a wide range of scenarios for the same delivery.

The Last-mile Impact Index (LM-LII) offers a tool to compare the potential impacts of different scenarios, to lead to the selection of the most efficient options with the lowest impacts. There is not a standard recipe for every city or every case. Understanding multiple options and opportunities is useful not only today, but this tool is useful in adapting to future demands.

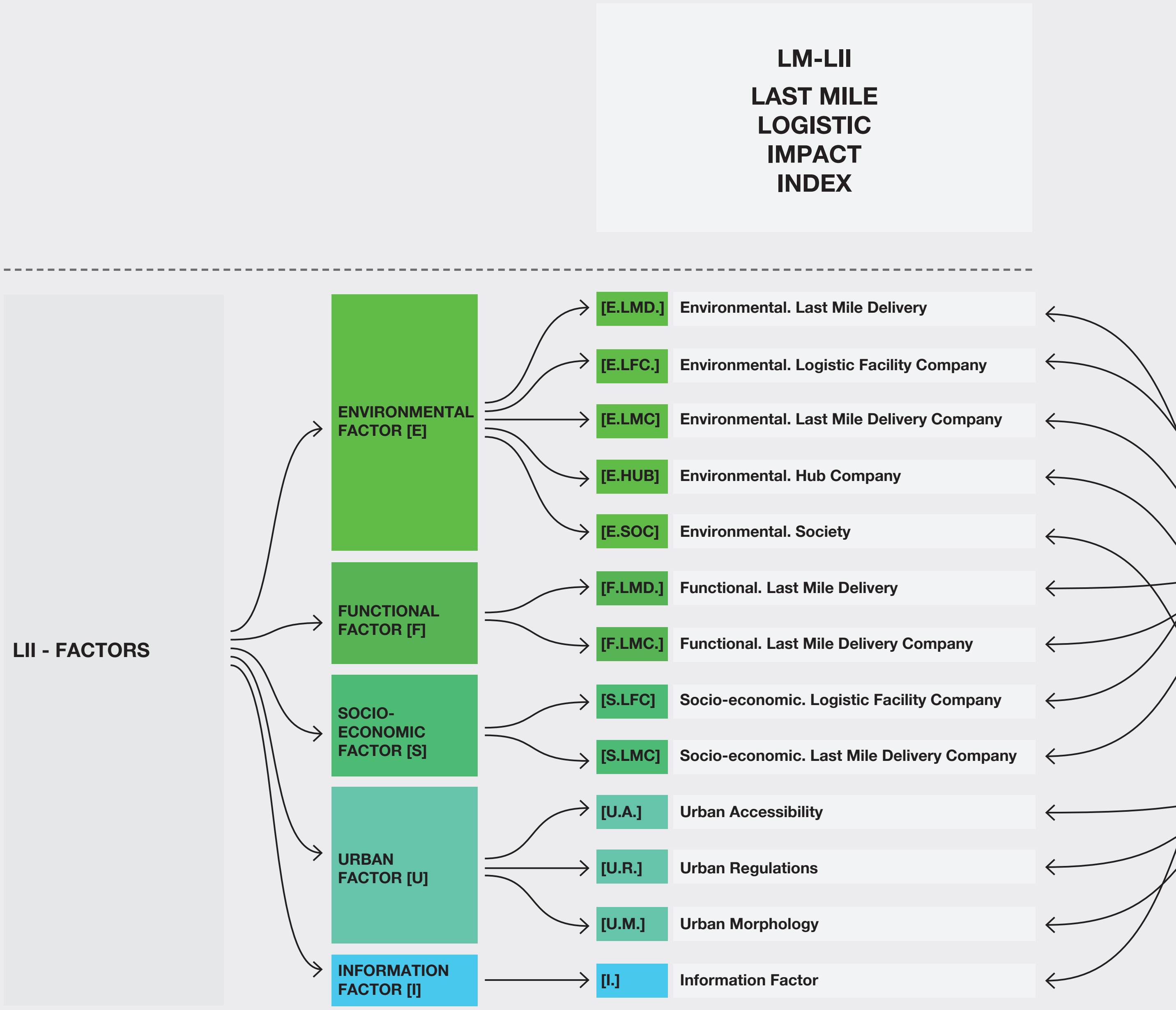
The diagram (left) summarizes the flow of goods across the last-mile ecosystem formed by the built environment of the city in relation to different stakeholders.



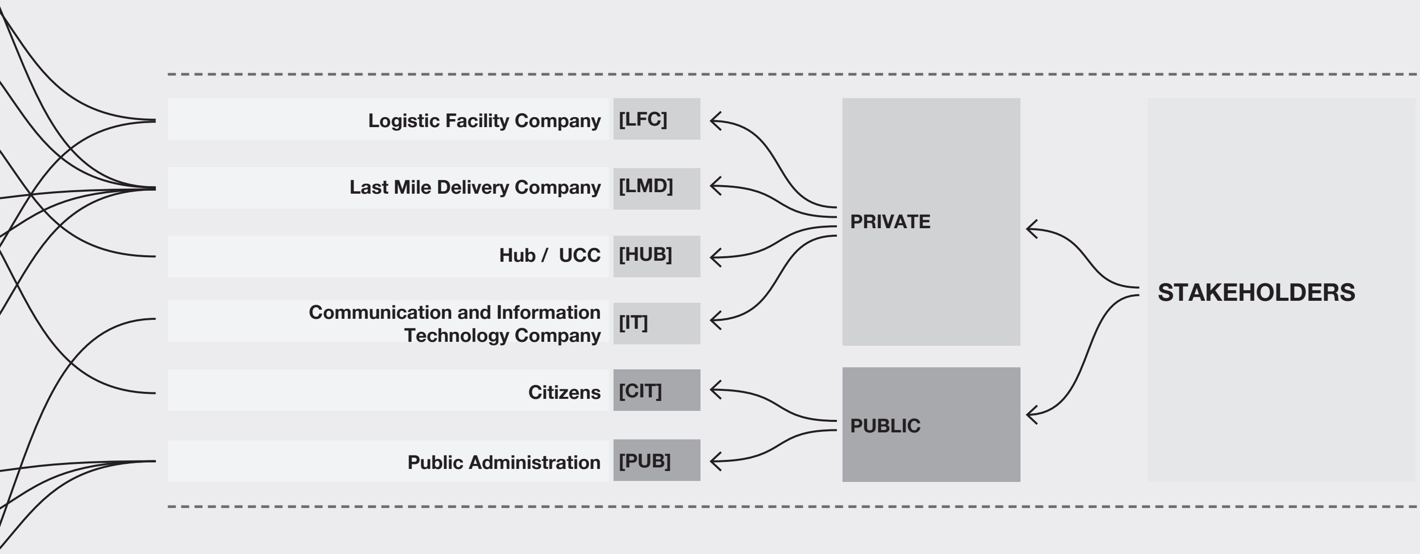
Last-Mile impact factors

6.6. The last-mile Impact factors.

The flow of goods across the last-mile ecosystem has different types of impacts on the city. Traditionally, the logistic literature has developed mathematical models based on environmental and functional factors. The challenges brought on by global warming have placed GHG emissions at the top of the list of concerns, together with other environmental factors such as noise levels.
To evaluate the real impact of the last-mile delivery is important to approach it from a holistic point of view. The environmental factors are just a part of a wide range of parameters, which include socioeconomic and urban aspects. Due to the high complexity of the last-mile ecosystem, all factors must be evaluated in parallel.
The definition of an index to evaluate the behavior of a system is not something new. Nowadays, many certification systems analyze the impact of a building on the environment. These measures, such as Beeam, Leed, WELL, or Gresb, while not perfect, are a way to contrast and compare approaches and performance. Likewise, it is easier for the public and policy officials to understand and implement widely accepted standards and seek their implementation.
After a careful analysis of existing certification systems, we have carefully defined a group of factors adapted to the last-mile ecosystem. The five factors are environmental, functional, socioeconomics, urban, and information and communication. Each one of these factors is subsequently broken down into sub-factors according to the stakeholders and the built environment.
The environmental parameters evaluate the impact of the last-mile delivery in terms of sustainability in its broadest sense. This factor includes all the pollution produced concerning the delivery, including air pollution (GHG emissions), noise pollution, and visual pollution (street presence). It also evaluates the sustainable design of the infrastructure as the warehouses, in terms of operational energy, embodied energy, or waste treatment. Finally, it includes all e Green Logistic Management Practices (GLMP), and the role of the final client, in relationship with the delivery time, packaging, and active pick-up/return.
The functional parameters are related to the efficiency of the delivery based on time, distance, and optimization. These factors consider delivery and peak hours, vehicle and circuit optimization, and fleet efficiency.
The socio-economic parameters evaluate the type of labor involved in the processes and the community involvement within the last-mile ecosystem. The socio-economic factor further considers the collaborative and sharing economy within city logistics.
The urban parameters evaluate the characteristics of the urban structure according to different sub-factors such as accessibility, public policies, and architectural typologies. The accessibility sub-factor analyzes how the urban structure supports the flow of goods, depending on the density, urban morphology, and loading and unloading areas. The urban regulations, codes, and restrictions include the role of the public administration. The architectural typologies evaluate how different building types support the delivery of goods.
The information parameters include all the information and communication technologies (ICTs) used across the last-mile delivery, tracing and tracking the whole supply chain process, optimizing delivery, or sharing resources.



Last-Mile impact factors and stakeholders


Logistic Facility Company
[LFC]
Last Mile Delivery Company
[LMD]
Hub / UCC
[HUB]
Communication and Information Technology Company
[IT]
Citizens
[CIT]
Public Administration
[PUB]
PRIVATE
PUBLIC
STAKEHOLDERS

E. ENVIRONMENTAL FACTORS. LM-DELIVERY / LOGISTIC FACILITIES / HUB / CITIZENS

ENVIRONMENTAL FACTOR- LM-DELIVERY (E.LMD)

E.LMD.1. Vehicle GHG Emissions.
E.LMD.2. Speed Vehicle.
E.LMD.3. Vehicle Age.
E.LMD.4 Type of energy source.
E.LMD.5. Total LM-GHG Emissions.
E.LMD.6. Noise Pollution.
E.LMD.7. Street Presence.
E.LMD.8. Last mile pollution impact reduction.
E.LMD.9. Capacity to adapt to future changes in city infrastructure.

ENVIRONMENTAL FACTOR- LOGISTIC FACILITY COMPANY. (E.LFC.)

E.LFC.1. Sustainable Infrastructure design.
E.LFC.2. Green Logistic Management Practices (GLMP)
E.LFC.3. Training for employees.
E.LFC.4. Publishing Sustainability Annual Report.

ENVIRONMENTAL FACTOR- LM-DELIVERY COMPANY (E.LMC.)

E.LMC.1. Sustainable Operational Strategies.
E.LMC.2. Training for employees.
E.LMC.3. Accident risk.
E.LMC.4. Publishing Sustainability Annual Report.
E.LMC.5. Building Green Partnership with clients.

ENVIRONMENTAL FACTOR- HUB COMPANY. (E.LFC.) (not for brownfield micro-hubs)

E.HUB.1. Sustainable Infrastructure design.
E.HUB.2. Green Logistic Management Practices (GLMP)
E.HUB.3. Training for employees.

ENVIRONMENTAL FACTOR- CITIZEN (E.CIT.)

E.CIT.1. Active (pick-up / return) / passive (at home delivery / return).
E.CIT.2. Sharing delivery (pick-up / return)
E.CIT.3. Sustainable delivery.
E.CIT.4. Sustainable packaging.

F. FUNCTIONAL FACTORS. LM-DELIVERY / LM-COMPANY

FUNCTIONAL FACTOR- LM-DELIVERY (F.LMD.)

F.LMD.1. Delivery hours.
F.LMD.2. Vehicle optimization.
F.LMD.3. Leg distance / time.
F.LMD.4. Circuit optimization.
F.LMD.5. Parcels handled per hour / per distance.
F. LMD.6. Vehicle Changes

FUNCTIONAL FACTOR- LM-DELIVERY COMPANY (F.LMC)

F.LMC.1. Fleet Information.
F.LMC.2. Fleet Efficiency.
F.LMC.3. Fleet Diversity.
F.LMC.4. Warehouse optimization.

S. SOCIO-ECONOMIC FACTORS. ECONOMY AND PLACE MAKING. LOGISTIC FACILITY COMPANY. (S.LFC) / LM-DELIVERY COMPANY (S.LMC)

SOCIO-ECONOMIC. LOGISTIC FACILITY COMPANY. (S.LFC)

- S.LFC.1. Permanent vs Temporary Employees.
- S.LFC.2. Social Infrastructure Design.
- S.LFC.3. Community Involvement.
- S.LFC.4. Collaborative Storage.

SOCIO-ECONOMIC. LM-DELIVERY COMPANY (S.LMC)

- S.LMC.1. Permanent vs Temporary Employees.
- S.LMC.2. Reduction of in-house costs.
- S.LMC.3. Collaborative City Logistics.
- S.LMC.4. Community Involvement.

SOCIO-ECONOMIC. INFORMATION and COMMUNICATION TECHNOLOGY COMPANY (S.IT.)

- S.IT.1. Permanent vs Temporary Employees.
- S.IT.2. Community Involvement.

U. URBAN FACTORS

URBAN ACCESSIBILITY. (UA)

- UA.1. Density / Population.
- UA.2. Urban Morphology / Architectural Typology.
- UA.3. Density of Loading and Unloading Areas.
- UA.4. Distance between Loading and Unloading Areas.
- UA.5. Loading and Unloading Areas Characteristics.
- UA.6. Street Crossing Distance.
- UA.7. Density and distance of doorways (residential) per block.
- UA.8. Density and distance of doorways (commercial) per block.

URBAN REGULATIONS. PUBLIC ADMINISTRATION. (UR)

- UR.1. Type of Urban regulations- City Logistics.
- UR.2. Loading and Unloading areas Regulation.
- UR.3. Urban Mobility Restrictions. Emissions.
- UR.4. Urban Mobility Restrictions. Low Impact Zones.

URBAN MORPHOLOGY- ARCHITECTURAL TYPOLOGY

- UM.1. Building Logistic Space.

I.INFORMATION AND COMUNICATION TECHNOLOGY FACTORS.

- ICT.1. Supply chain traceability (SCT).
- ICT.2. IT platform.
- ICT.3. Public Administration.

6.7. Implementation of the last-mile impact factors.

As said above, each factor has been broken down into several sub-factors, to provide a numerical value, which is based on a unit of measurement.

The units are related to the evaluation of the impact, and they can be either standard units as g/km CO_2, dB, m3, or absolute values. In some cases, the value is binary (0-1), and in others, the value is obtained through the application of a formula.

A description of each sub-factor and its calculation and application is listed in the following pages.

E. ENVIRONMENTAL FACTORS

LM-DELIVERY (E.LMD)	Measurement	Formula	Value
Basically, the environmental factors for the Last Mile Delivery evaluate the impact of vehicles on the different forms of pollutions as air, noise, and visual pollution.			
E.LMD.1. Air Pollution: vehicle GHG Emissions. GHG emissions produced in transport, with special focus on CO_2 emissions. For most vehicles, this factor is given g/km CO_2, for a speed vehicle at 100 km/h. Renewable factor (Check with Iberdrola) Due to the Return Factor (returning the vehicle to the origin point) it is necessary to increase a 20% the GHG emissions. In the case of a EV, it is important to check the % of renewable energy for electricity production.	Quantity factor. *g/km CO_2* *g/km (other GHG)*	Absolute value	0-1
E.LMD.2. Air and noise pollution: vehicle age. The age of the vehicle is an important factor to determine its efficiency, in terms of emissions, noise, risk of accident…	Quantity Factor	1-3 years (1) 4-7 years (0,5) 7-10 years (0,25) >10 years (0)	0-1
E.LMD.3. Air and noise pollution: speed vehicle. GHG emissions are related with vehicle speed. More speed means more emissions, although very low speed also means more emissions. It is important to know the average speed, the highest (how much time/ distance over 100 km/h) and lowest (how much time/distance lower than 100 km/h).	Quantity factor.	Relative value The formula includes the average speed / highest speed over 100 km/h per time-duration / lowest speed than 100 km/h per time-duration	0-1
E.LMD.4. Air and noise pollution: type of energy source. Renewable / fossil	Binary	0- Fossil 1- Renewable	0-1
E.LMD.5. Air pollution: total LM-GHG Emissions. Last-Mile total GHG emissions, based on the most efficient GHG emissions.	Quantity factor	CO_2 x km x average speed	0-1
E.LMD.6. Noise Pollution. Noise pollution is a multi-factor based on the following: - Motor vehicle (combustion vs electric) - Vehicle Speed - Type of pavement - Type of unloading	Quantity factor. *dB*	Multifactors: - Motor vehicle - Vehicle Average Speed. - Vehicle average speed in LI zones. - Type of unloading. - Type of trolleys	0-1

E.LMD.7. Visual Pollution. Visual pollution is based on the street presence of the vehicle, according to its volume.	Quantity factor. m^3	Relative value	0-1
E.LMD.7. Last mile pollution impact reduction. Strategies and actions for the reduction of emissions and congestions produced from other vehicles not involved in the Last-Mile delivery.	Quantity factor,	Relative value. Presence or non-presence of cars.	K?
E.LMD.8. Adaptability for pollution restrictions. Capacity to adapt to future changes in city infrastructure, based on pollution restrictions.	Quantity factor	Availability / possibility of: - EV - IT platform. - Collaborative logistic	0-1

E. ENVIRONMENTAL FACTORS

Stakeholder: LOGISTIC FACILITY COMPANY (E.LFC.)	Measurement	Formula	Value
The environmental factors for the Logistic Facility Company evaluates the sustainable design of the infrastructure (warehouses), and the Green Logistic Management Practices (GLMP).			
E.LMD.1. Sustainable Infrastructure design. This factor evaluates the sustainable design of the Logistic Facillity (warehouse) based on the following factors: *Brownfield / Greenfield* - Existing or new building. *Operational energy:* - % of renewable energy (company supplier) - % renewable production energy. - efficiency / smart consumption. *Embodied energy:* - % of materials with low carbon emissions. - % of Modern Construction Methods (MCM) - Materials Life Cycle Assessment (LCA) *Charging points:* - % of renewable energy for EV charging points. - % renewable production energy. *Passive measures:* - Passive measures (orientation, sun radiation, thermal insulation, cross-ventilation…) *Waste Collection:* - % of recycled waste. *Water:* - % of recycled water. - separative supply and collection of rain, grey and waste water. *Biodiversity:* - % of Green Areas. *Green Certification:* - Type and level of Green Certification.	Quantity factor.	Each subfactor has a value between 0-1 Brownfield / Greenfield (0-1) Operational (0-1) Embodied (0-1) Charging (0-1) Passive (0-1) Waste (0-1) Water (0-1) Biodiversity (0-1) Green certif. (0-1)	0-10
E.LMD.2. Green Logistic Management Practices (GLMP). The Green Logistic Management Practices includes the following strategies and actions: - Director of Sustainability. - Establishing Sustainable Long-term goals. - Green information system processing / sharing.	Quantity factor.	- Director (0,4) - Long-term (0,3) - Green Info (0,3)	0-1
E.LMD.3. Training for employees and clients. This factor evaluates the training in sustainability and safety of employees and clients: - Sustainability - Safety	Quantity factor.	- Sustainability (0,5) - Safety (0,5)	0-1
E.LFC.4. Publishing sustainability annual report This factor evaluates the publishing of a sustainability annual report, with easy access to download it.	Binary	Yes- No	0-1

E. ENVIRONMENTAL FACTORS

Stakeholder: **LM-DELIVERY COMPANY (E.LMC.)**	**Measurement**	**Formula**	**Value**
The environmental factors for the Logistic Delivery Company evaluates the Green Logistic Management Practices (GLMP).			
E.LMC.1. Green Logistic Management Practices (GLMP). The Green Logistic Management Practices includes the following strategies and actions: - Director of Sustainability. - Establishing Sustainable Long-term goals. - Green information system processing and sharing.	Quantity factor.	- Director (0,4) - Long-term (0,3) - Green Info (0,3)	0-1
E.LMD.2. Training for employees and clients. This factor evaluates the training in sustainability, safety and friendliness of employees and clients.	Quantity factor.	- Sustainability (0,5) - Safety (0,5)	0-1
E.LMD.3. Accident risk. This factor evaluates the risk of accident based on the following aspects: - Track record. - Number of vehicles / hours driving - Driver's experience. - City risk.	Quantity factor	- Record (0,25) - Vehicles / Drivers (0,25) - Experience (0,25) - City Risk (0,25)	0-1
E.LMD.4. Publishing sustainability annual report This factor evaluates the publishing of a sustainability annual report, with easy access to download it.	Binary	Yes- No	0-1
E.LMD.5. Building Green Partnerships with clients. This factor encourages building Green Partnership with clients in terms of: - Packaging. Type of material (recycle and recyclable) and optimization of the package. - Time delivery. Avoiding 24 hours delivery and peak times. - Client's pick-up and return. Encouraging clients to pick-up and return in hubs, PUDOS, UCC. - Return Agreements with clients.	Quantity factor	- Packaging (0,25) - Time (0,25) - Pick-up (0,25) - Return (0,25)	0-1

E. ENVIRONMENTAL FACTORS

Stakeholder: **HUB / UCC COMPANY (E.HUB.)** **(not for brownfield micro-hubs)**	**Measurement**	**Formula**	**Value**
The environmental factors for the Logistic Facility Company evaluates the sustainable design of the infrastructure (warehouses), and the Green Logistic Management Practices (GLMP).			
E.HUB.1. Sustainable Infrastructure design. This factor evaluates the sustainable design of the Logistic Facillity (warehouse) based on the following factors: *Brownfield / Greenfield* - Existing or new building. *Operational energy:* - % of renewable energy (company supplier) - % renewable production energy. - efficiency / smart consumption. *Embodied energy:* - % of materials with low carbon emissions. - % of Modern Construction Methods (MCM) - Materials Life Cycle Assessment (LCA) *Charging points:* - % of renewable energy for EV charging points. - % renewable production energy. *Passive measures:* - Passive measures (orientation, sun radiation, thermal insulation, cross-ventilation…) *Waste Collection:* - % of recycled waste. *Water:* - % of recycled water. - separative supply and collection of rain, grey and waste water. *Biodiversity:* - % of Green Areas. *Green Certification:* - Type and level of Green Certification.	Quantity factor.	Each subfactor has a value between 0-1 Brownfield / Greenfield (0-1) Operational (0-1) Embodied (0-1) Charging (0-1) Passive (0-1) Waste (0-1) Water (0-1) Biodiversity (0-1) Green certif. (0-1)	0-10
E.HUB.2. Green Logistic Management Practices (GLMP). The Green Logistic Management Practices includes the following strategies and actions: - Director of Sustainability. - Establishing Sustainable Long-term goals. - Green information system processing / sharing.	Quantity factor.	- Director (0,4) - Long-term (0,3) - Green Info (0,3)	0-1
E.HUB.3. Training for employees and clients. This factor evaluates the training in sustainability and safety of employees and clients.	Quantity factor.	- Sustainability (0,5) - Safety (0,5)	0-1
E.HUB.4. Publishing sustainability annual report This factor evaluates the publishing of a sustainability annual report, with easy access to download it.	Binary	Yes- No	0-1

E. ENVIRONMENTAL FACTORS

Stakeholder: CITIZENS (CIT)	Measurement	Formula	Value
The environmental factors for society encourage the active role of the final client in the delivery.			
E.CIT.1. Active / passive. Active pick-up / return of final client. Passive means at home delivery	Binary	Passive / Active	0-1
E.CIT.2. Sharing delivery. Sharing the Pick-up / Return with another client.	Binary	Yes- No	0-1
E.CIT.3. Sustainable Delivery The objective of this factor is to reduce the amount of freight transport, by the selection from the client of not to deliver in 24 hours and peak times.	Binary	Yes- No	0-1
E.CIT.4. Sustainable Packaging This factor encourage the selection from the client of a sustainable material for the packaging (recycle and recyclable) and the optimization of the package volume by putting together more than one delivery.	Binary	Yes- No	0-1

F. FUNCTIONAL FACTORS.

LM-DELIVERY (F.LMD.)	Measurement	Formula	Value
The functional factor for the Last Mile Delivery evaluates the efficiency and optimization of the shipping,			
F.LMD.1. Delivery Hours Delivery hours related to peak hours across the day as school times, office entrance…	Quantity factor or binary	0 (in peak hours) 1 (out of peak hours). Factor increases as the delivery is done far away from peak times.	0-1
F.LMD.2. Vehicle optimization. Goods transported related to maximum load / or volume of the vehicle. This factor punishes the transport of vehicles with few packages.	Quantity factor.	Kg / max. kg.	0-1
F.LMD.3. Legs distance / time. Distance and parts in the supply chain: - From warehouse to delivery. - From warehouse to hub - From hub to delivery	Quantity Factor	Km/ total time (Max-min) Limit?	0-1
F.LMD.4. Circuit optimization. Circuit optimized in terms of the shortest, number of deliveries, number of changes for delivery, share with others, stop time per delivery,…	Quantity factor.	Optimize circuit / real circuit	0-1
F.LMD.5 Parcels handled per hour / per distance. Number of parcels handled per hour. Number of parcels handled per distance.	Quantity factor.	Number of parcels / hour (0-5) Number of parcels / distance (0-5)	0-1
F.LMD.6. Parcels organization inside vehicle. System organization of the parcels inside the vehicle for a more efficient delivery. The organization of parcels must be synchronized with the order of the delivery.	Binary	Yes / No	0-1

F. FUNCTIONAL FACTORS.

LM-DELIVERY COMPANY (F.LMC.)	Measurement	Formula	Value
This factor evaluates the efficiency and optimization of the fleet and warehouses.			
Fleet			
F.LMC.1. Fleet information. Is there any delivery tracking information?	Binary	Yes- No	0-1
F.LMC.2. Fleet optimization. This factor evaluates the optimization of the fleet based on the following terms: - Load optimization - Circuit optimization - All vehicles delivering / vehicles parked	Quantity factor	Relationship.	0-1
F.LMC.3. Fleet Diversity. This factor evaluates the diversity of the fleet based on: - % of different type of vehicles (bikes, vans), for the adaptability to future changes (infrastructure, regulations) - % of low/high emissions. It is accepted any agreement with other shipping companies, with different vehicles.	Quantity factor.	% of the fleet.	0-1
Warehouse			
F.LMC.4. Warehouse optimization. Good stored related to the maximum storage of the warehouse.	Quantity factor	m3/ max. m3	

S. SOCIO-ECONOMIC FACTORS.

LOGISTIC FACILITY COMPANY (S.LFC.)	Measurement	Formula	Value
The socio-economic factors of the Logistic Facility Company evaluate the relationship with the employees, the community involvement and sharing strategies.			
S.LFC.1. Permanent vs Temporary employees. Relationship between permanent Employees and temporary Employees	Quantity Factor	% Permanent	0-1
S.LFC.2. Social Infrastructure Design. This factor evaluates the application of the concept of Park Life, where the employees and clients have some social infrastructures as: *Social facilities:* - Cafeterias / restaurants - Sport areas - Other social facilities. *Social actions:* - Social clubs or actions. - Other social actions.	Quantity factor.	Social facilities (0-0,5) Social actions (0-0,5)	0-1
S.LFC.3. Community Involvement. Community social actions.	Binary	Yes- No	0-1
S.LFC.4. Collaborative Storage. Agreements with other Logistic Facility Companies to optimize the facility.	Binary	Yes-No	0-1

S. SOCIO-ECONOMIC FACTORS.

LM DELIVERY COMPANY (S.LMC.)	Measurement	Formula	Value
The socio-economic factors of the Last-Mile Delivery Company evaluates the relationship with the employees, the community involvement and sharing strategies.			
S.LMC.1. Permanent vs Temporary employees. Relationship between permanent Employees and temporary Employees	Quantity Factor	% Permanent	0-1
S.LMC.2. Reduction of in-house costs. Strategies for reduction of in-house costs as optimization of packaging and spaces, and the application of ICTs to improve efficiency.	Quantity factor	Packing- Spaces- Information-	0-1
S.LMC.3. Collaborative City Logistics Agreements with other LM Delivery companies. Agreements with micro-HUBs. Agreements with other forms of delivery.	Quantity factor	Other LMC (0,5) HUBS (0,5)	0-1
S.LMC.4. Community Involvement. Community social actions and providing local services.	Binary	Yes- No	0-1

S. SOCIO-ECONOMIC FACTORS.

INFORMATION TECHNOLOGY COMPANY (S.IT.)	**Measurement**	**Formula**	**Value**
The socio-economic factors of the Information and Communication Technologies Company (ICTs) evaluates the relationship with the employees, the community involvement and sharing strategies.			
S.IT.1. Permanent vs Temporary employees. Relationship between permanent Employees and temporary Employees	Quantity Factor	% Permanent	0-1
S.IT.2. Community Involvement. Community Social Actions.	Binary	Yes-No	0-1
S.IT.3. Collaborative logistics. Application of strategies to enhance collaborative logistics.	Binary	Yes-No	0-1

U. URBAN FACTORS.

URBAN – ACCESIBILITY (UA)	Measurement	Formula	Value
The urban factors related with accessibility evaluate how the urban structure affects the last-mile delivery.			
UA.1. Density / Population Population per km2	Quantity Factor	To define reference value.	0-1
UA.2. Urban Morphology. Relationship between population, street pattern, street impedance.	Quantity Factor	To define reference value.	0-1
UA.3. Density of Loading / unloading areas Density of loading and unloading areas in terms of population.	Quantity factor. *Sqm loading / population*	To define reference value	0-1
UA.4. Distance between Loading / unloading areas Average distance between loading / unloading areas.	Quantity factor. *m*	Apart from the average, how can include the longest and shortest?	0-1
UA.5. Loading / unloading areas Characteristics. - Type of pavement. - Noise barrier - Visual barrier - Design improvement. - Benefits to the city. - Time	Quantity factor.		0-1
UA.6. Street crossing distance. Crossings together with traffic lights have a strong influence in delivery.	Quantity factor. *Average block longitude*		0-1
UA.7 Density and distance of doorways (residential) per block. Density of doorways (residential) per block Average distance between doorways	Quantity factor. *Number of loading / block distance* *Average distance between doorways*	Formula must include density and distance. If not, two different factors?	0-1
UA.8 Density and distance of doorways (commercial) per block. Density of commercial per block Average distance between commercials	Quantity factor. *Number of loading / block distance* *Average distance between doorways*	Formula must include density and distance. If not, two different factors?	0-1

U. URBAN FACTORS.

ARCHITECTURE TYPOLOGY (TYP)	Measurement	Formula	Value
This urban factor about architectural typology evaluates how buildings are prepared for the delivery.			
UR.1. Building Logistic Space. Availability of a specific space for Logistics.	Binary	Yes- No	0-1
UR.2. Building services. Presence of a janitor for pick-up and return.	Binary	Yes- No	0-1
UR.3. Access control. The presence of an access control affects the delivery times.	Binary	Yes- No	0-1

U. URBAN FACTORS.

URBAN – REGULATIONS. (UR) PUBLIC ADMINISTRATION	Measurement	Formula	Value
This factor evaluates the role of the local public administration in terms of urban regulations, codes and restrictions.			
UR.1. Urban Regulations City Logistics. Detailed and specific regulation for City Logistic	Binary	Yes- No	0-1
UR.2. Loading and Unloading Areas Regulations.	Binary	Yes- No	0-1
UR.3. Urban Mobility Restrictions. Emissions. GHG emission Restrictions. Sustainable Local Regulations for City Logistics.	Binary	Yes- No Type of restriction.	0-1
UR.4 Urban Mobility Restrictions. Low Impact Zones. Pedestrian areas, or areas limited to certain type of traffic.	Binary or percentage. %	Difficult to measure. It could be a % of streets limited to traffic in the neighborhood.	0-1
UR.5. Active role of the local public administration in City Logistics. Studies, committees, task forces about city logistics ordered by the local public administration.	Binary	Yes- No	0-1

ICT. INFORMATION AND COMUNICATION TECHNOLOGY FACTORS.

INFORMATION AND COMUNICATION TECHNOLOGIES (ICT)	**Measurement**	**Formula**	**Value**
This factor evaluates the application and implementation of ICTs tools.			
ICT.1. Supply chain traceability. (SCT) Track information of the LM-Delivery about time, distance, geolocalization… Public Information.	Quantity factor	Factors:	0-1
ICT.2. Collaborative ICTs Platform Sharing information / co-work/ crowd logistic/ platform.	Binary	Yes- No	0-1
ICT.3. Public administration. Active role of the public administration to provide data collection and visualization about Loading / Unloading zones in real time, restrictions…	Binary	Yes- No	0-1

07: Scenario

os

7. Scenarios

7.1. Methodology

Eleven different scenarios were proposed for modeling and evaluation, each aiming to visualize and understand the impact of specific strategies on the last mile delivery. The data used for modeling the scenarios were obtained from the analysis of the literature reviewed in combination with data gathered from the field studies.

Within the selected areas, 20 stops were randomly chosen to represent both private citizens and commercial ventures. This number, based on the data collected in our field studies, was used because it provides a scalable model of the last-mile delivery over one day.
Our proposed scenarios tackle a wide range of possibilities, most dealing with the reduction of the environmental footprint, while at the same time positively impacting city life.

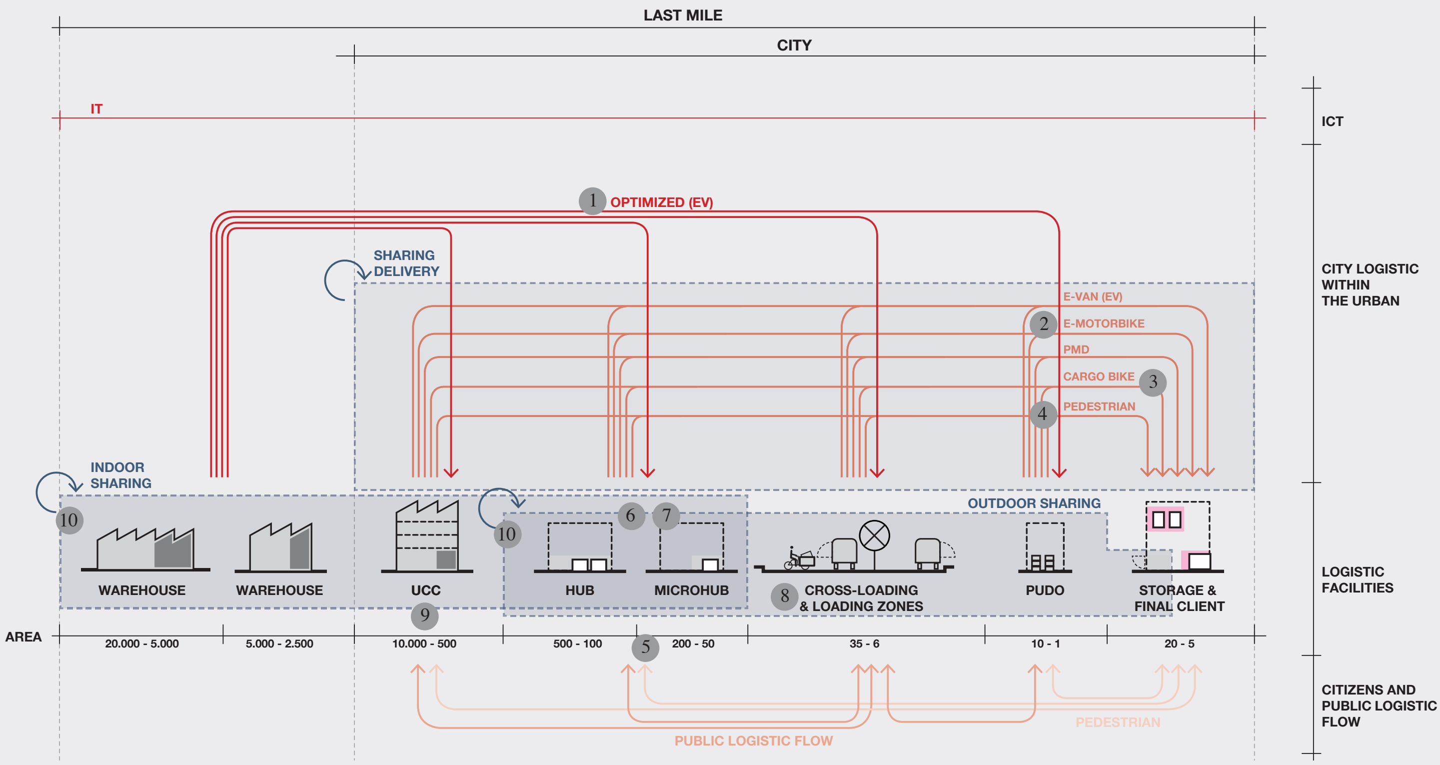
Except for the Business-As-Usual model (BAU), all scenarios were developed optimizing the driver's route. The optimization was carried out through an algorithm, which in essence calculated the shortest distance between two points. By crossing data with the urban fabric, street type, traffic restrictions, and average traffic intensity an optimized route was then created. This data is available from the Open Maps platform, which creates models of traffic predictions for different periods, based on historical data collected via mobile devices. For example, this modeling technique can predict that certain roads will experience more traffic during rains, than other times of the year. This methodology is then applied over different modes of last-mile delivery.
The most relevant data for modeling the scenarios had to do with time, distance, and the disruptive presence of the street of logistics vehicles. They provided indicators of the performance of each scenario for its later evaluation by the LM-LII (Last-Mile Logistic Impact Index). The results obtained from the LM-LII allowed an objective comparison between models. The scenarios were calculated individually, but they open the possibility of exploring combinations between them, allowing the creation of hybrid models that can perform better in the LM-LII.

7.2. Objectives.

Focusing on the reduction of the impact of the last-mile delivery in the city, four questions were constantly asked throughout the process of modeling the scenarios:

- Circuit. How to get closer to the final delivery point with the minimum environmental impact?

- Vehicle. Which vehicles provide better balance in the trade-off between efficiency and environmental impact? There is a wide range of possibilities from different sizes of Vans (ICE or EV), cargo-motorcycle, cargo-bike, PMD,



Scenarios Modeled, Simulated and Evaluated

0. Business as Usual (BAU)
1. Optimized Circuit with Electric Van
2. Optimized Circuit with Electric Motorcycle
3. Optimized Circuit with Cargo-bike
4. Optimized Circuit with Pedestrian delivery
5. Microhubs with Pick-Up
6. Microhubs with Cargo-Bike delivery
7. Microhubs with Pedestrian delivery
8. Cross-Loading & Unloading zones
9. Urban Consolidation Centers
10. Optimization Platforms

and pedestrian delivery.

- Logistics Facility. Which type of logistics facility can be included in the last mile, between the last warehouse and the final delivery, to improve the efficiency and to reduce the environmental impact? There are several options, such as Urban Consolidation Centers, Hubs and micro-hubs, Smart Lockers, or loading and unloading areas.

- Urban Structure. Which delivery method performs better according to the specific urban structure?

- The last-mile delivery was approached from different scales, which included the scale of the city (from the last warehouse to the area of study), the scale of the neighborhood (the areas of the city center, city expansion area, and outskirts), and the small scale of the street. Obviously, these scales are interconnected, and it is required to approach them as a complex network under constant change.

7.3. Proposed Scenarios.

TThe following scenarios were analyzed and modeled, for later evaluation and comparison with the LM-LII. The Business as Usual, considered the scenario 0, is the benchmark for the modeling and comparisons:

Scenario 0- Business as Usual (BAU)

Scenario 1- Optimized route with Electric Van

Scenario 2- Optimized route with Electric Motorcycle

Scenario 3- Optimized route with Cargo-bike

Scenario 4- Optimized route with Pedestrian delivery

Scenario 5- Micro-hubs with pick-up

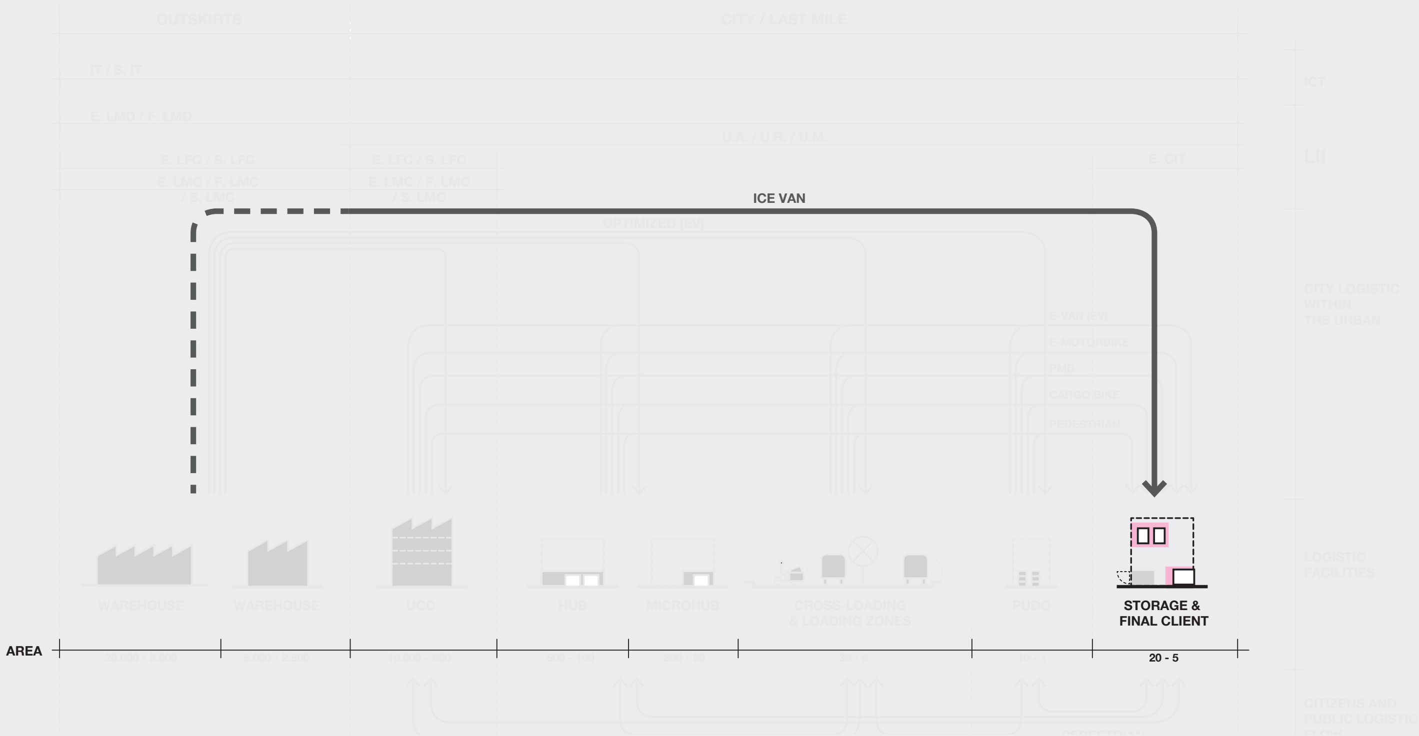
Scenario 6- Micro-hubs with bike delivery

Scenario 7- Micro-hubs with pedestrian delivery

Scenario 8- Cross-loading/unloading with pedestrian delivery

Scenario 9- Urban Consolidation Centers

Scenario 10- Optimization Platforms



0. Business as Usual (BAU) Scenario

7.3. Proposed scenarios
7.3.0. Business as Usual (BAU)

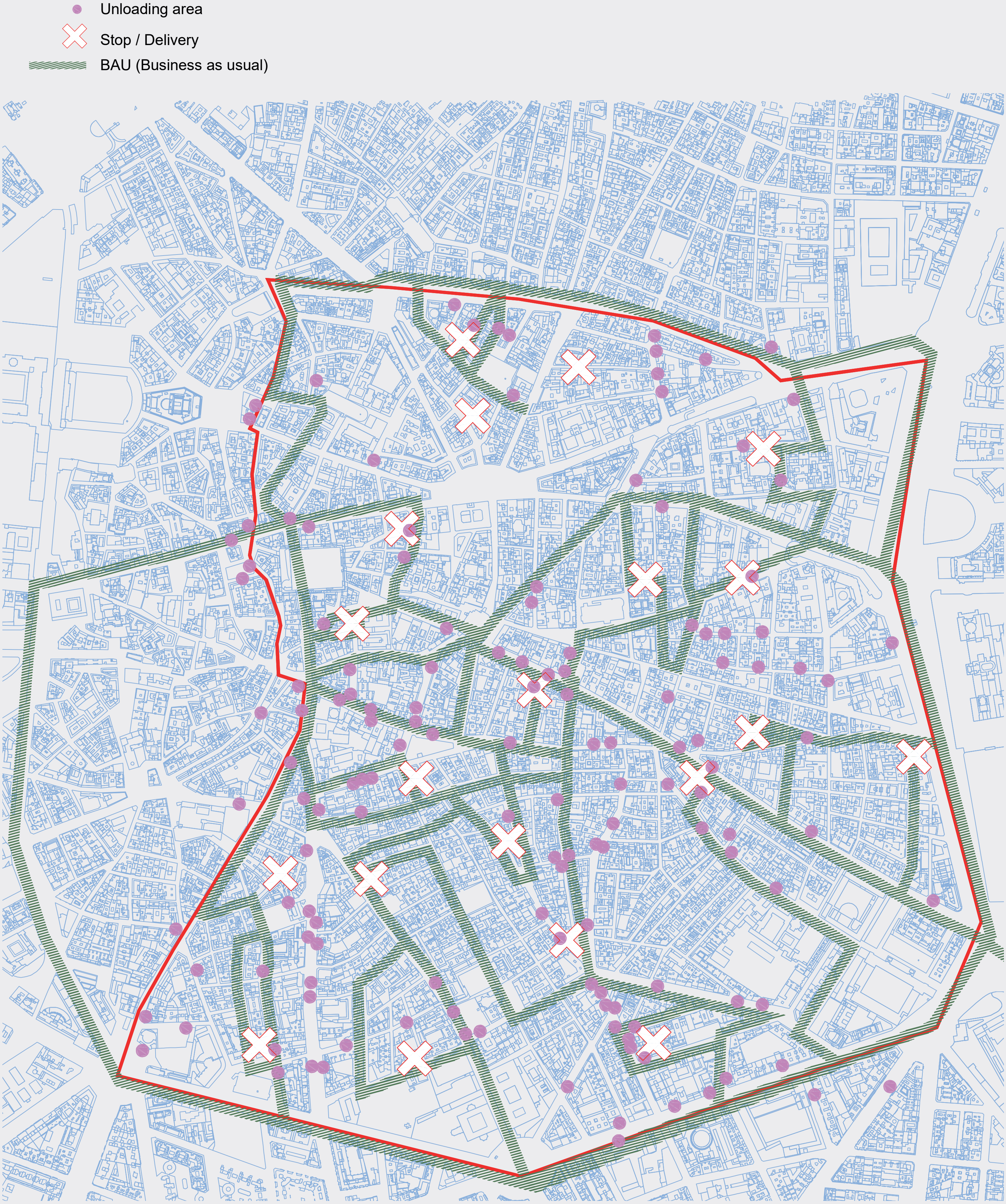
The first scenario is the BAU (Business As Usual) model, which was built and calibrated with the help of the data collected in the field studies. The BAU scenario looks at 20 deliveries in each of the three areas analyzed, for both Madrid and Barcelona. The premise of the BAU model resides in deliveries undertaken with the use of an ICE Van that leaves the last warehouse, crosses the city to reach the center of the study area, and begins its delivery process. In this scenario, we looked at delivery once the van has reached the center of a study area. In the final measurements of its performance, time and kilometers are added for its journey from the warehouse closest to the city to that point in the study area.

This scenario is the only one with a high C02 footprint, using data from the European Environmental Agency with measures and ICE Van typical emission at 158.4 CO2/km. The 20 delivery addresses were chosen at random, but with an even distribution throughout the neighborhood. Approximately 30% of the addresses correspond to commercial spaces and 70% to private residences. These proportions come from observations done in the field studies and the literature review.

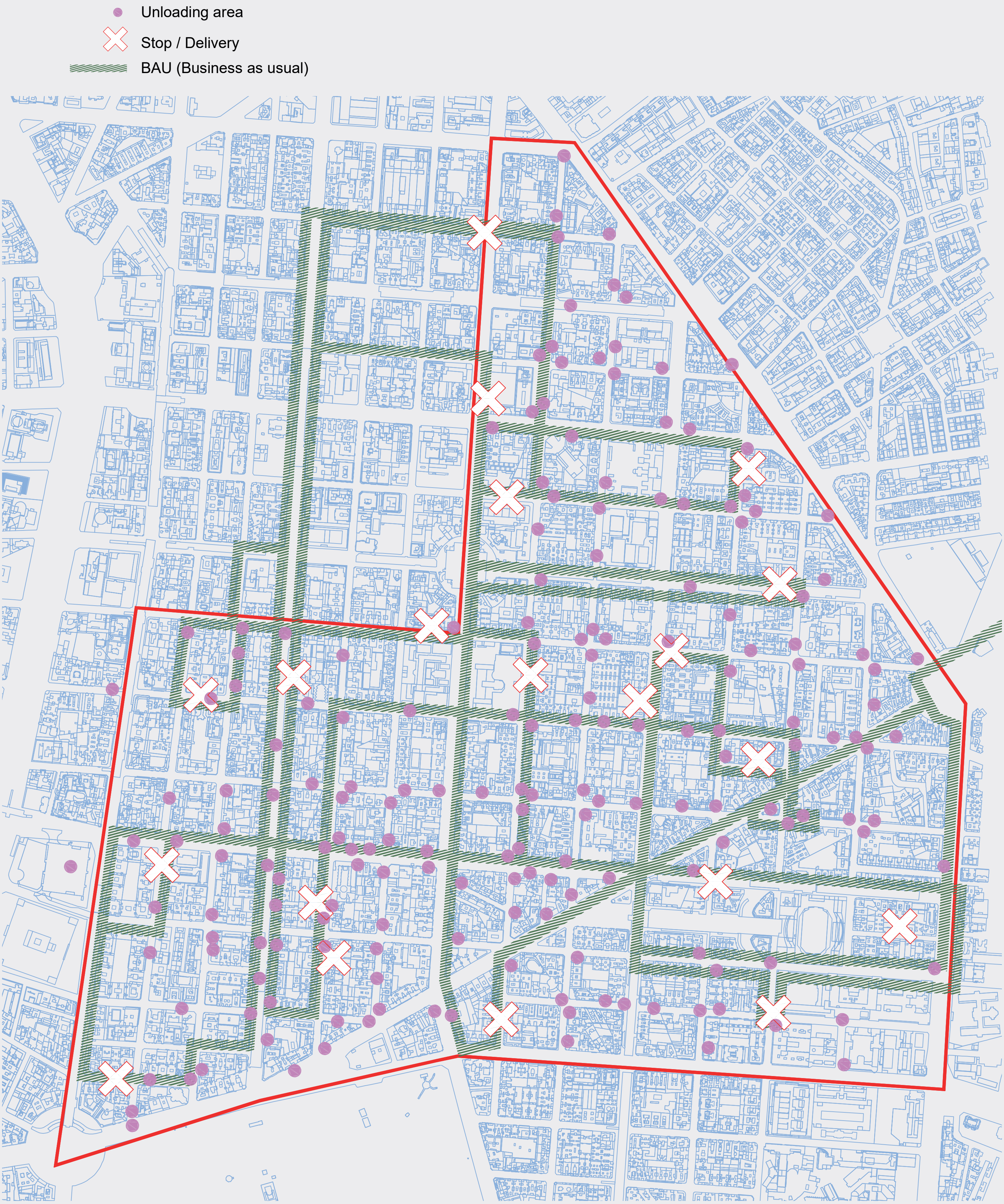
The order of deliveries is random, to mimic two existing realities: 1. the delivery companies in the field study do not use a circuit optimization tool and base their route purely on drivers' experience. 2. clients choose priority parameters of delivery when ordering a package and/or certain clients have only specific opening hours which disrupts the optimization of the route.

From a CO2 and noise pollution point of view, this scenario has the most negative environmental impact and it has the highest street presence.

Madrid
scale 1:10.000



Madrid
scale 1:10.000



Madrid
scale 1:20.000

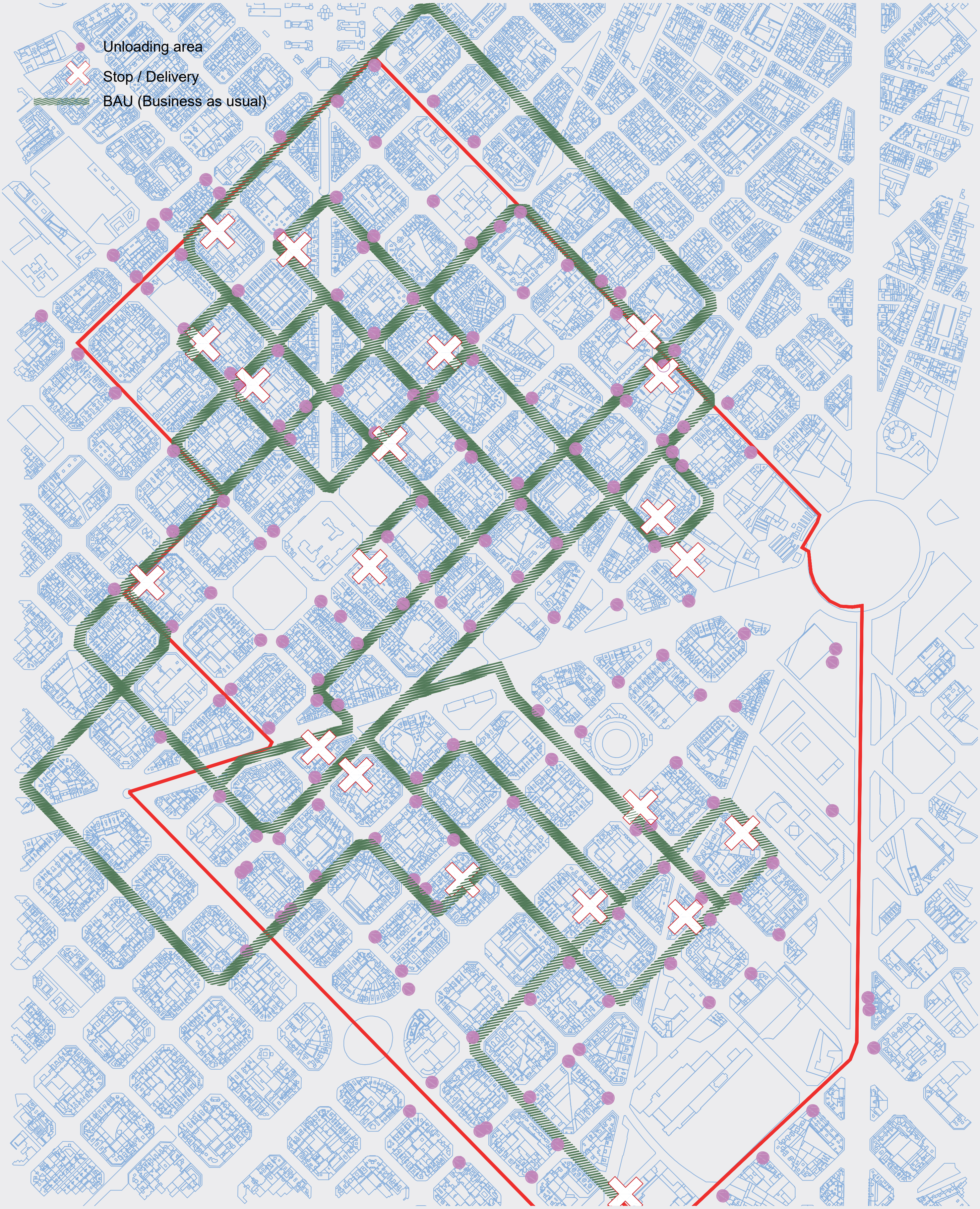
Barcelona
scale 1:10.000

Unloading area

Stop / Delivery

BAU (Business as usual)

Barcelona
scale 1:10.000

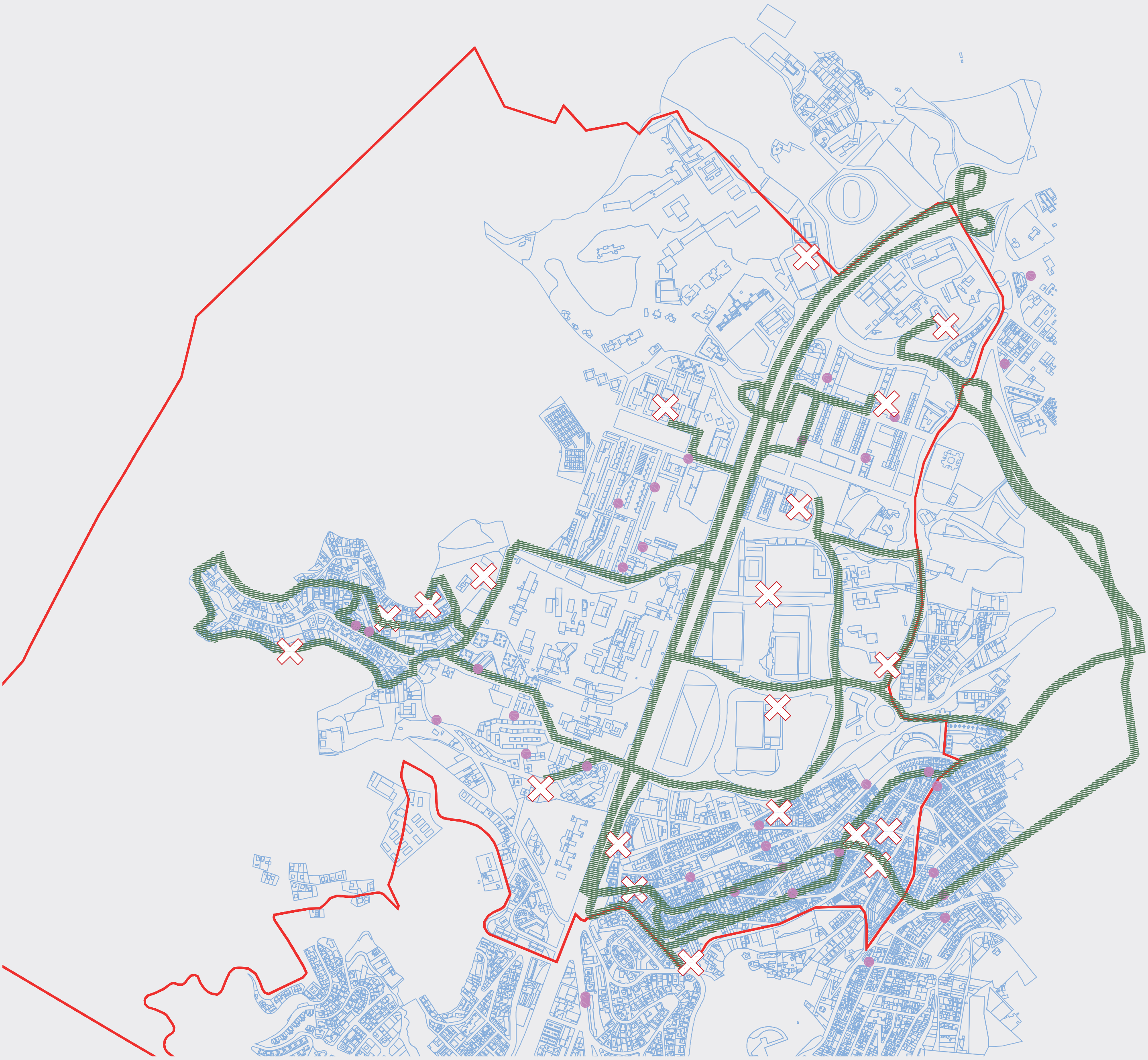


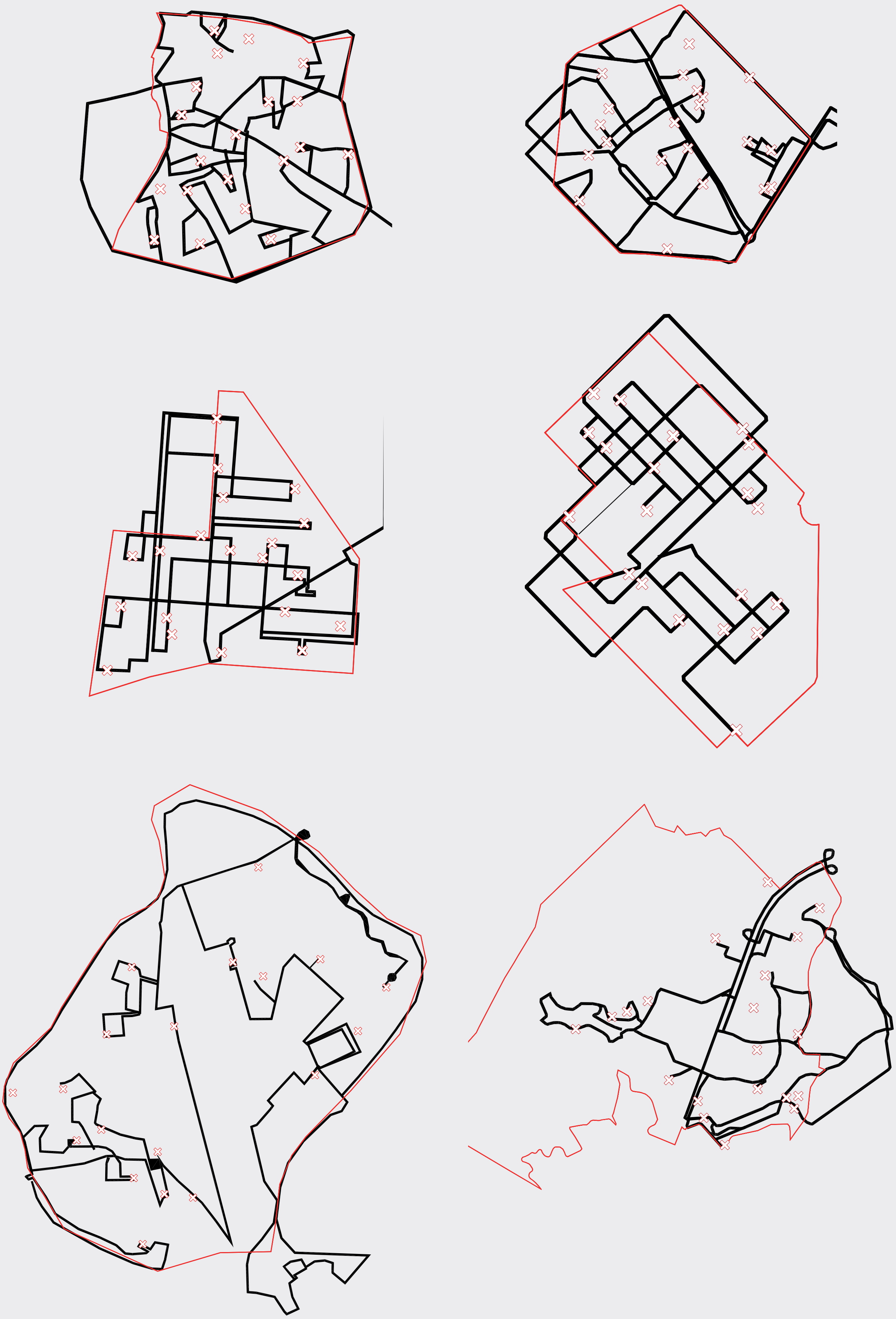
Barcelona
scale 1:15.000

Unloading area

Stop / Delivery

BAU (Business as usual)



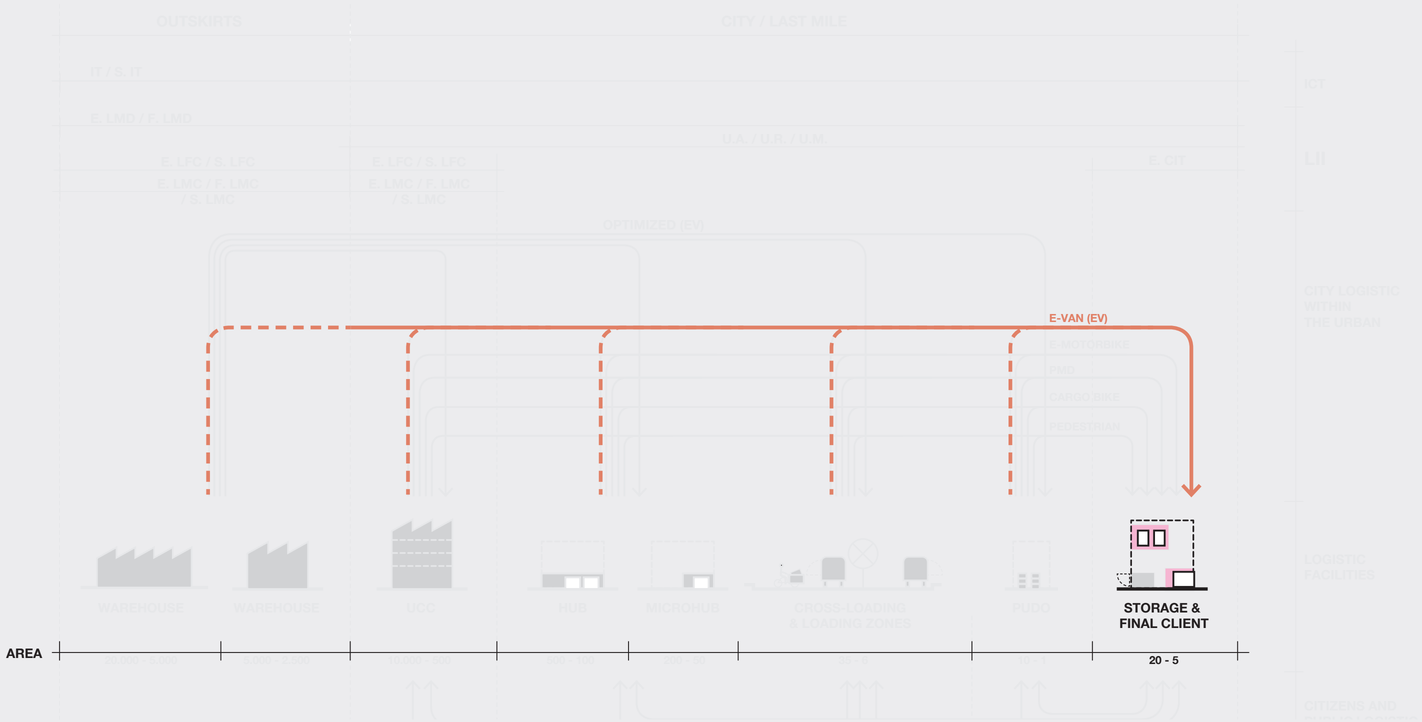


Business as Usual (BAU)
Conclusions:

The BAU model has the greatest impact on the city from an ecological and a social standpoint. From the 6 modeled scenarios in both cities, we can draw the following conclusions:

The distances traveled in the less dense areas of the cities are normally far greater than those closer to the city center and this is a direct link to the size population density of the urban area. In Madrid, the numbers related to distance traveled double in terms of kilometers between the city center and the outskirts. However, in the case of the center of Barcelona, distances traveled in the city center were longer than expected due to the many traffic restrictions and the street typology that forced the driver to take longer paths to complete deliveries.

Even if the distances traveled vary greatly between the urban areas studied, the time difference between them is insignificant, with the exception again of the city center of Barcelona. This exceptional case required such large distances to be traveled that it goes hand in hand with much longer delivery times. In other words, thinking of deliveries via van, where the low-density areas of outskirts of the cities lose in terms of kilometers, they gain for in terms of time. And this is because of the higher limit on speed, lesser number of pedestrianized areas, and overall fewer traffic restrictions and less traffic intensity.
In the BAU scenario, the ICE van enters the heart of the city. However, in the case of Madrid is not possible due to emissions restrictions in place creating low emissions zones where traffic is limited. This would be the case for many cities. The model we developed has made assumptions about such regulations in order to more correctly measure performance.



1. Optimised route with Electric Van Scenario

7.4. Proposed scenarios
7.4.1. Optimised route with Electric Van

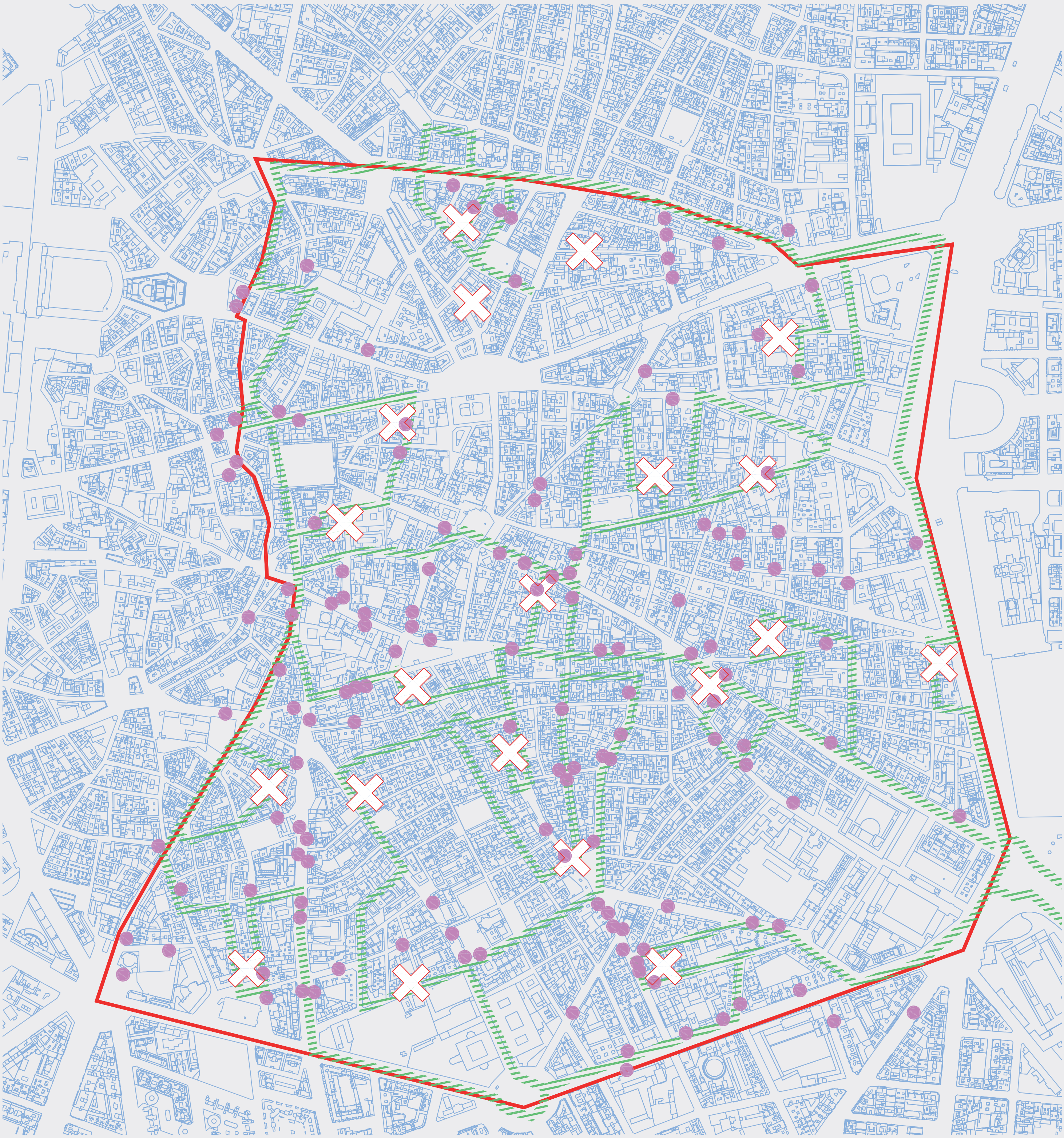
This scenario is similar to the baseline BAU model following the same path from the warehouse to the delivery area where it is confronted with the same 20 address drop-offs. However, this model proposes two radical changes. First, it is based on a fleet completely electric of vans and the driver receives an optimized route for the day. Electric vans reduce the C02 contamination to zero (when compared to the BAU model and not including calculations for the environmental costs of the manufacturing and shipping of the vehicle itself).

The driver with an optimized route reduces the number of kilometers traveled by an average of 35 % the kilometers. For example, we can cite an extreme case inside the Madrid grid Area. In this case, the BAU model resulted in 27.3km, while with the optimized model, the distance was only 13.,2km, a reduction of 52%. This reduction in kilometers traveled goes hand in hand with a reduction in the time spent on the road and the time between deliveries.   Even though electric vans still have a significant physical presence on the street, their lower speeds (10-20km/h, which match the average speeds of traffic inside the city) also mean a 10-decibel decrease in noise (M. Iversen, 2015) and therefore a less intrusive presence for the pedestrians transiting the area and residents living there.

In addition, this data varies based on the type of street pavement.

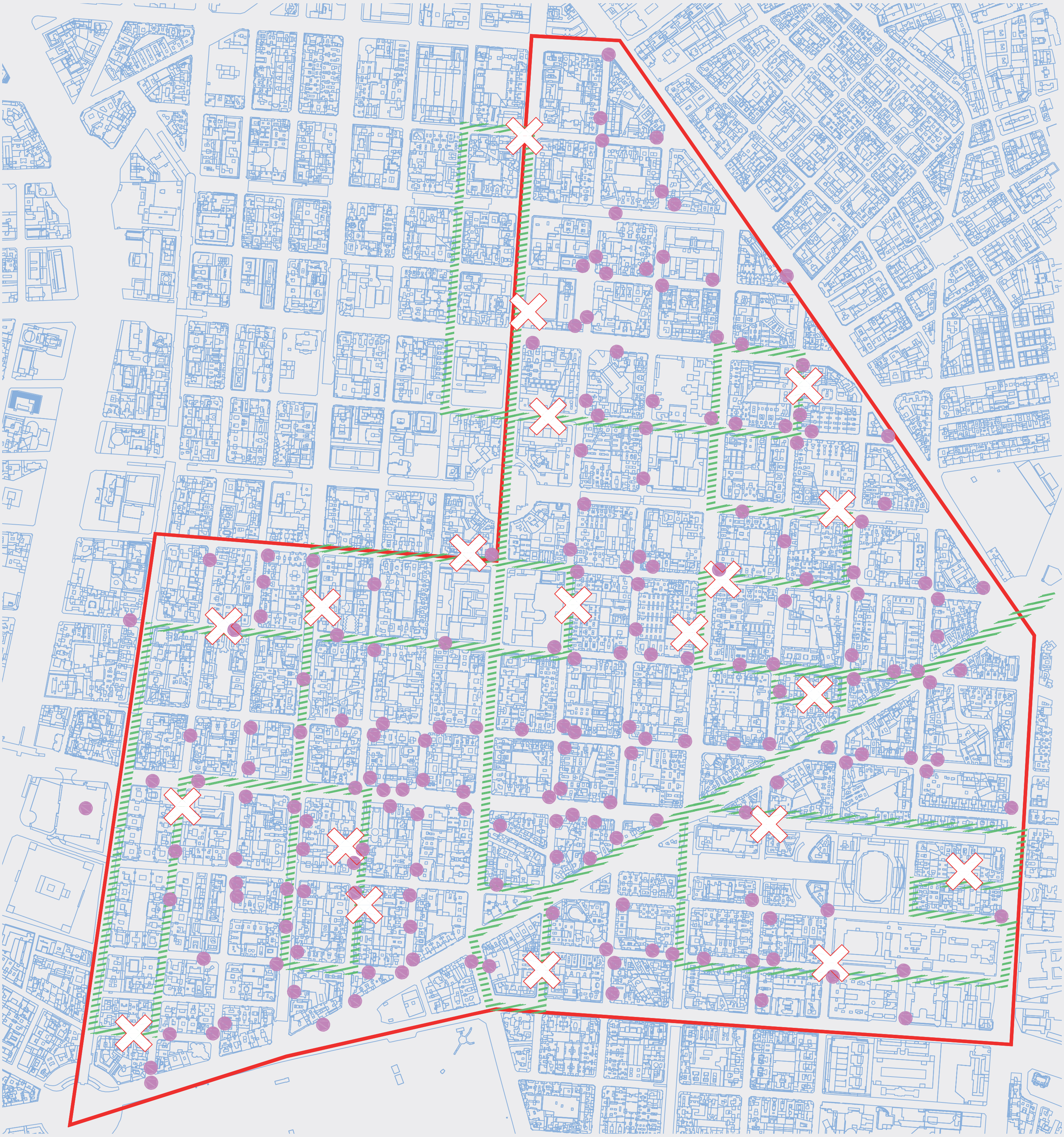
Madrid
scale 1:10.000

Unloading area
Stop / Delivery
Electric Vehicle
Zone Boundary

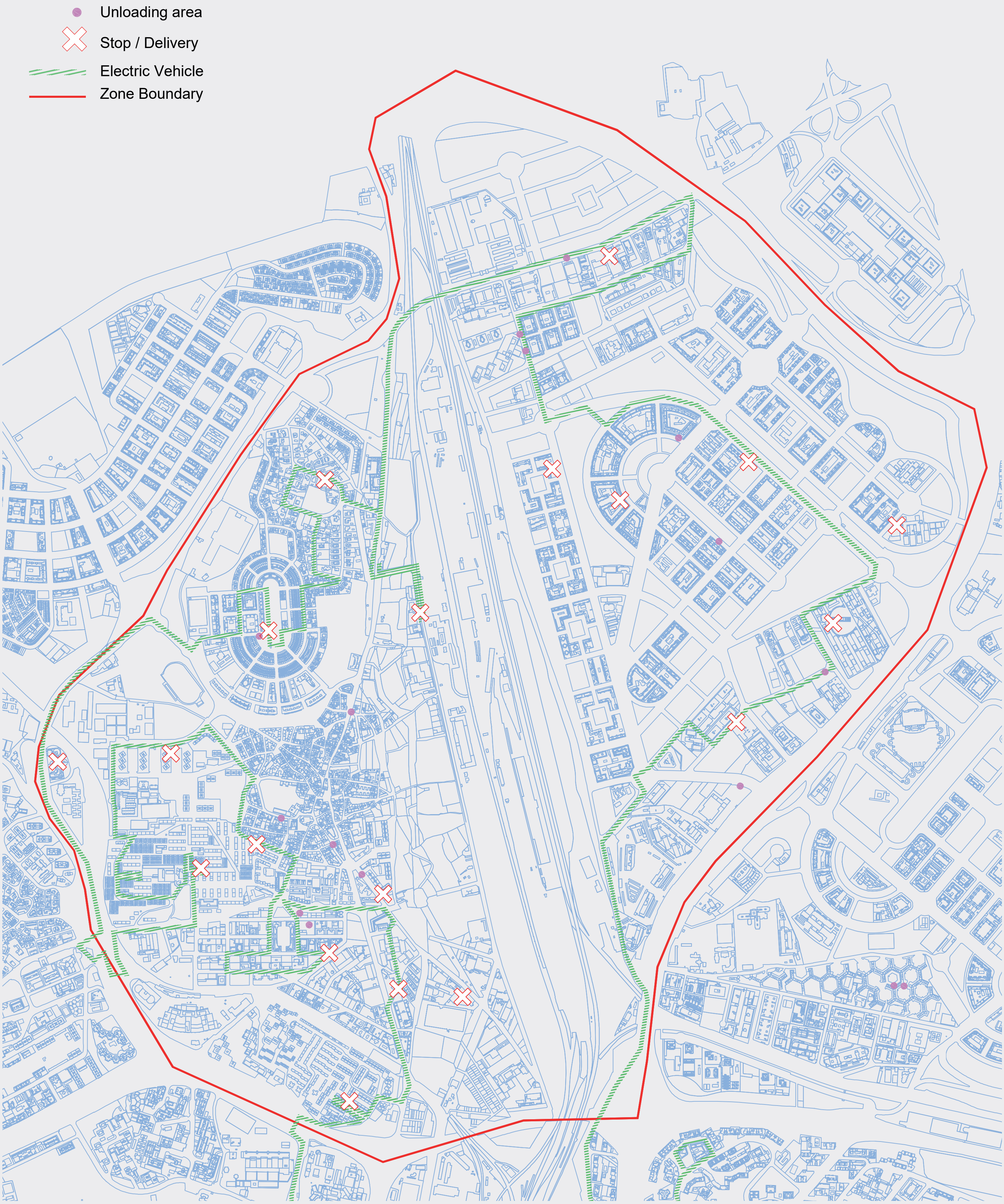


Madrid
scale 1:10.000

Unloading area
Stop / Delivery
Electric Vehicle
Zone Boundary

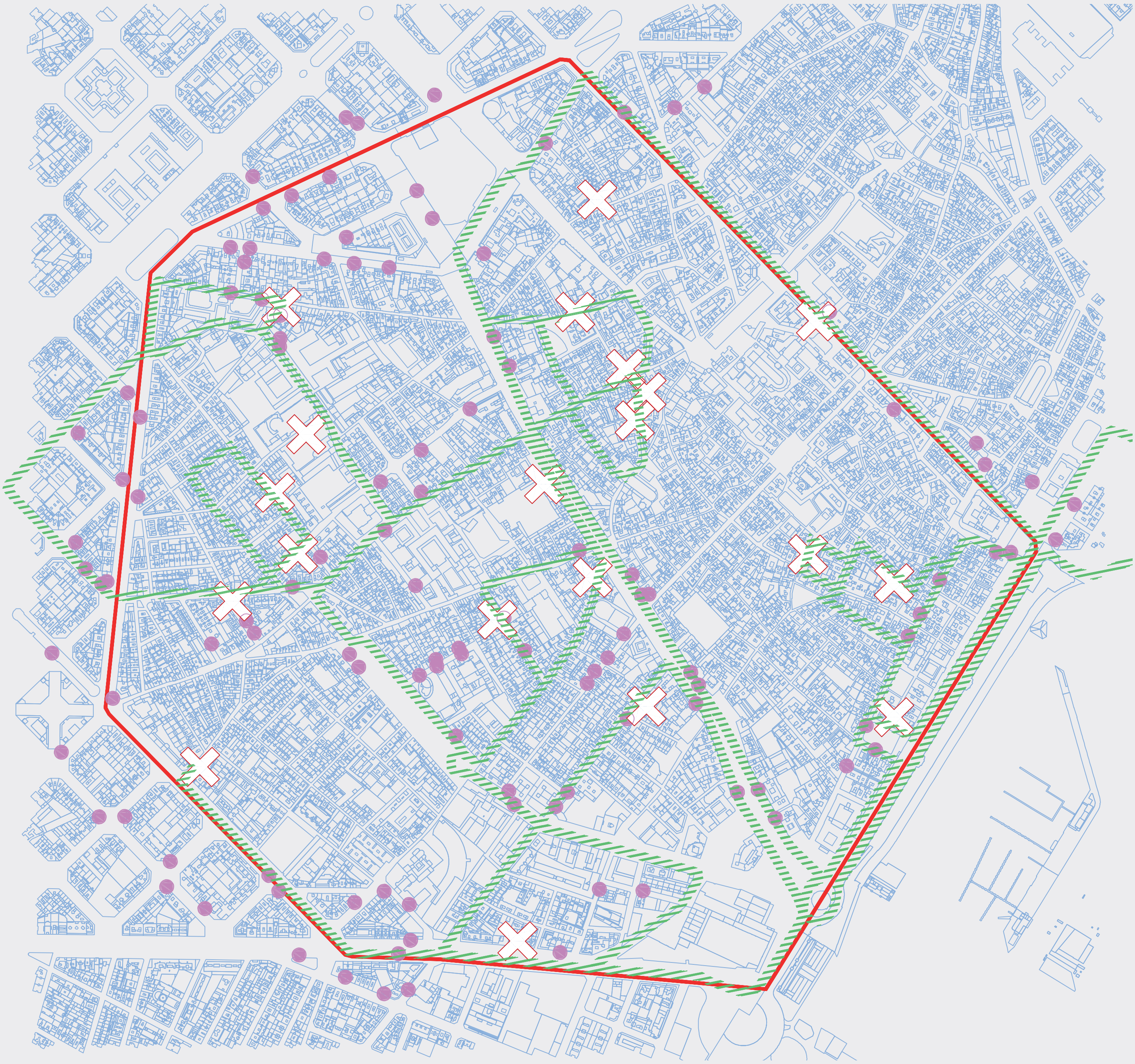


Madrid
scale 1:20.000

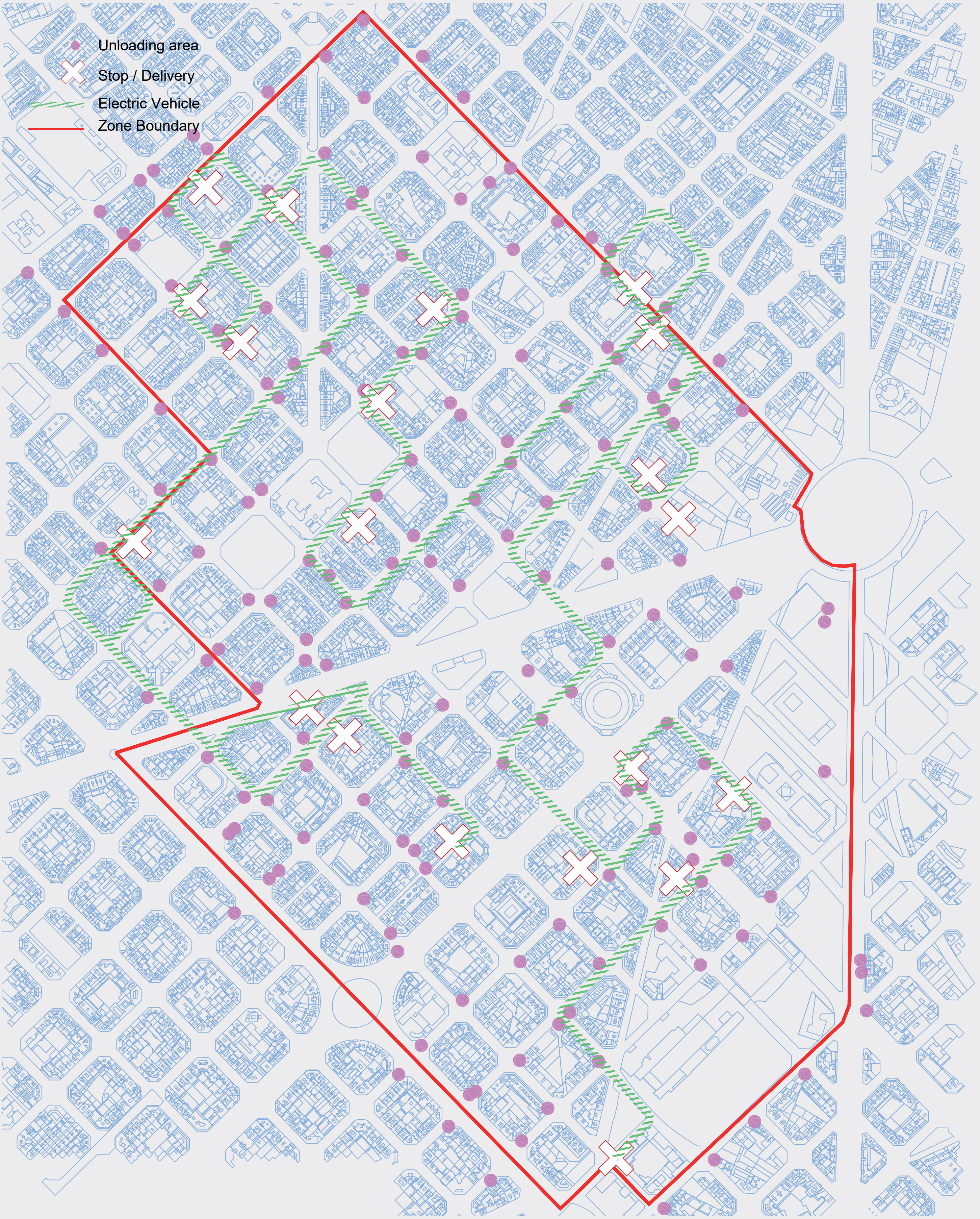


Barcelona
scale 1:10.000

Unloading area
Stop / Delivery
Electric Vehicle
Zone Boundary

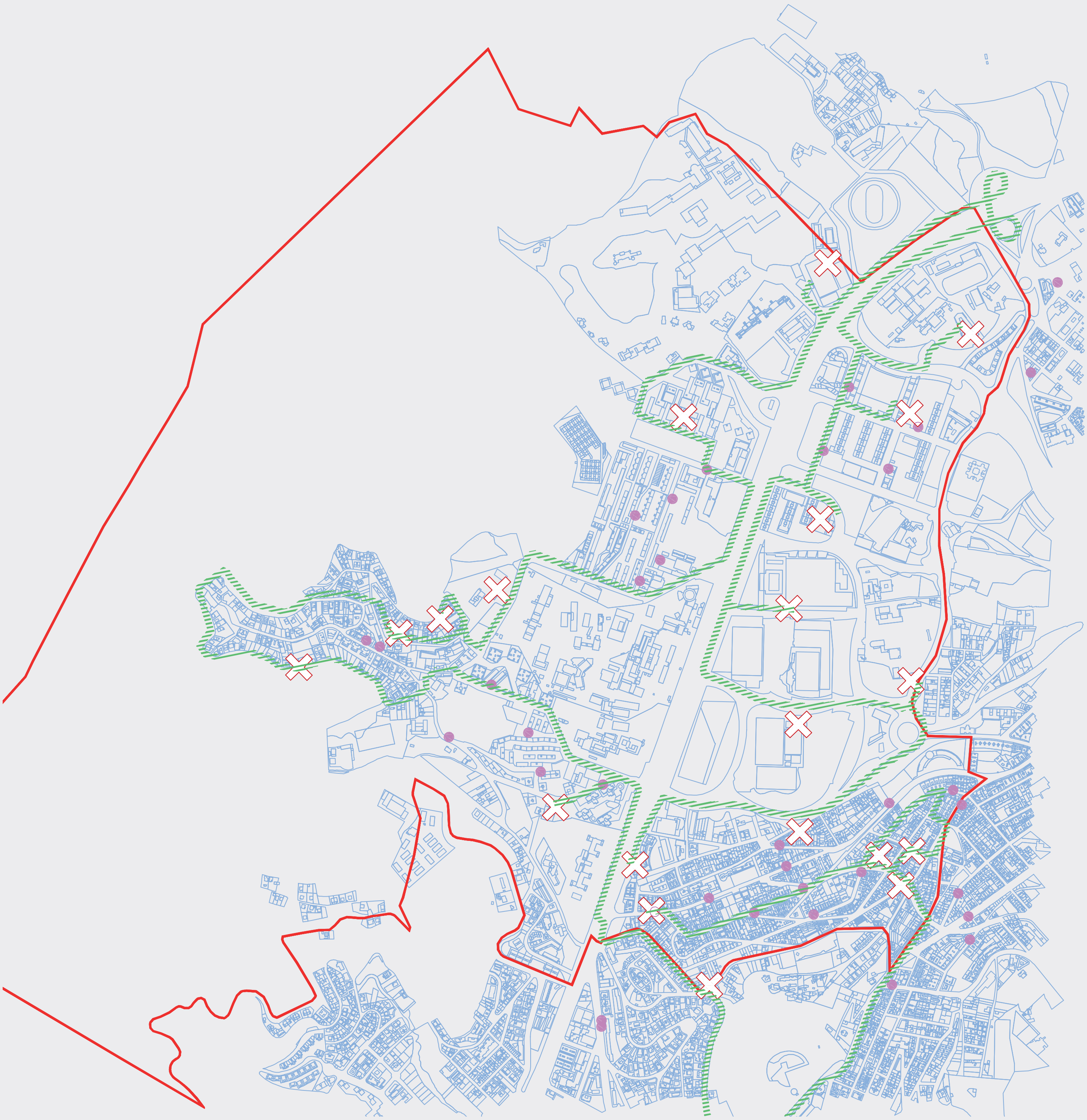


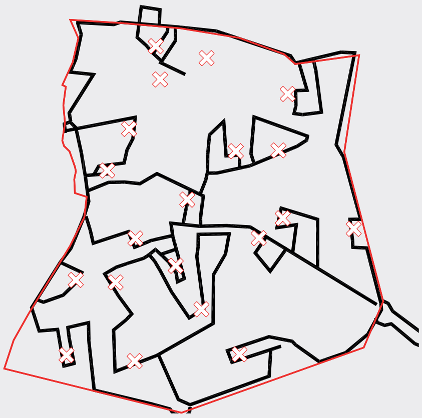
Barcelona
scale 1:10.000

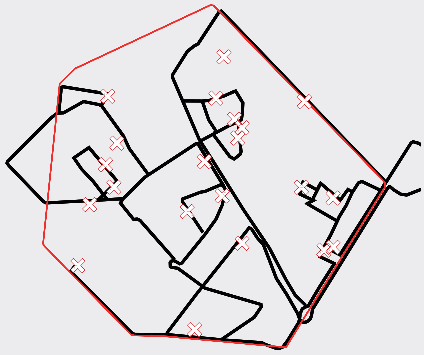


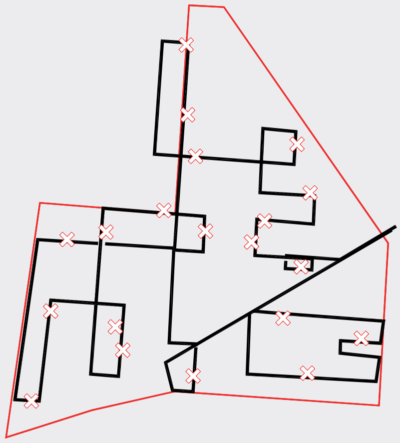
Barcelona
scale 1:15.000

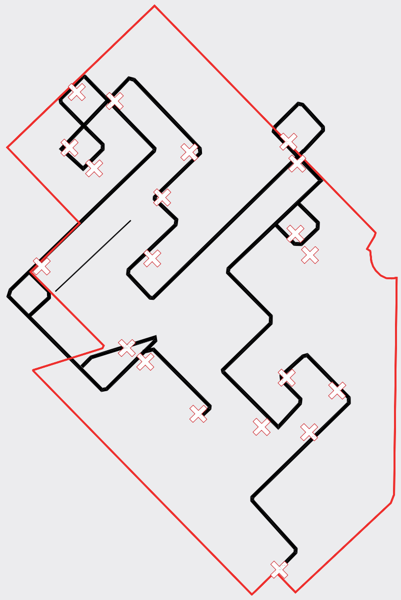
Unloading area
Stop / Delivery
Electric Vehicle
Zone Boundary

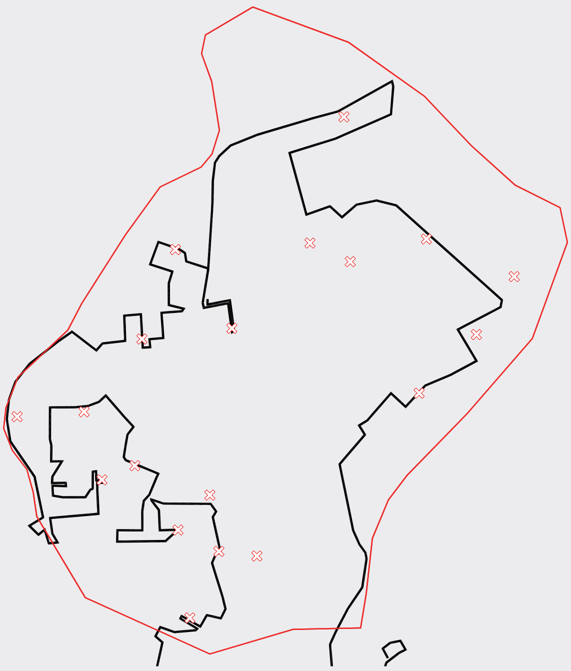


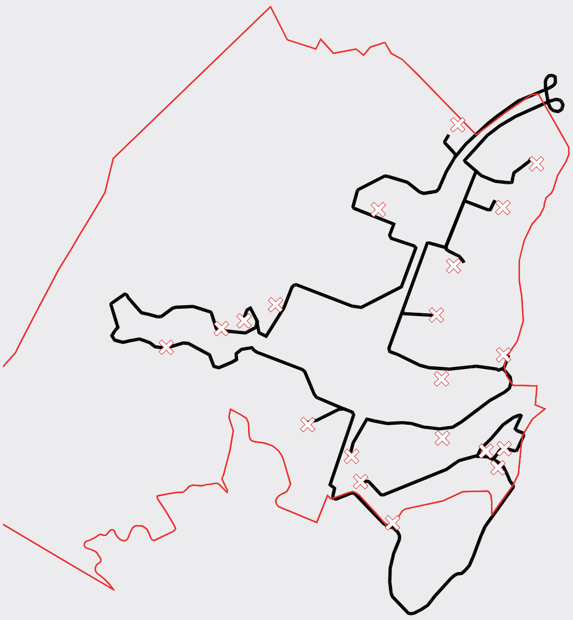












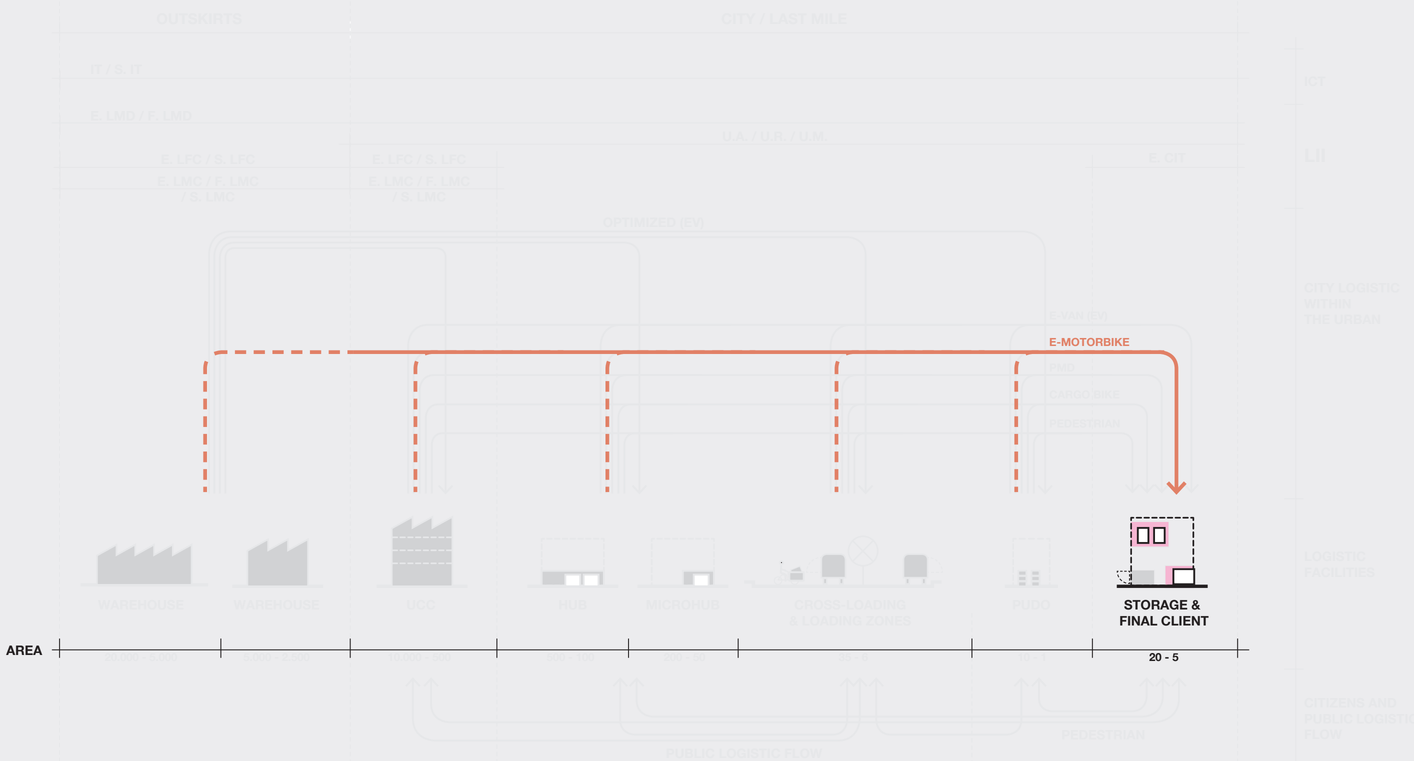
Optimised route with Electric Van Conclusions:

When Electric Vans are refueled from sustainable sources, the environmental impact of this model is dramatically reduced when compared to the BAU model.

Our assumption is (confirmed by the interviews conducted in the field study) that currently, most cities do not provide enough recharging options for electrical vehicles, which is discouraging to many drivers. This could signal the opportunity for logistics facilities to provide charging stations and fill in the operational gaps for the benefit of their clients.

Scenario 1 also introduces a crucial new element in our analysis that is repeated from here on in all scenarios: creating the delivery route using an optimization algorithm. This significantly reduces the presence of the vehicle on the street, in most cases by 30%. This figure is even more important at the outskirts of the of Barcelona and Madrid and in Barcelona city center where the decrease in vehicle presence is 50%.

The optimization of the route also means that the clients must renounce their priority delivery option or at least increase the timeframe of their availability. For example, instead of requesting delivery from 10 to 11 am, the delivery window needs to grow to 8 am-12 pm to allow for a delivery window large enough to program a sufficient number of deliveries in one timeframe and create an optimized route. Educating the end client about the connection between delivery types and delivery time options and impacts can encourage them to choose more environmentally friendly options.



2. Optimised route with Electric Motorcycle Scenario

7.3. Proposed scenarios
7.3.2. Optimised route with Electric Motorcycle

The optimized route via electric motorcycle faces the same challenges in the number of drop-offs., However, in its evaluation, it is assumed that the motorcycle gets its supply of packages from a closer point than the existing warehouses, proposing here combinations with scenarios discussed below. Micro-hubs with bike delivery (Scenario 6) Cross-loading/unloading with pedestrian delivery (Scenario 8) and Consolidation centers (Scenario 9)

The electric motorcycle's environmental impact is considered zero and contributes to reducing noise pollution by up to 20db (Fiebig A.,2012). Similarly, its street presence is significantly less. The small physical presence of electric motorcycles also has its benefits. For one, there is a smaller footprint in the overall street traffic and second, its size also requires less parking space. The human scale of this vehicle versus a van has a positive impact on the livability of a street during logistics operations.

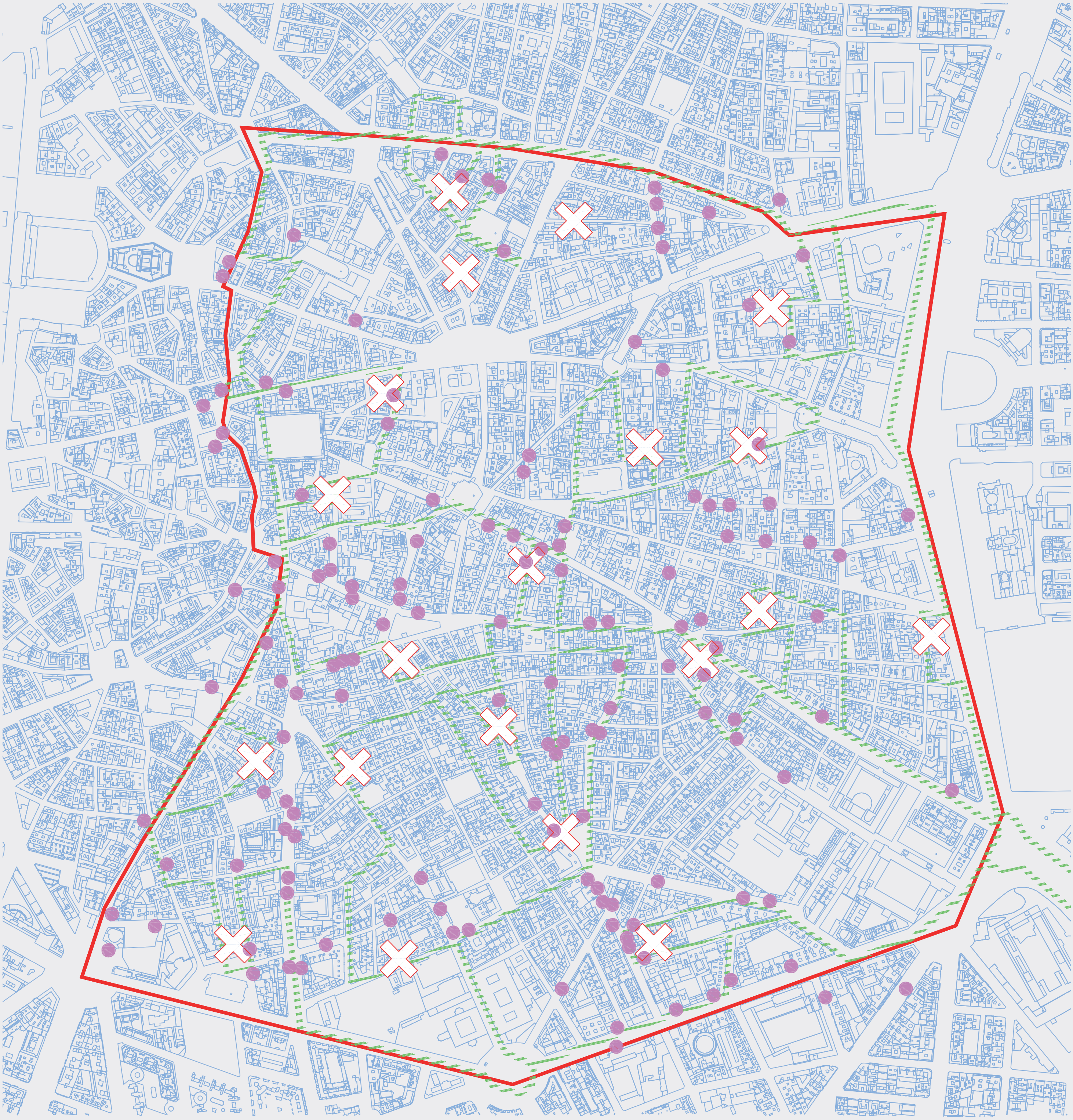
Madrid
scale 1:10.000

Unloading area

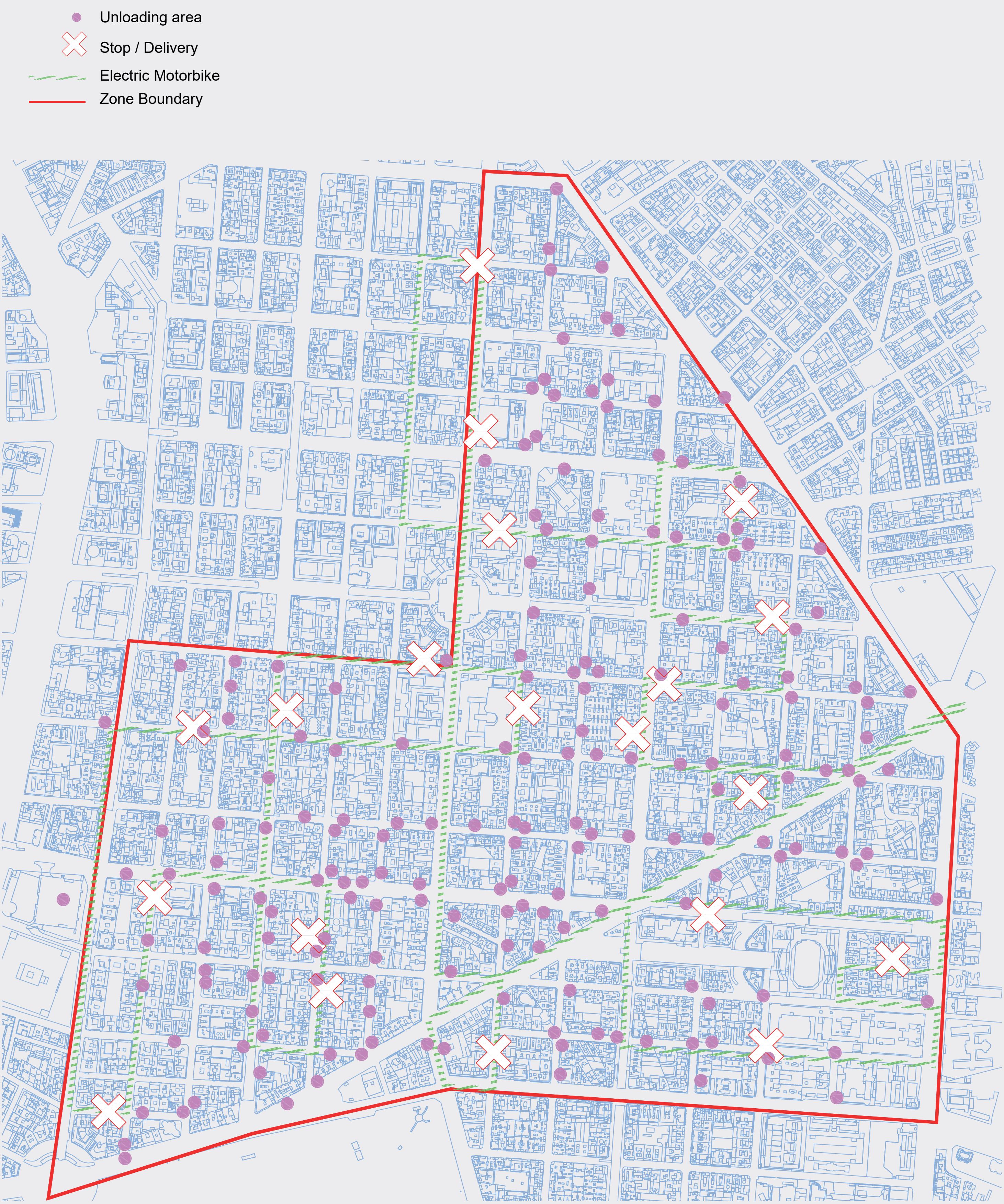
Stop / Delivery

Electric Motorbike

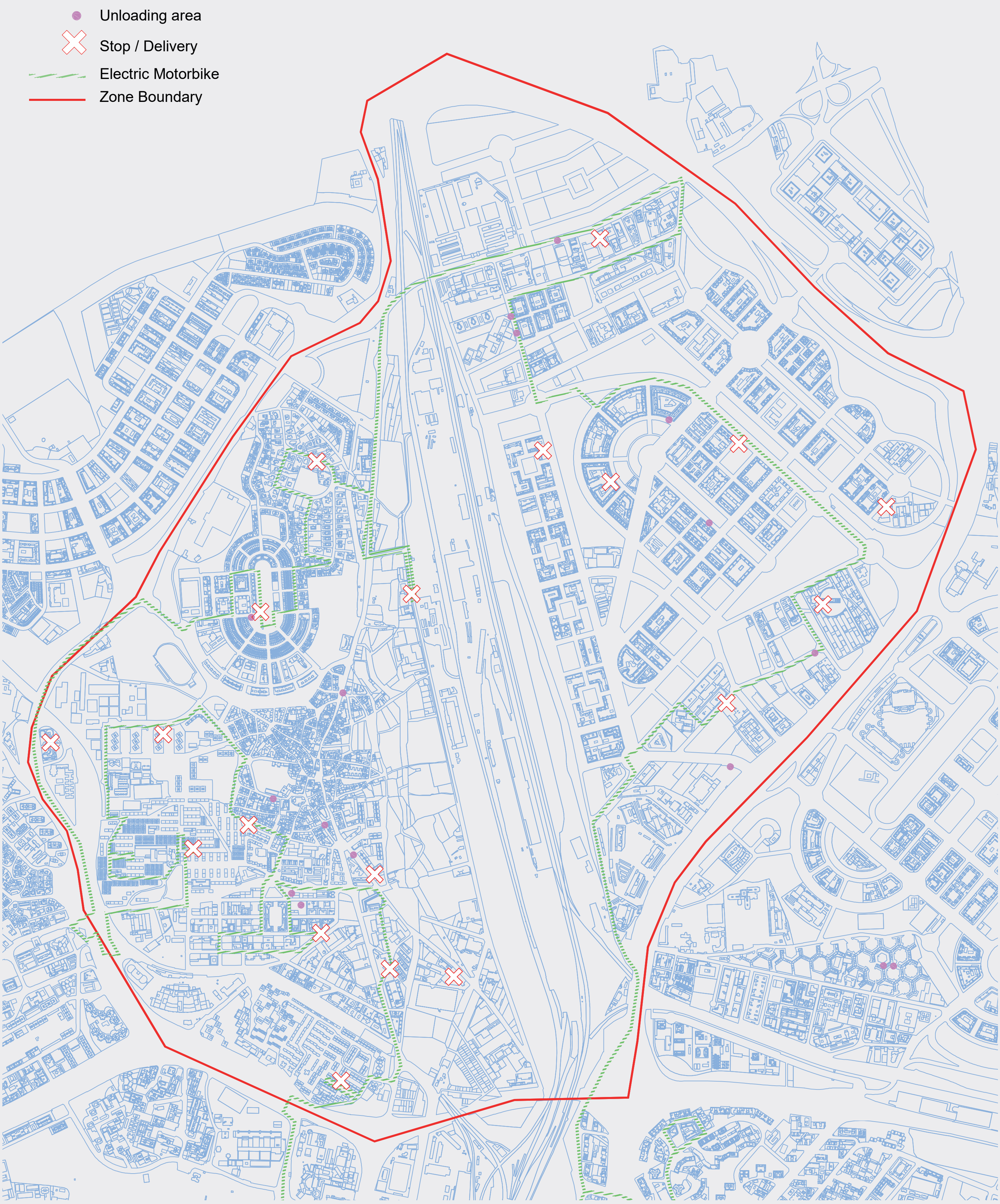
Zone Boundary



Madrid
scale 1:10.000

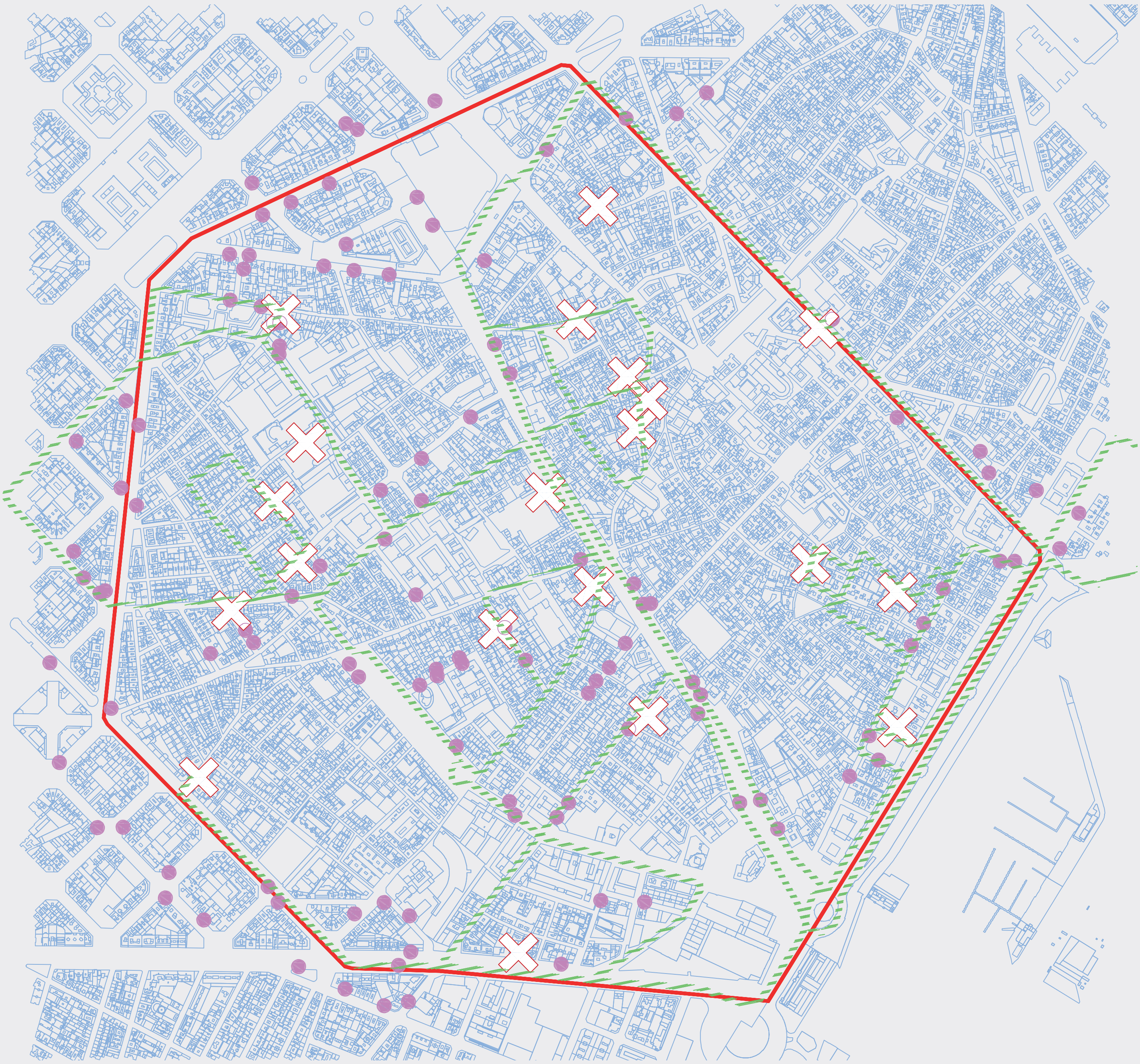


Madrid
scale 1:20.000

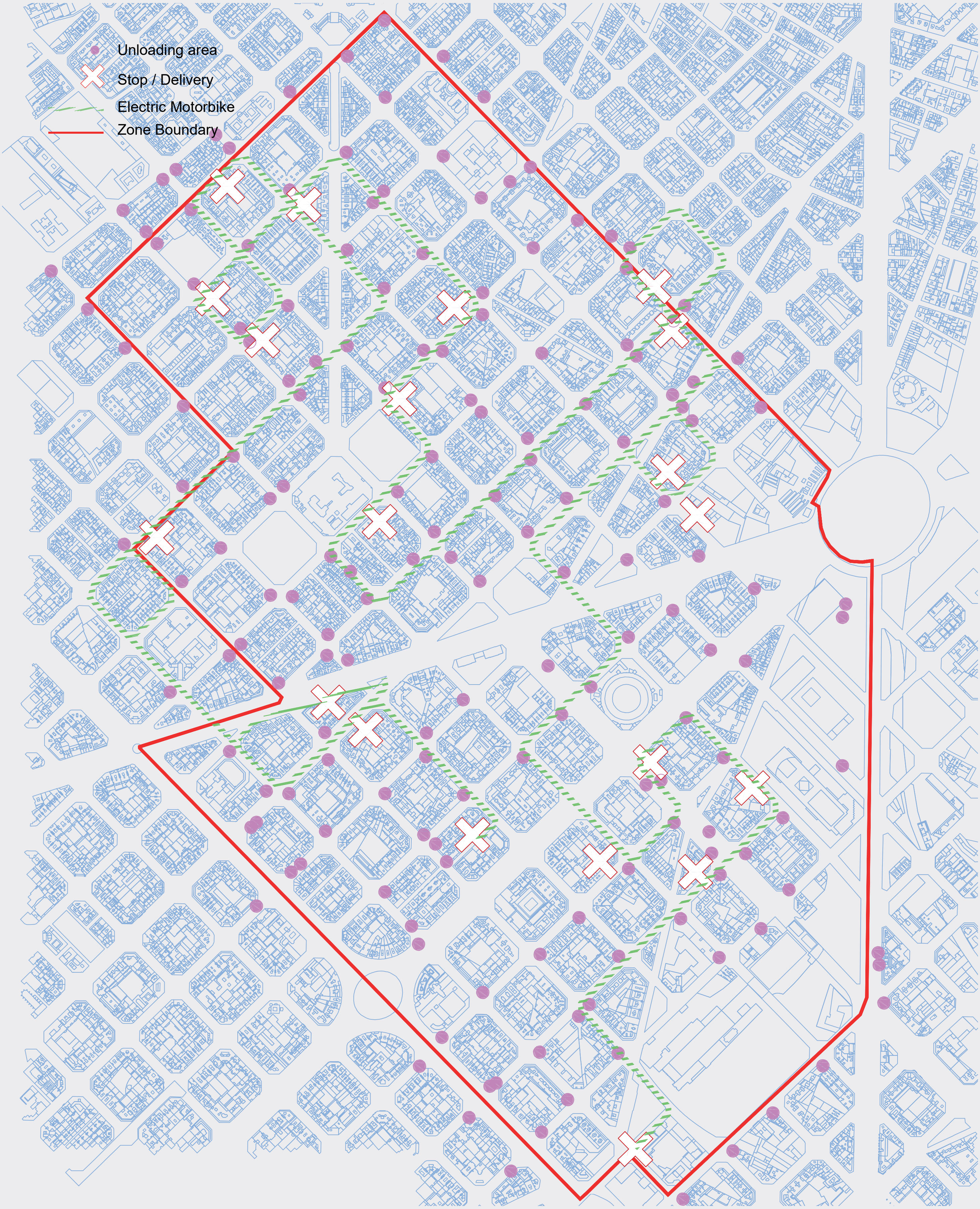


Barcelona
scale 1:10.000

- Unloading area
- Stop / Delivery
- Electric Motorbike
- Zone Boundary

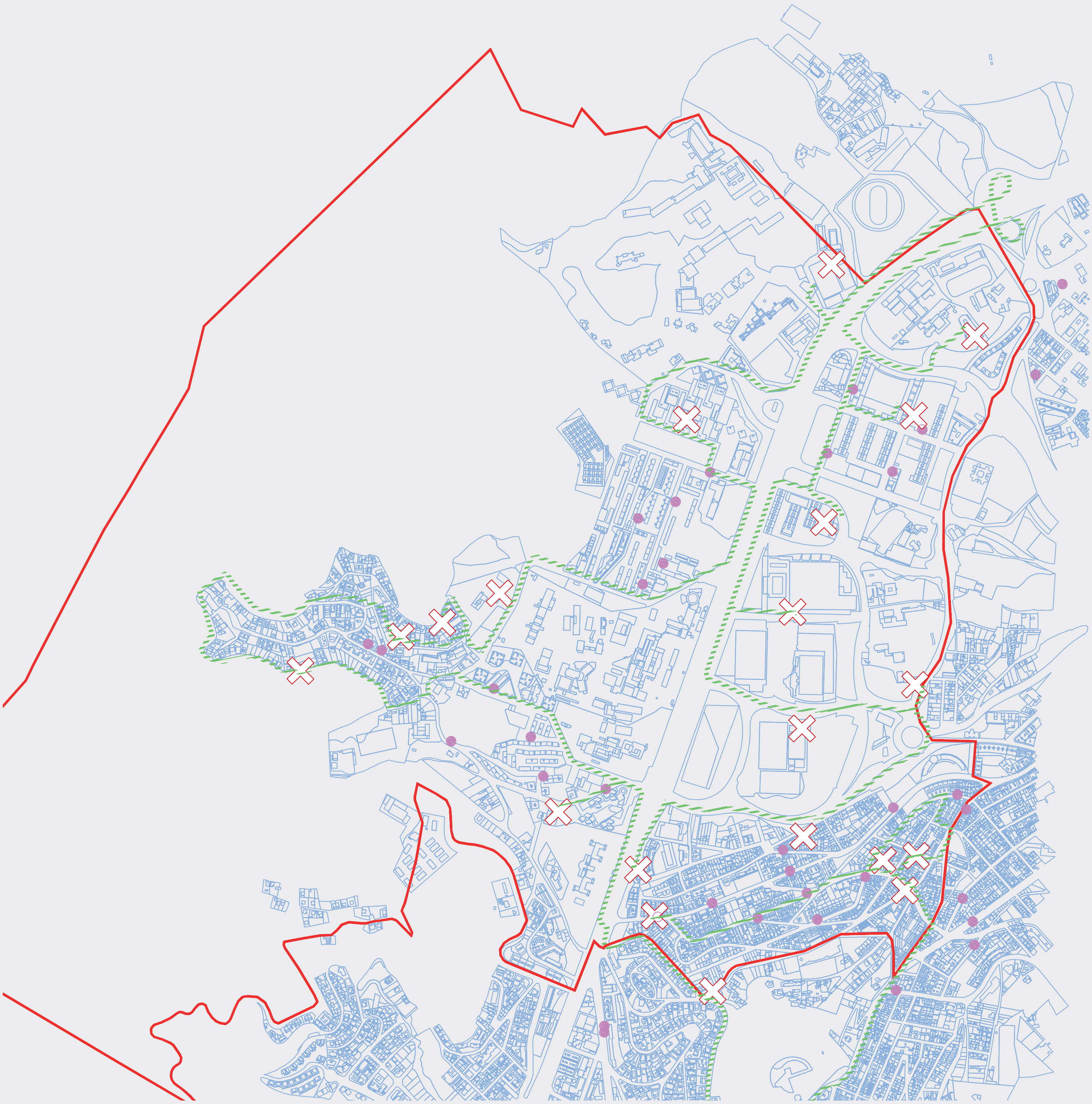


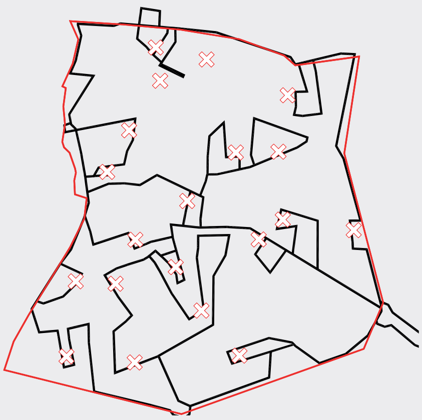
Barcelona
scale 1:10.000

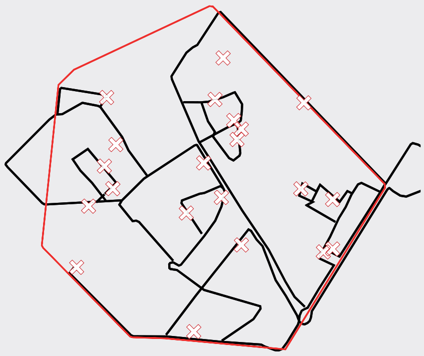


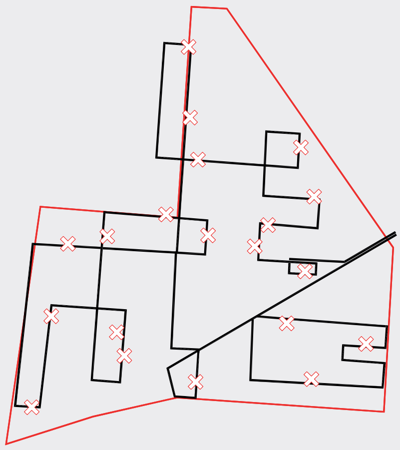
Barcelona
scale 1:15.000

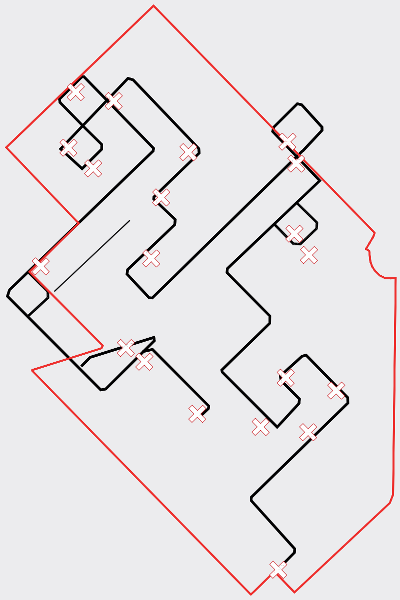
Unloading area
Stop / Delivery
Electric Motorbike
Zone Boundary

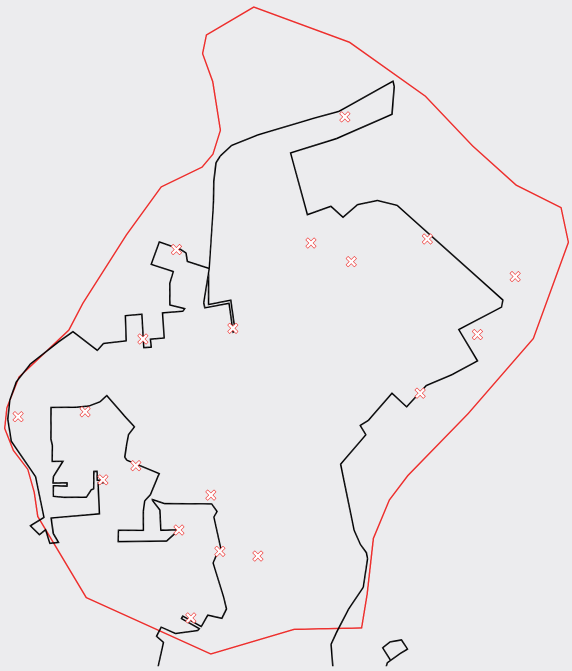


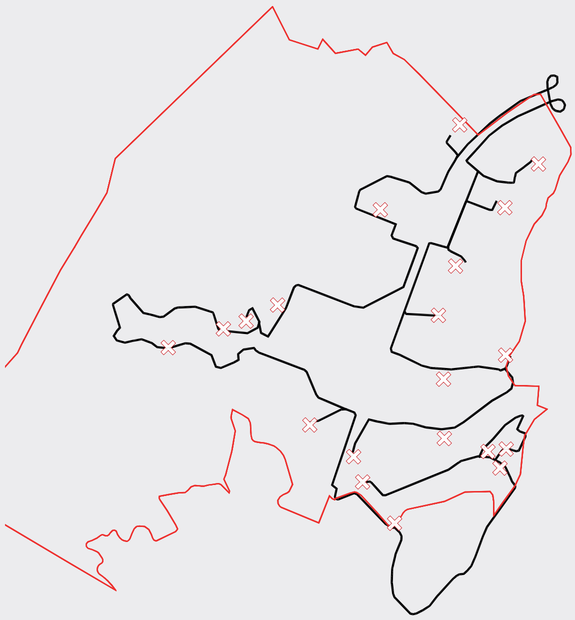








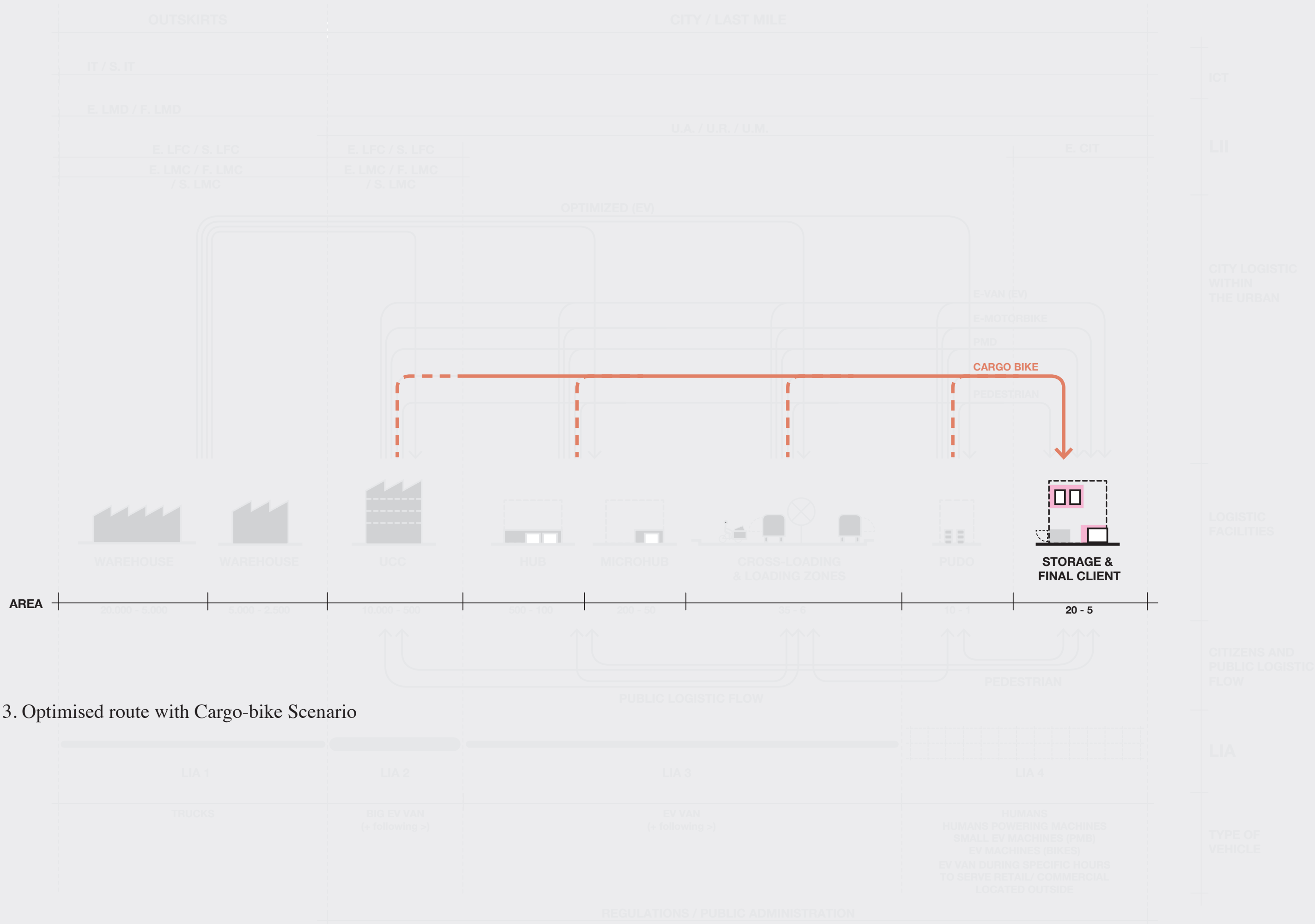




Optimised route with Electric Motorcycle Conclusions:

In addition to the positive aspects of the scenario of the Optimized Route with Electric Van (Scenario 1), the electrical motorbike has a smaller footprint at street scale and is more agile maneuvering and finding parking options. Its cargo limitations mean that it needs to be re-supplied more frequently to achieve the same performance as larger vehicles. However, what may be considered a limitation due to size is also a benefit because it can better fit into narrow and crowded streets, and it has significantly fewer problems when finding a parking space. Its agility and speed make it perfect for the increasing demand for one-hour and same-day delivery of small parcels.

Electric motorcycles face the same issue as the electrical van regarding the availability of charging points. This, again, could present opportunities for the logistic facilities to expand their services. Using electrical motorcycles is a good fit for dense urban areas that typically have a large number of “urgent” deliveries. In comparison with an electrical van, it performs only slightly better timewise and has limited cargo capacity. However, its accessibility range, near imperceptible noise contamination, and low visual impact on the city makes it a good choice for city center deliveries.



3. Optimised route with Cargo-bike Scenario

7.3. Proposed scenarios
7.3.3. Optimised route with Cargo-bike

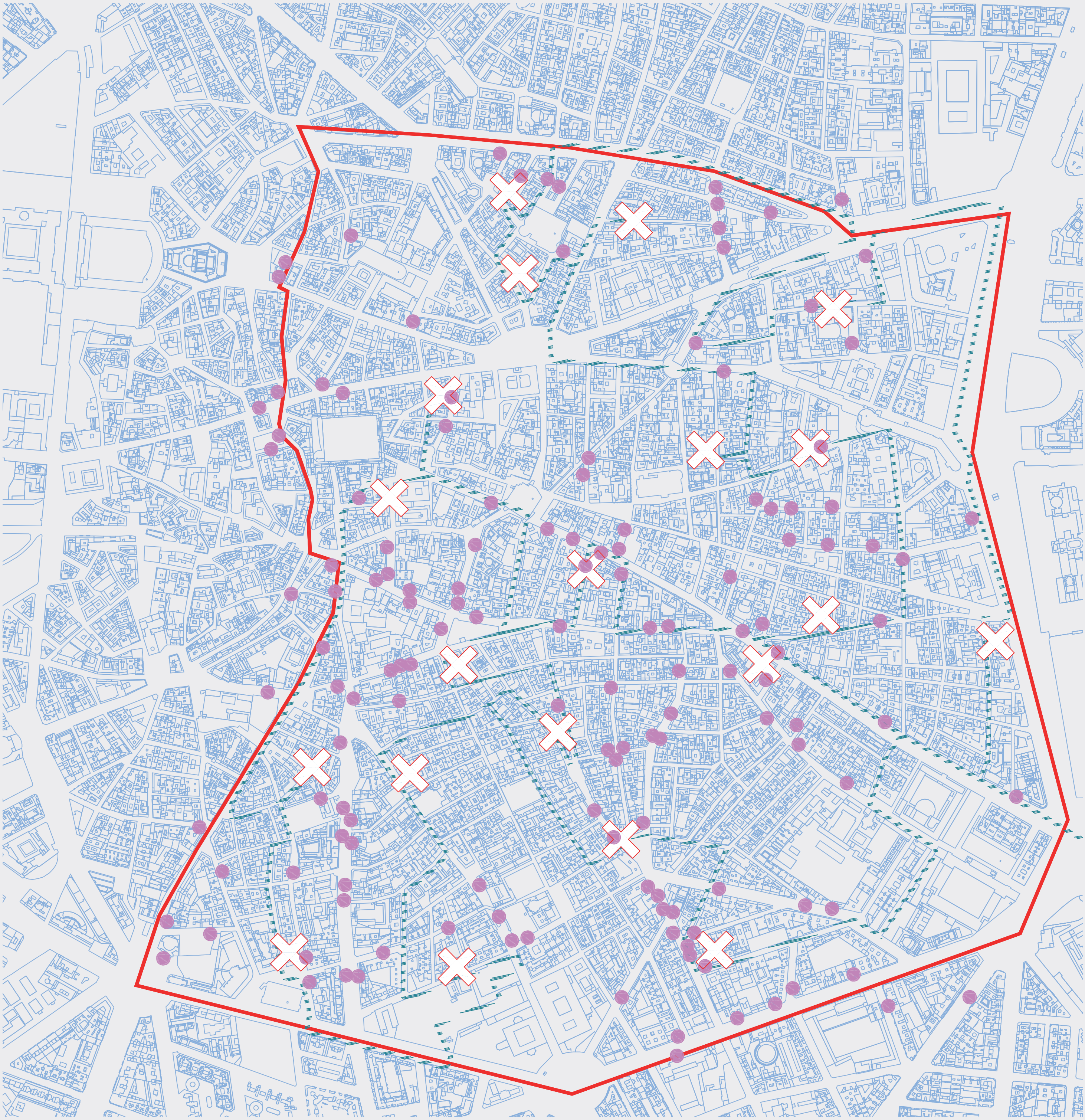
This scenario proposes a completely human-powered vehicle with cargo capabilities that follows similar parameters as the previous scenario.

There are two additional positive aspects that this scenario provides, including the fact that cargo-bikes are allowed in solely pedestrian streets, which means that they can reach easier in parts of the city (typically city centers) that are heavily pedestrianized, it has zero environmental impact. Its presence in the street is perceived as a benign addition to the city, considering the near-zero noise pollution and its insignificant physical presence when compared to the previous scenarios.

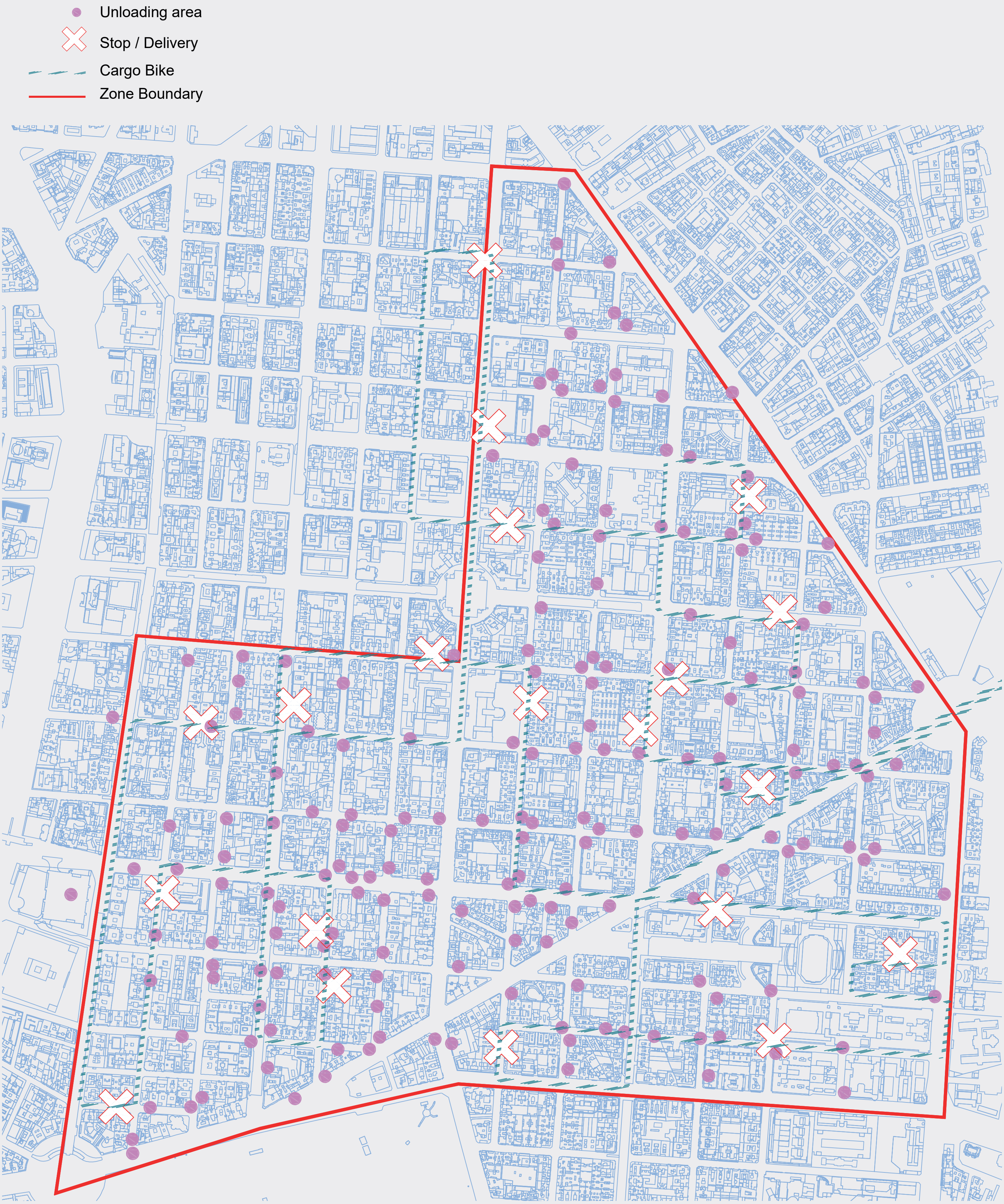
In the evaluation of this scenario, the impossibility of making the full journey from the warehouse to the delivery areas was considered. Therefore, we added the time and kilometers traveled by an electric van from the nearest warehouse to the center of the selected urban area to make our analysis completer and more reliable.

Madrid
scale 1:10.000

Unloading area
Stop / Delivery
Cargo Bike
Zone Boundary



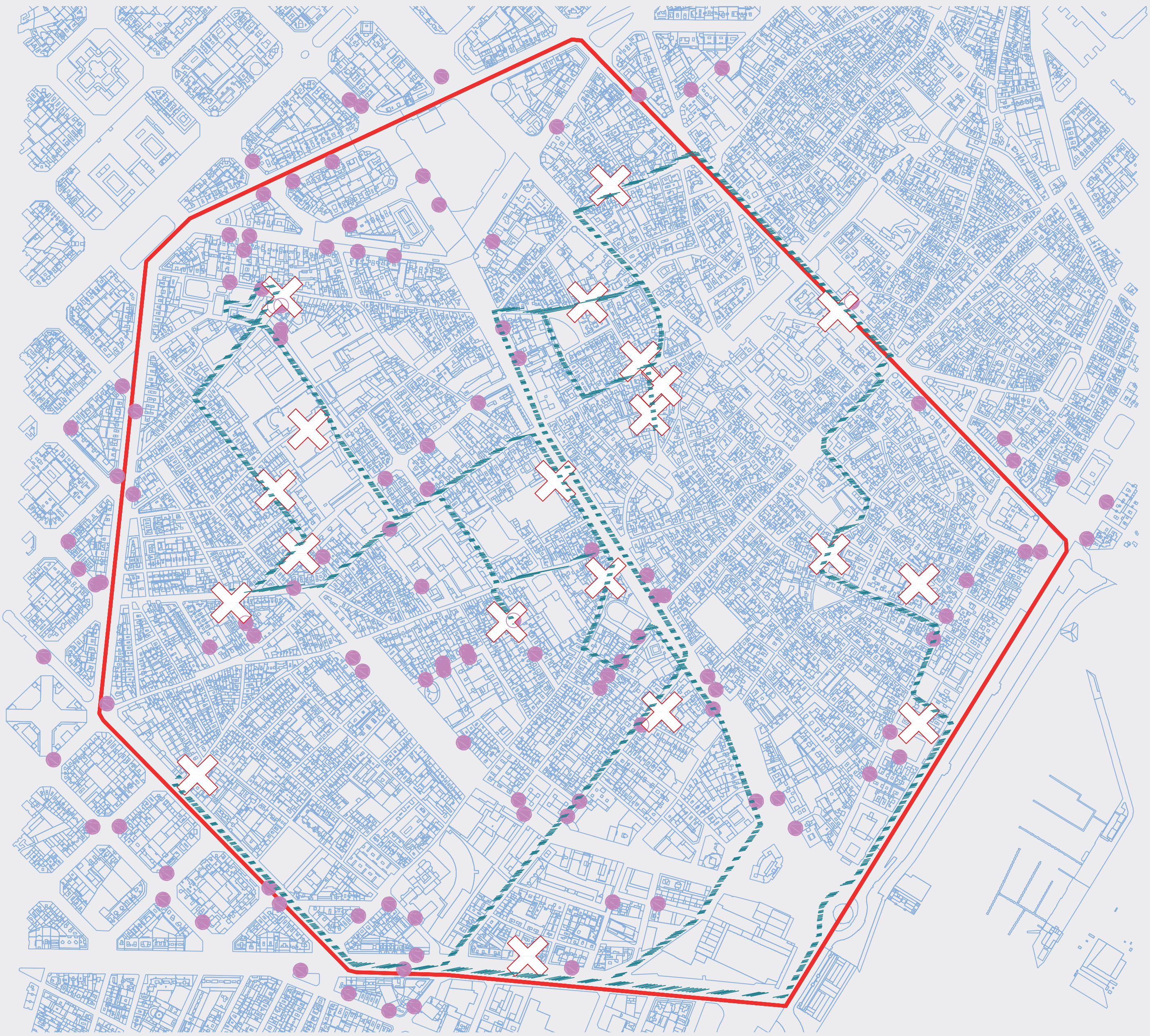
Madrid
scale 1:10.000



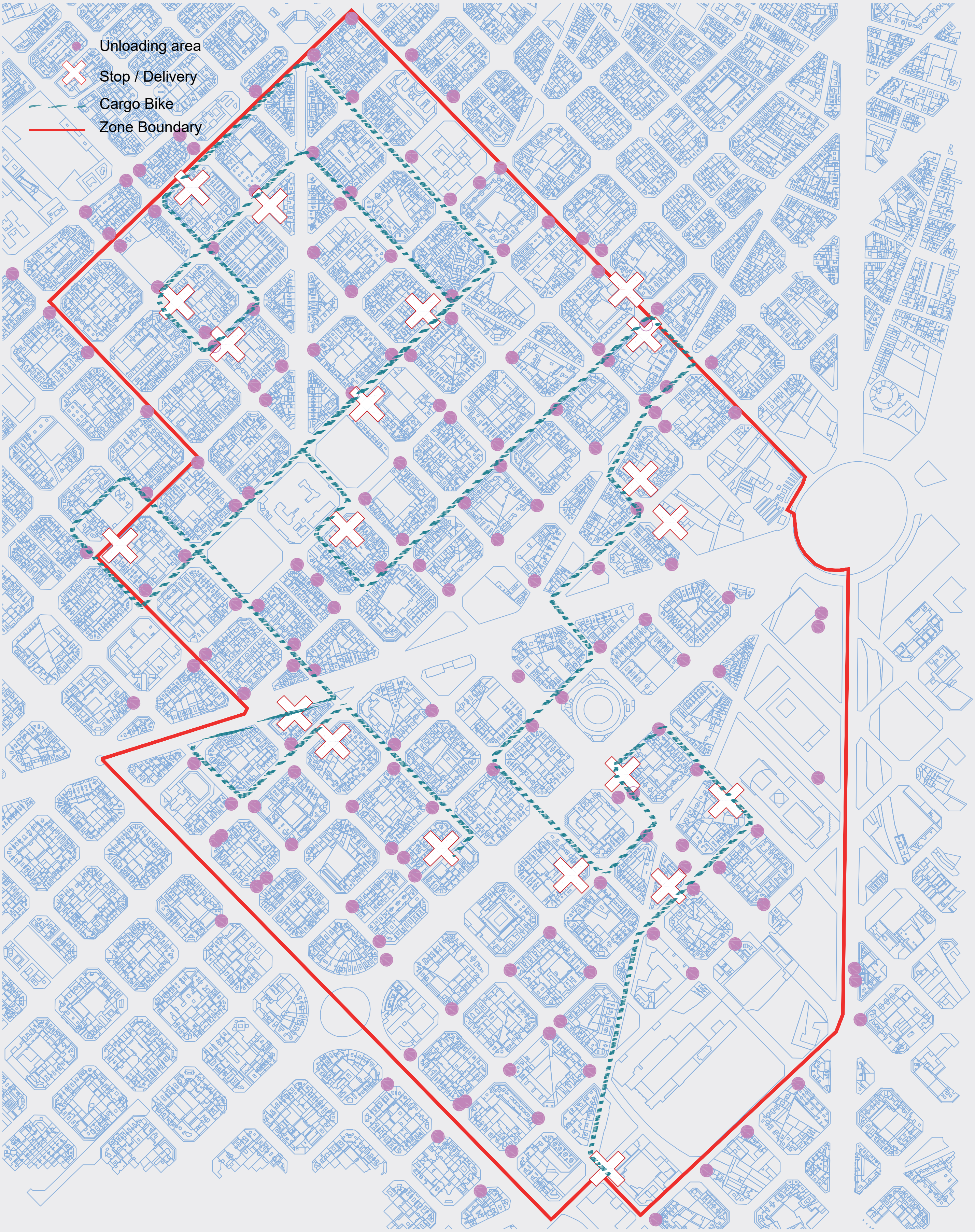
Madrid
scale 1:20.000

Barcelona
scale 1:10.000

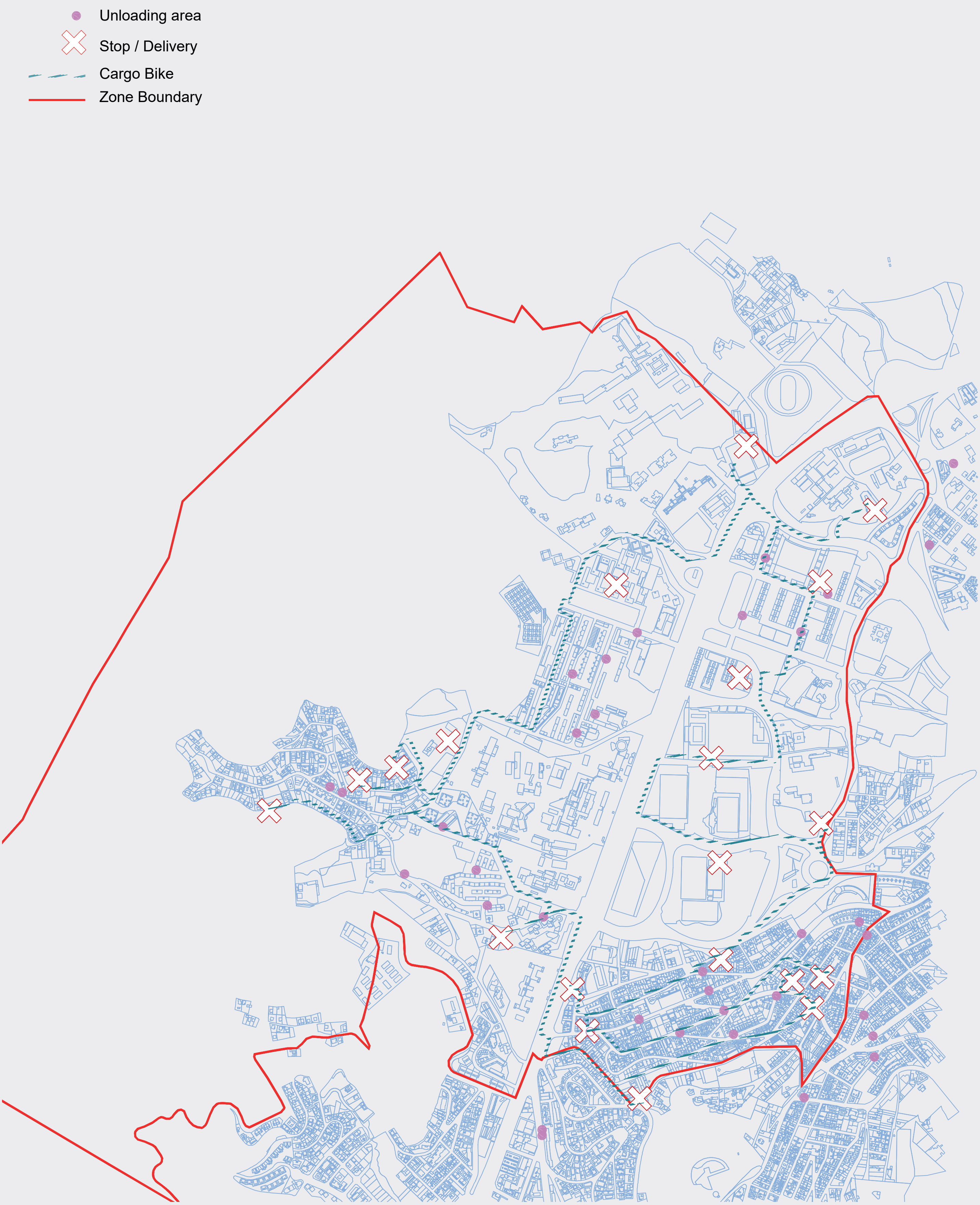
Unloading area
Stop / Delivery
Cargo Bike
Zone Boundary

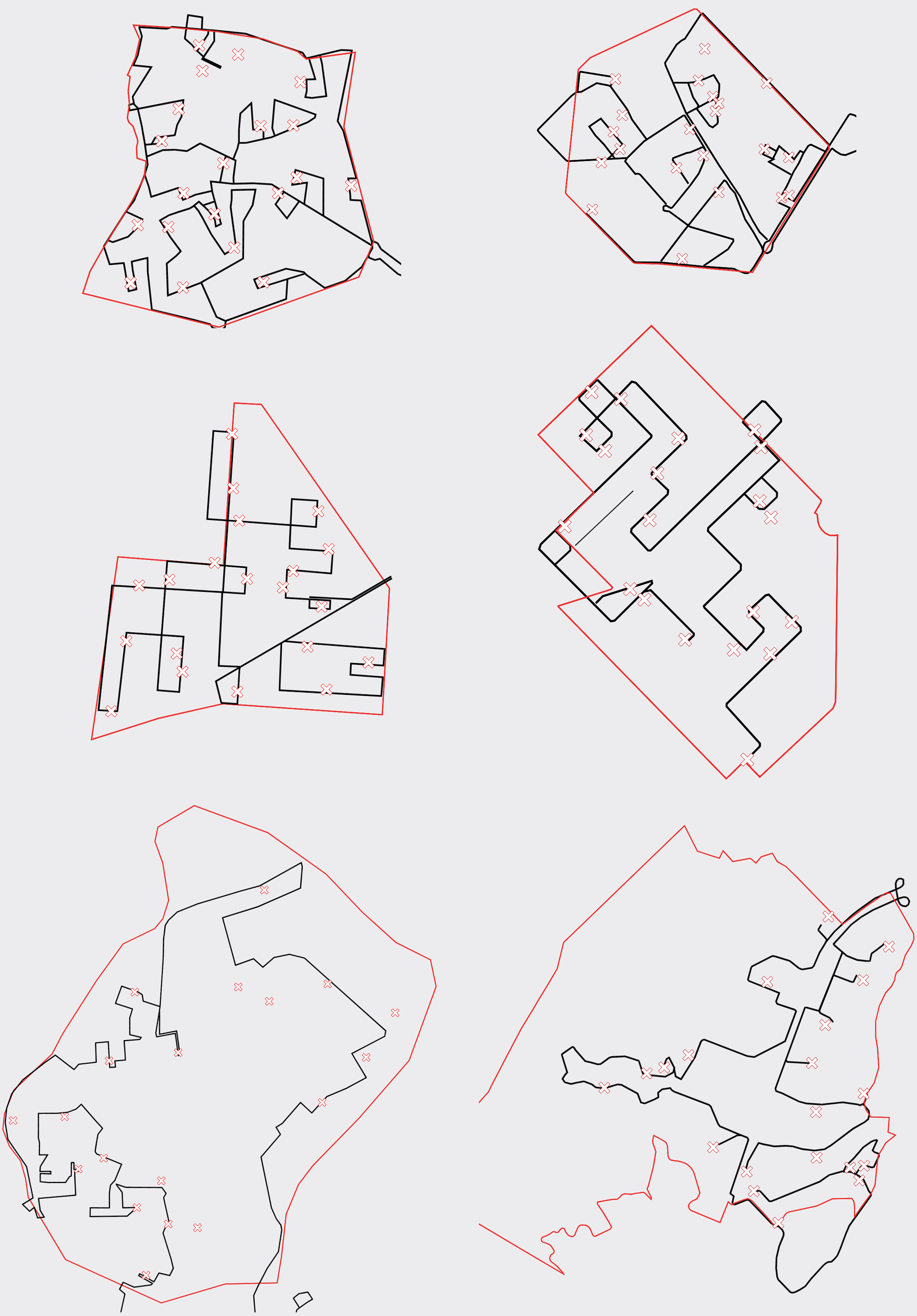


Barcelona
scale 1:10.000



Barcelona
scale 1:15.000

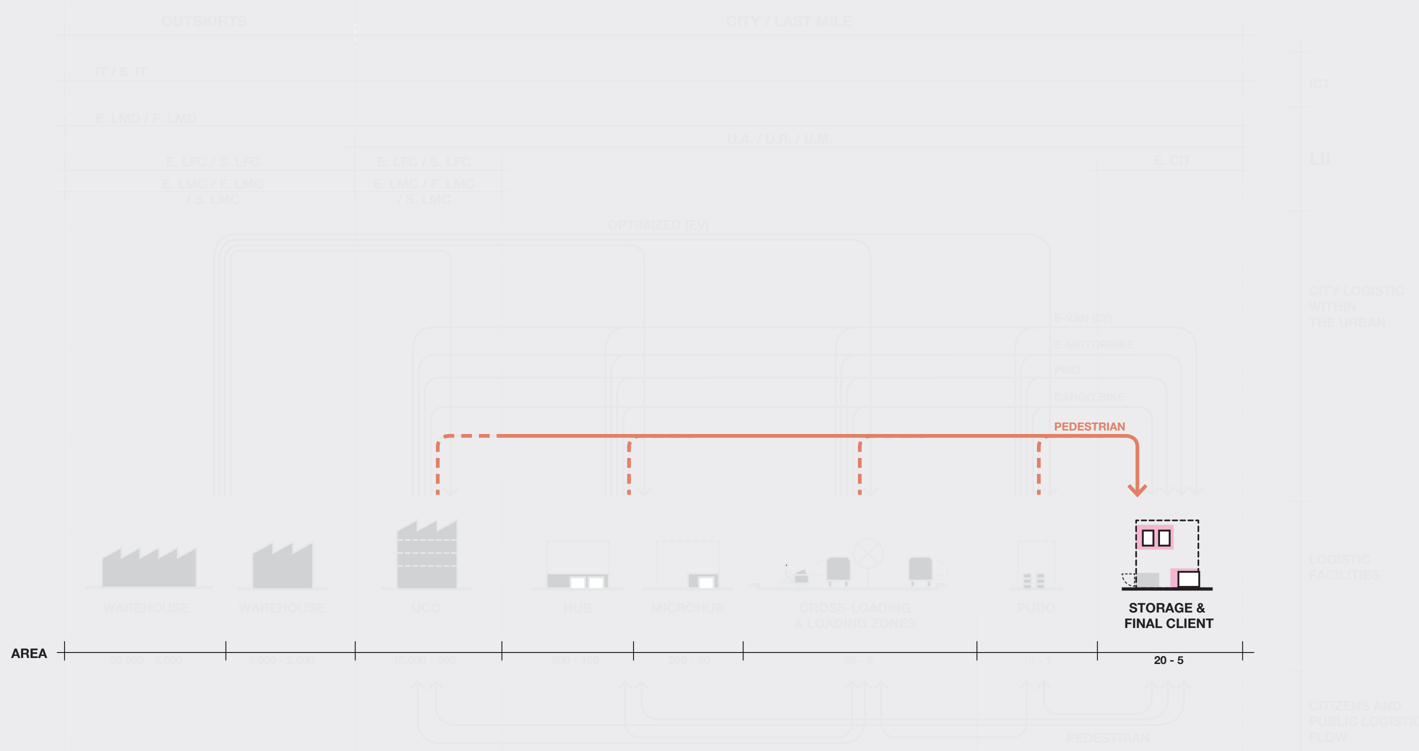




Optimised route with Cargo-bike
Conclusions:

Cargo bikes, like cargo motorcycles, have a limited load capacity but make up for that with increased accessibility on nearly all street typologies (in Madrid they are allowed in pedestrian areas). This is a huge advantage in dense city centers that tend to add more and more traffic restrictions as they slowly move towards full pedestrianization. The advantage of cargo bikes is evident in the case of the city center of Madrid. An optimized route with an electric motorcycle completed its 20 deliveries in 1 hour and 49 minutes, while the cargo bike completed it in 35 minutes.

Cargo bicycles' zero environmental impact mixed with their zero necessity of charging make this a low maintenance, city-friendly, flexible option for certain situations. Moreover, this option opens up the world of logistics to a population that does not have a driver's license, encourages a more transparent logistics process, and can even build new relationships with small local companies that offer cargo-bike deliveries at the neighborhood level. The literature reviewed states that cargo bikes deliver about 60% faster than vans and at a rate of 10 parcels per hour (Carrington, 2021).



4. Optimised route with Pedestrian delivery Scenario

7.3. Proposed scenarios
7.3.4. Optimised route with Pedestrian delivery

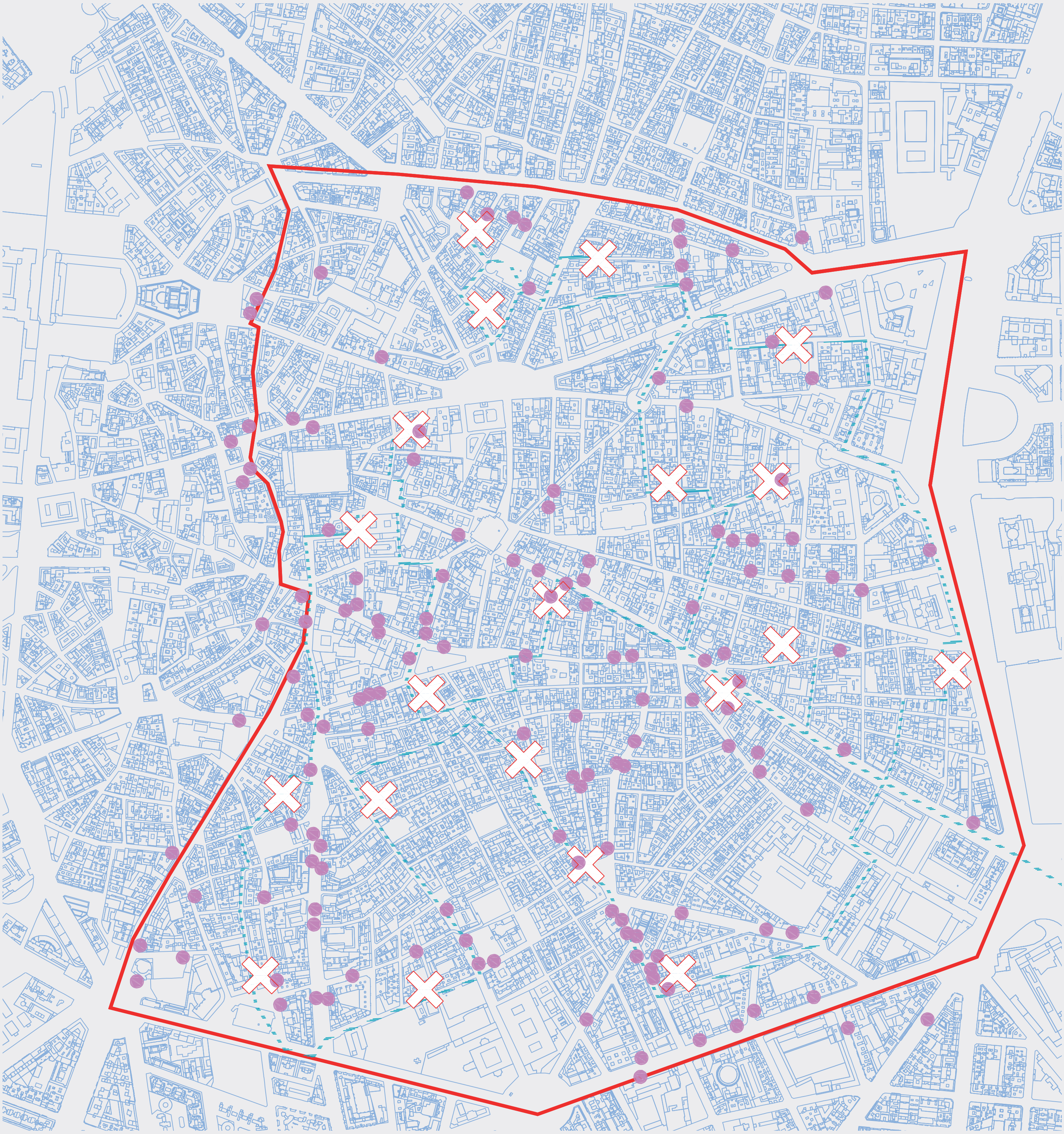
This scenario looks at the possibility of pedestrian delivery (with the help of a parcel cart) within selected areas and assumes that the packages enter the area via an Electric Van that comes directly from the warehouse.

This scenario loses efficiency due to the limited speeds of pedestrians and their capacity to carry heavy loads. However, it has zero environmental impact and a positive impact on the social health of a community. Pedestrian presence has little or no negative impact on traffic, the daily life of residents, and has the potential of positively changing the perception of logistics operations at the level of the community.

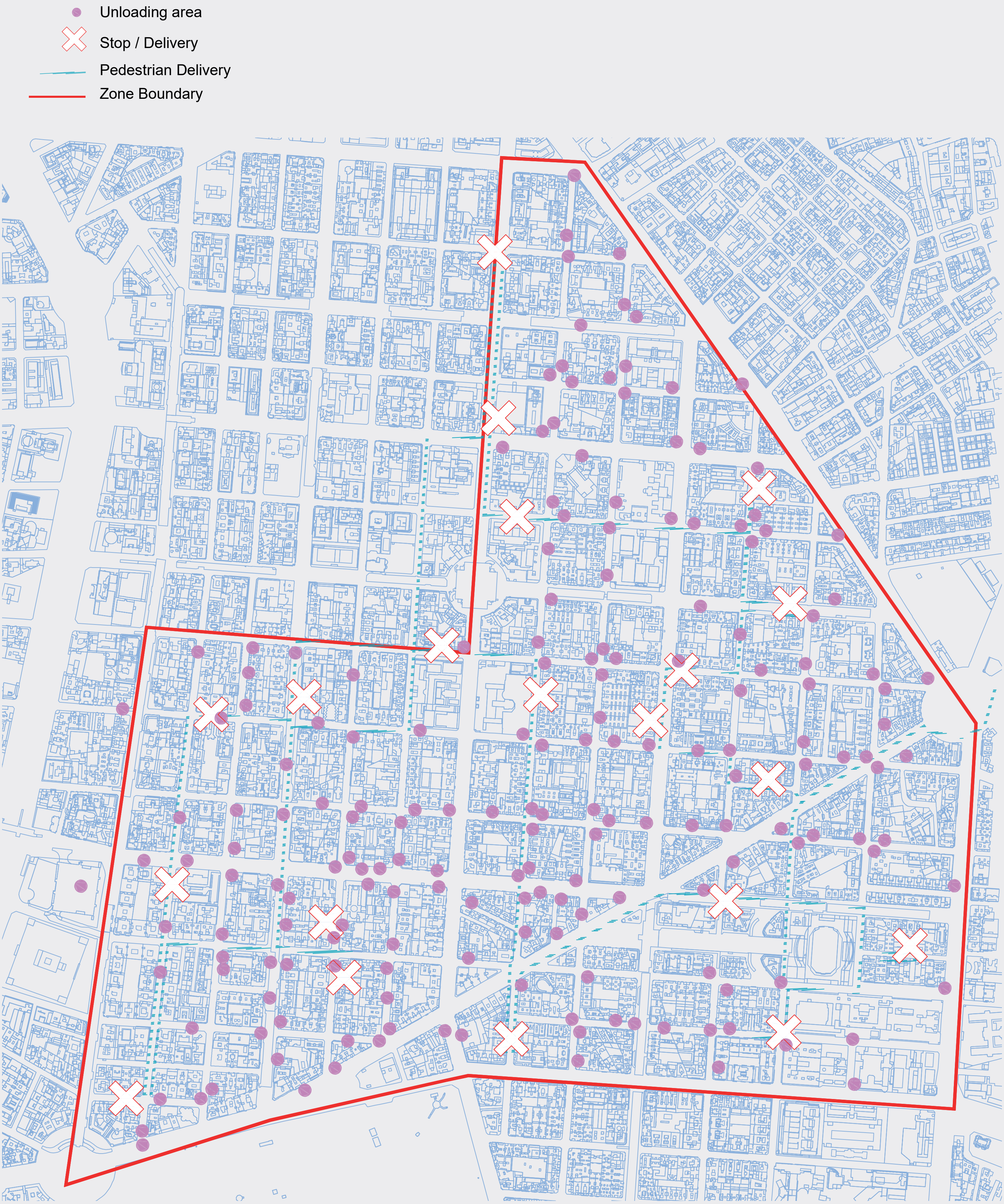
This scenario was heavily inspired by the Correos case study, which uses a significant number of pedestrian units distributed throughout the city. Apart from the environmental impact, what they lose in fast delivery they gain in image, creating a recognizable and reliable representative of the brand and its services. In turn, this slowly becomes seen by the local community as a trustworthy "neighbor".

Madrid
scale 1:10.000

Unloading area
Stop / Delivery
Pedestrian Delivery
Zone Boundary



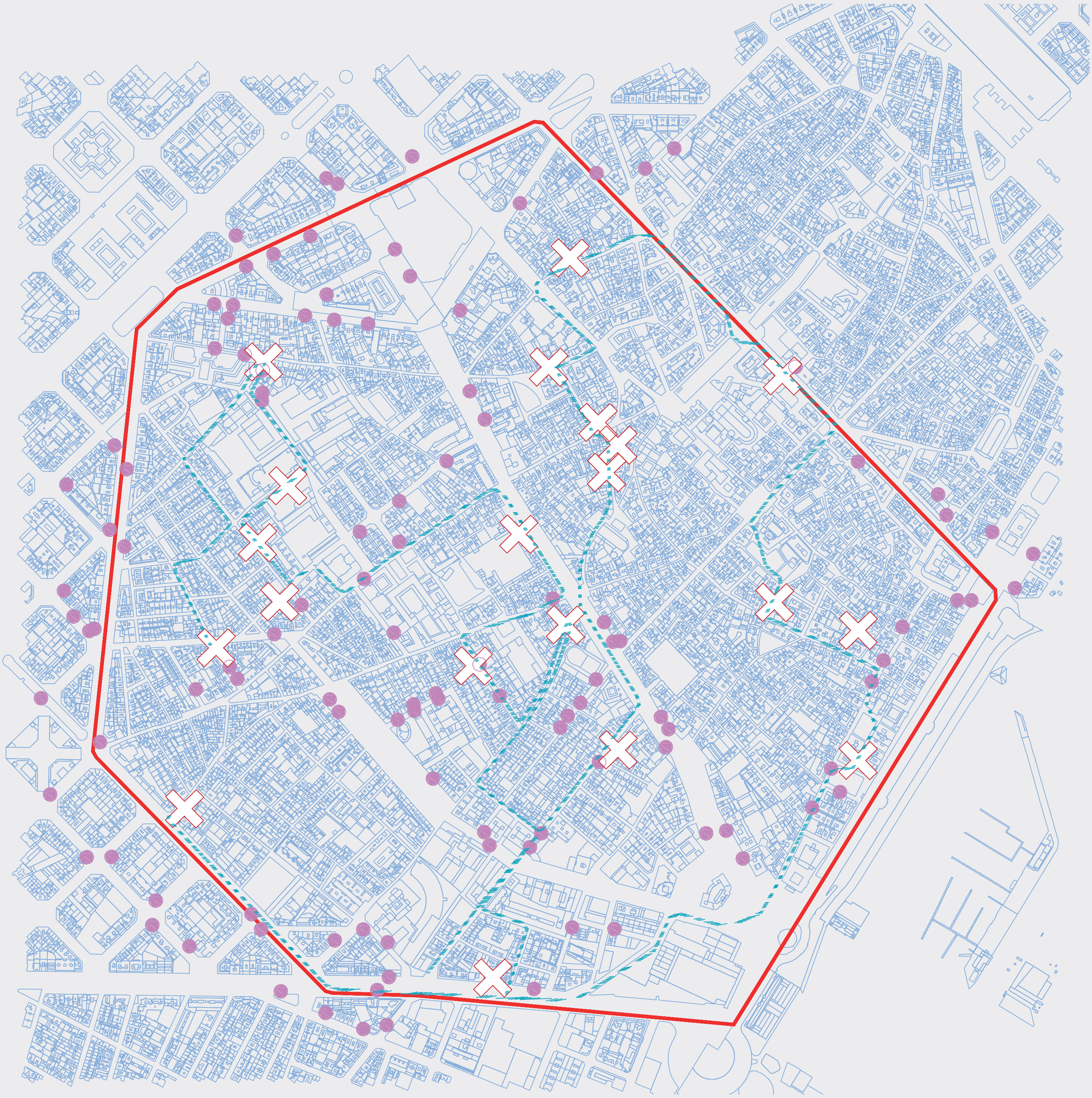
Madrid
scale 1:10.000



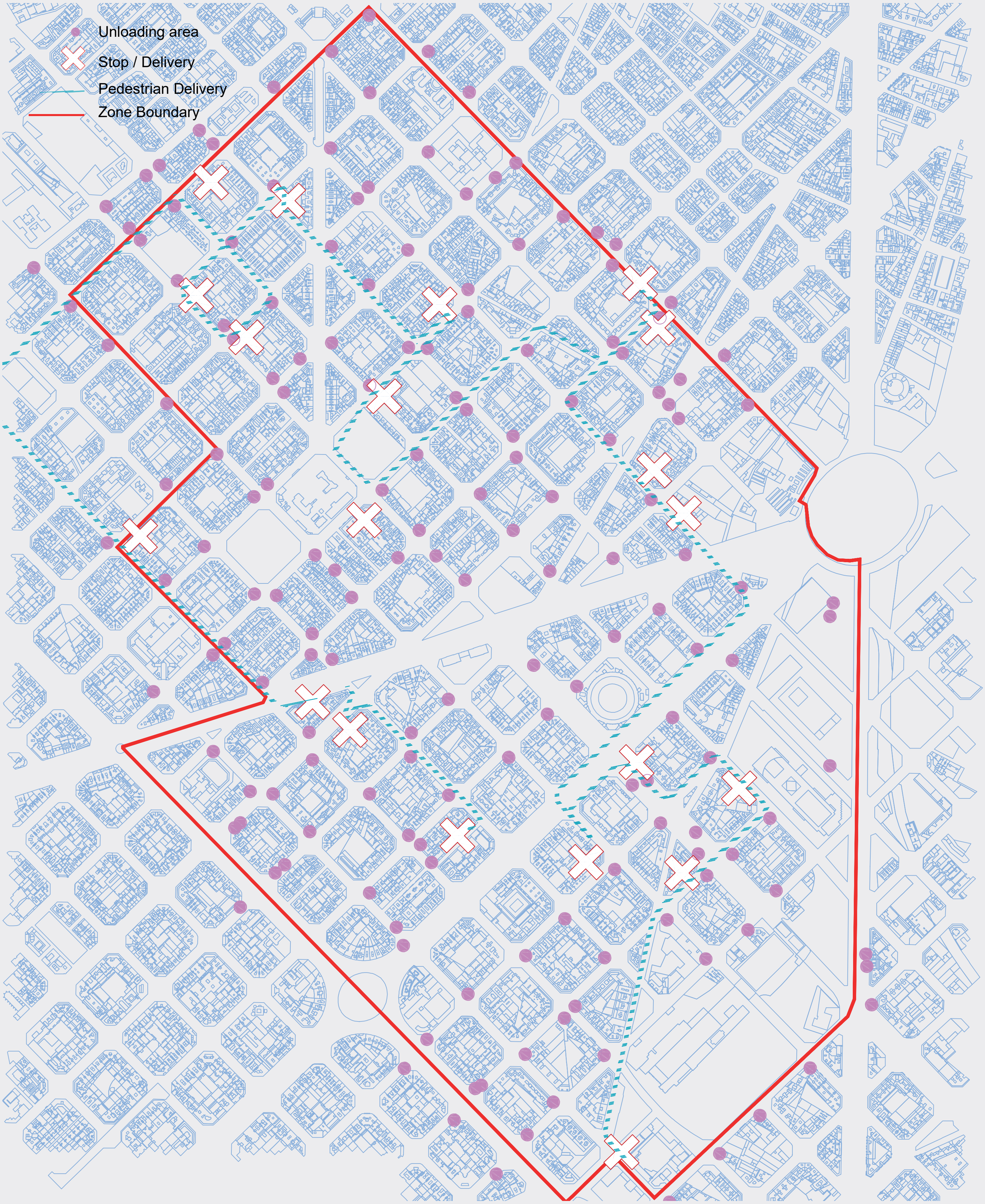
Madrid
scale 1:20.000

Barcelona
scale 1:10.000

- Unloading area
- Stop / Delivery
- Pedestrian Delivery
- Zone Boundary

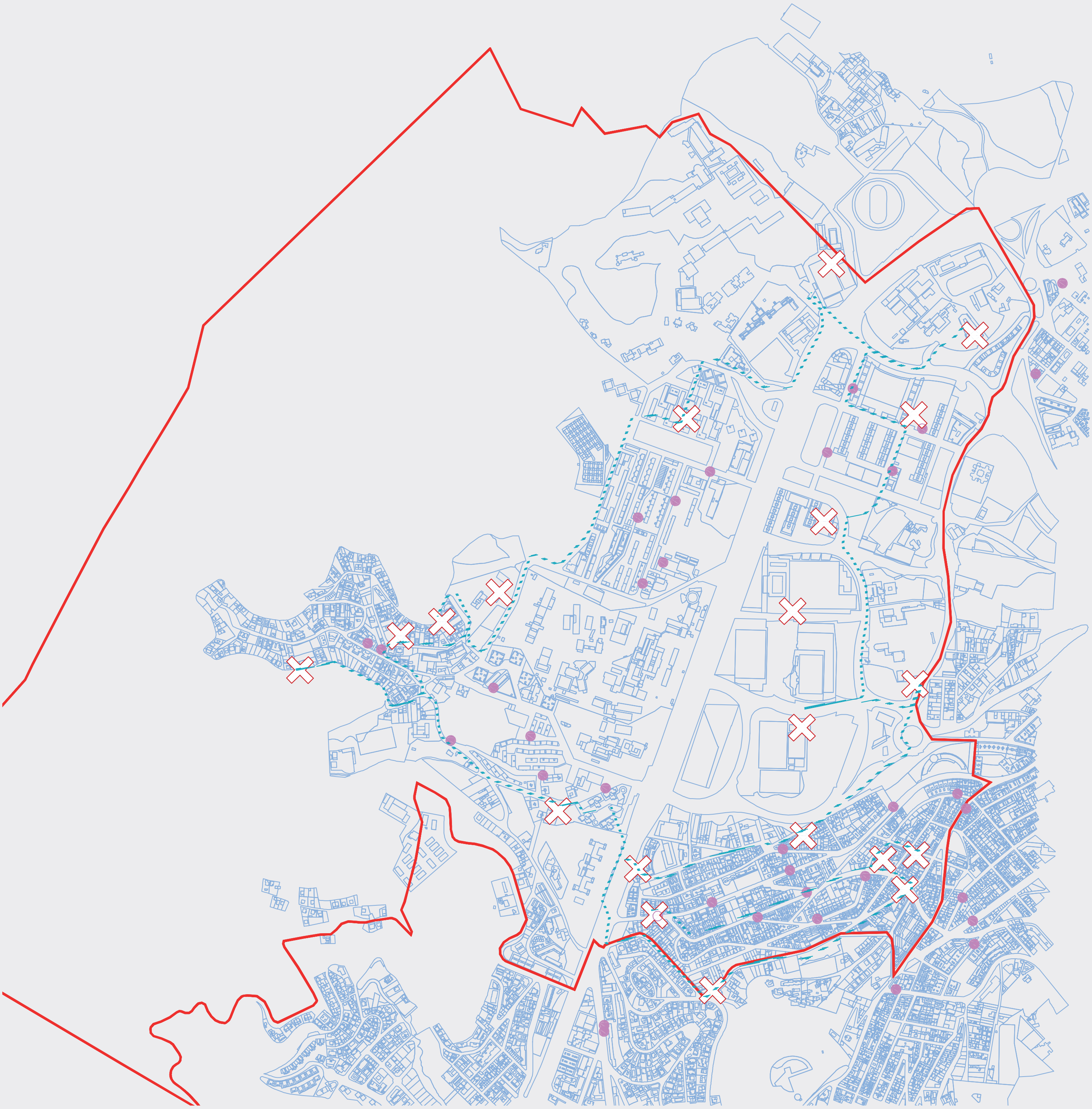


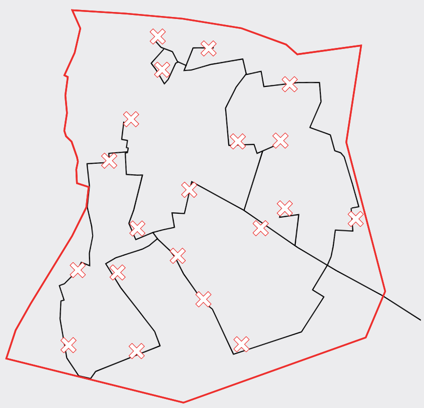
Barcelona
scale 1:10.000

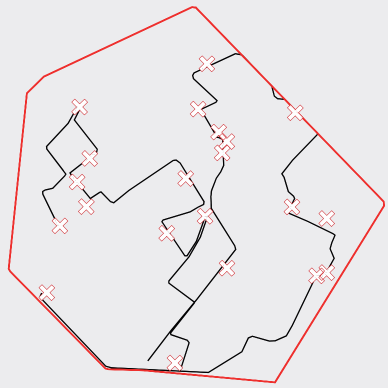


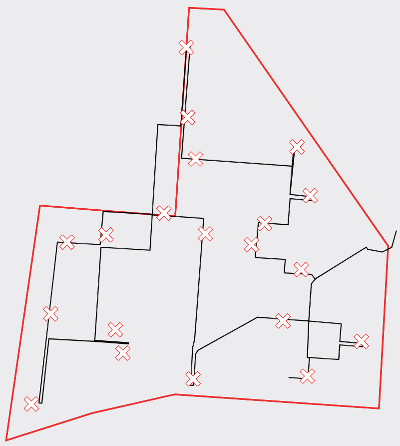
Barcelona
scale 1:15.000

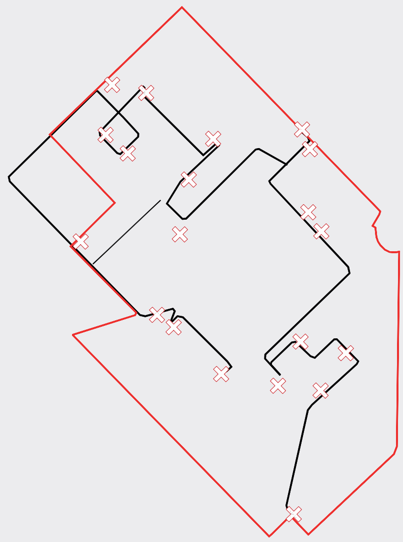
- Unloading area
- Stop / Delivery
- Pedestrian Delivery
- Zone Boundary

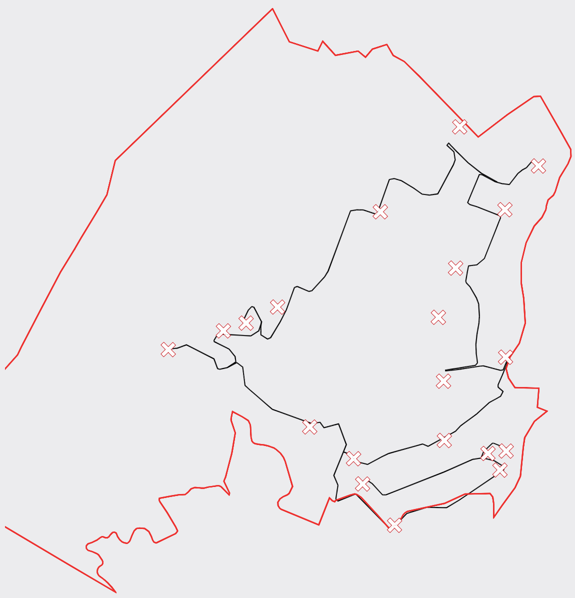










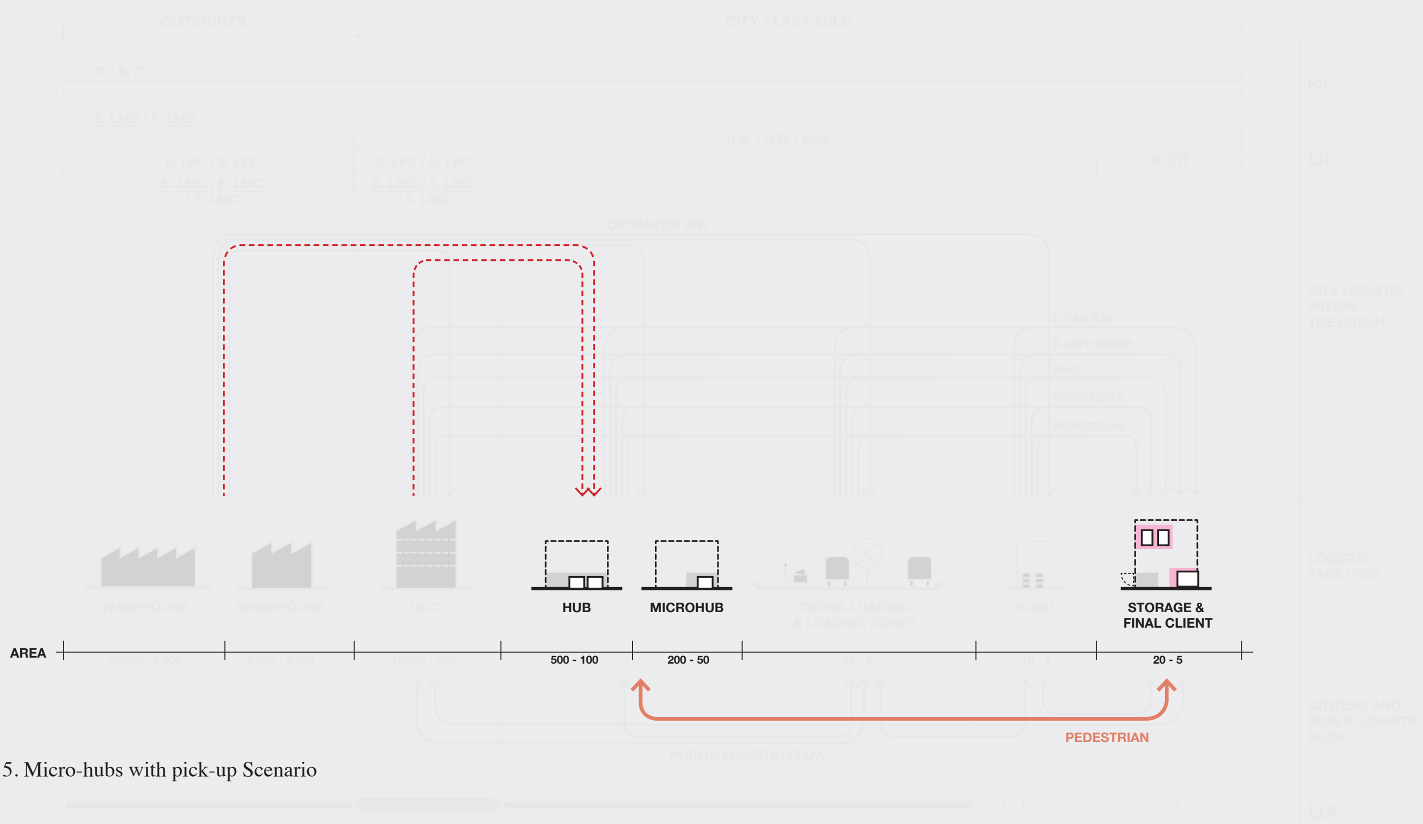


Optimised route with Pedestrian delivery Conclusions:

Pedestrian delivery, even with an optimized route, is the lowest-performing scenario in terms of efficiency as compared to scenarios electric vans (Scenario 1) or electric bicycles(Scenario 2), However, it must be remembered that this typology allows for access all throughout the city and means a reduction of kilometers traveled. The load and speed limitations are evident.

However, this scenario, in addition to its zero environmental footprint inside the urban area, has a significant effect on the perception of logistics in the community that it serves. It is important to underline that, as logistic operations inside cities grow, there is a responsibility to add a positive effect on both the environmental and the social components, and not only use efficiency as the sole objective to achieve.

This human scale is valuable because of its potential to increase livability of the area it serves. This scenario is highly valuable inside the city centers. However, in less dense areas, the large distances the pedestrian would need to travel could defeat its purpose.



5. Micro-hubs with pick-up Scenario

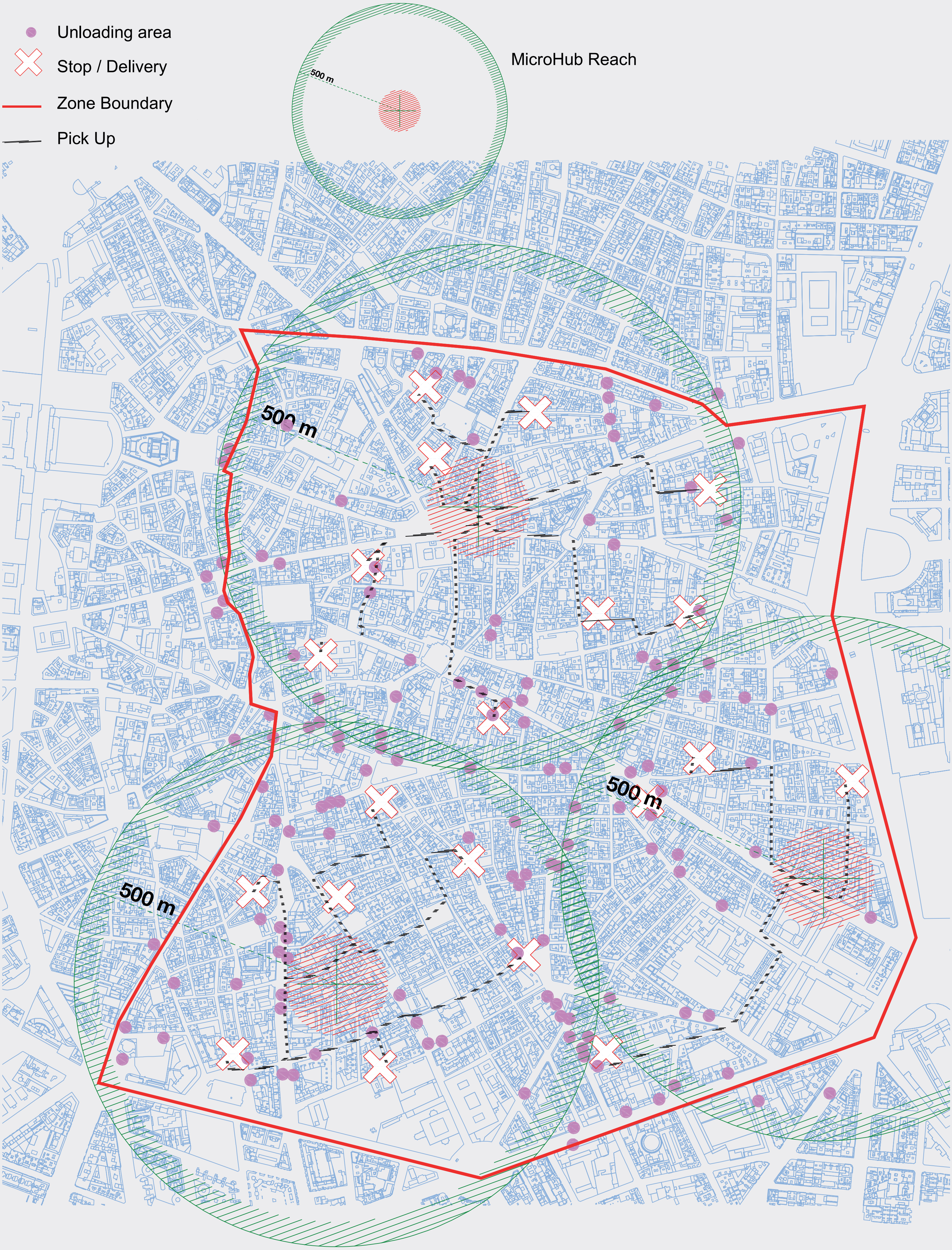
7.3. Proposed scenarios
7.3.5. Micro-hubs with pick-up

The Micro-hub scenario explores the possibility that the deliveries are no longer brought to an end client´s door and opens up the possibility of pick-up by the client. This has two important effects. On the one hand, it loses the convenience appeal of delivery to a private address and creates a more responsible attitude towards the process of parcel shipments. It also reduces the constant presence of logistics operations at a street level during the day. On the other hand, it promotes more flexible systems, where neither client nor company is dependent on each other’s availability and schedules.

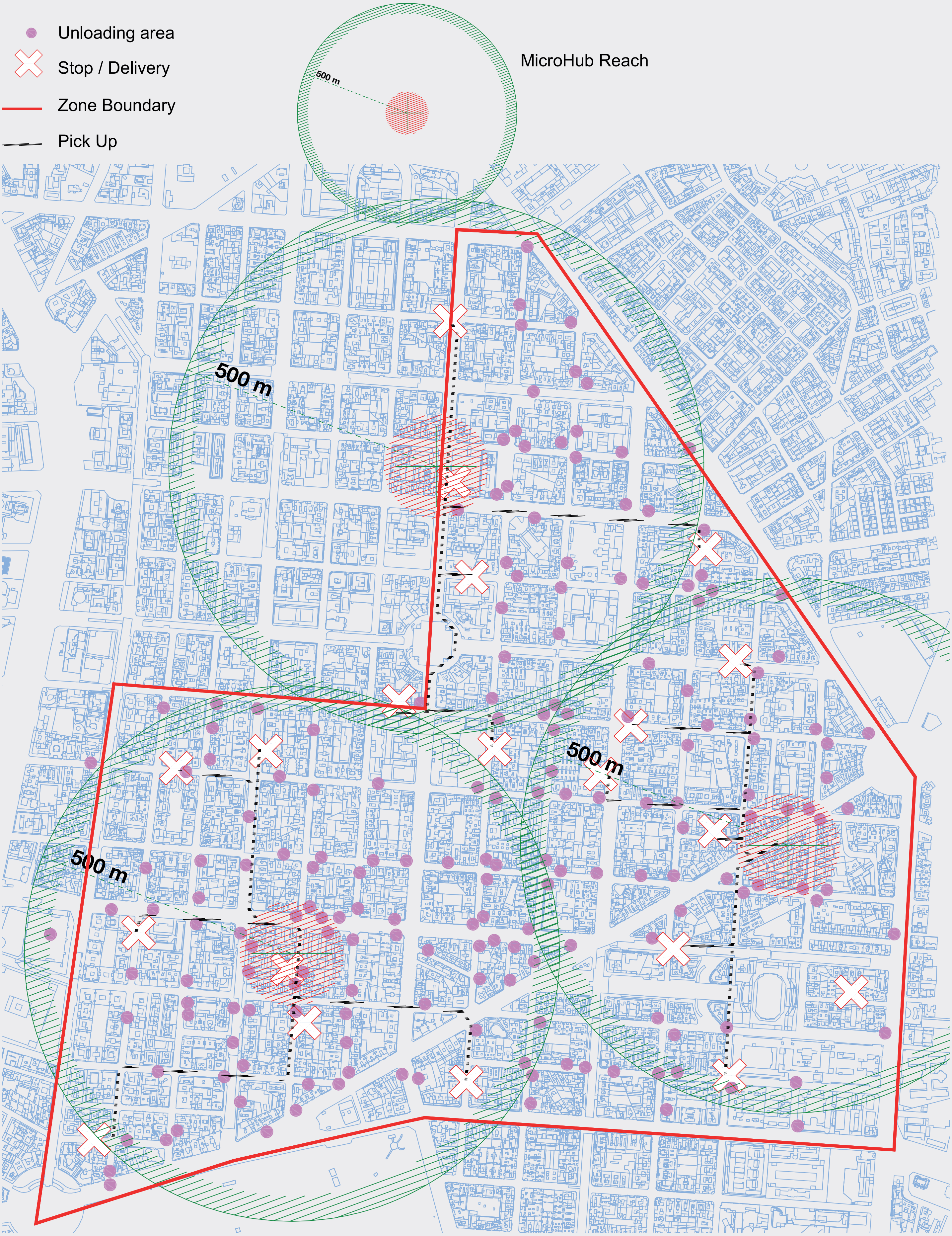
At the community level, this kind of approach has a positive effect on the neighborhood. It is an added local service that has the potential to engage the residents and include them in the previously opaque logistics process. With this in mind, micro-hubs proposed in this scenario are distributed throughout the selected areas within a 10-minute walking radius to allow for all residents to have convenient access to a pick-up point. The physical sizing of the proposed micro-hubs has not been analyzed and their location in the selected study areas is an approximation meant to evenly Distribute them throughout.
In this evaluation, we do not consider how the micro-hubs are supplied by the warehouse.
Further research into this scenario from a supply perspective is advisable and could work well in combination with scenario Optimized route with Electric Van (Scenario 1) and Consolidation Centers (Scenario 9).

To maintain consistency overall scenarios evaluated, the results of this scenario show 0 km and 0-time parameters for the index, as we are only measuring company time and kilometers traveled.

Madrid
scale 1:10.000



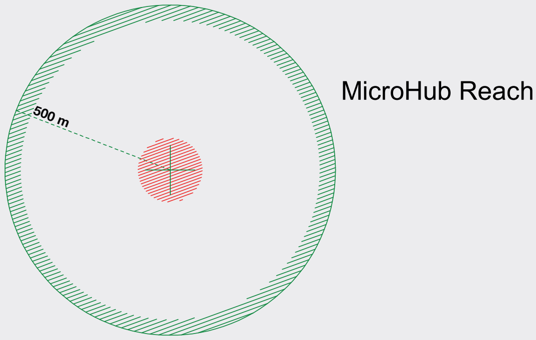
Madrid
scale 1:10.000



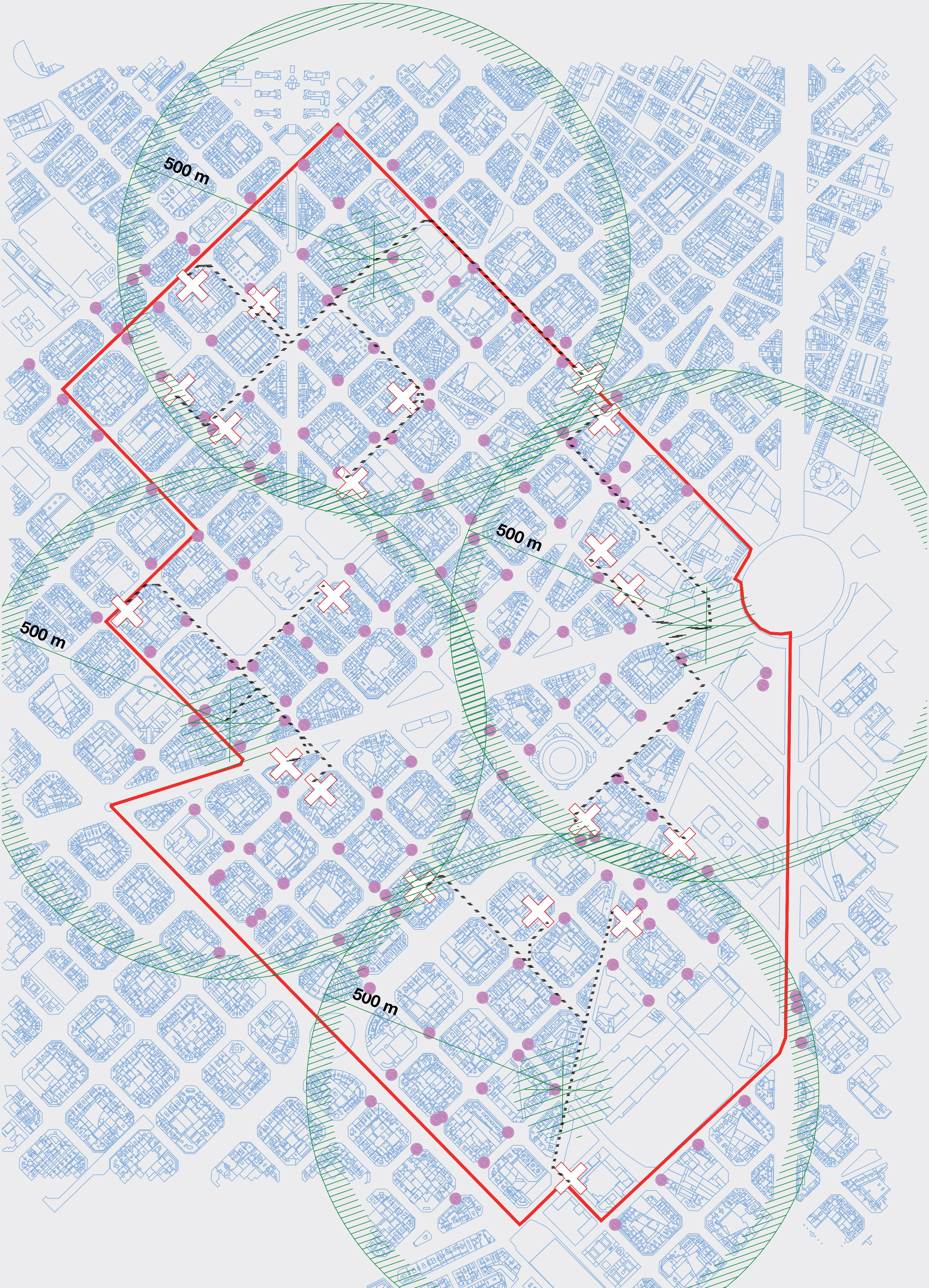
Madrid
scale 1:20.000

Barcelona
scale 1:10.000

Unloading area
Stop / Delivery
Zone Boundary
Pick Up

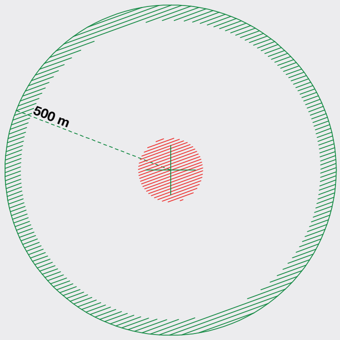


Barcelona
scale 1:10.000

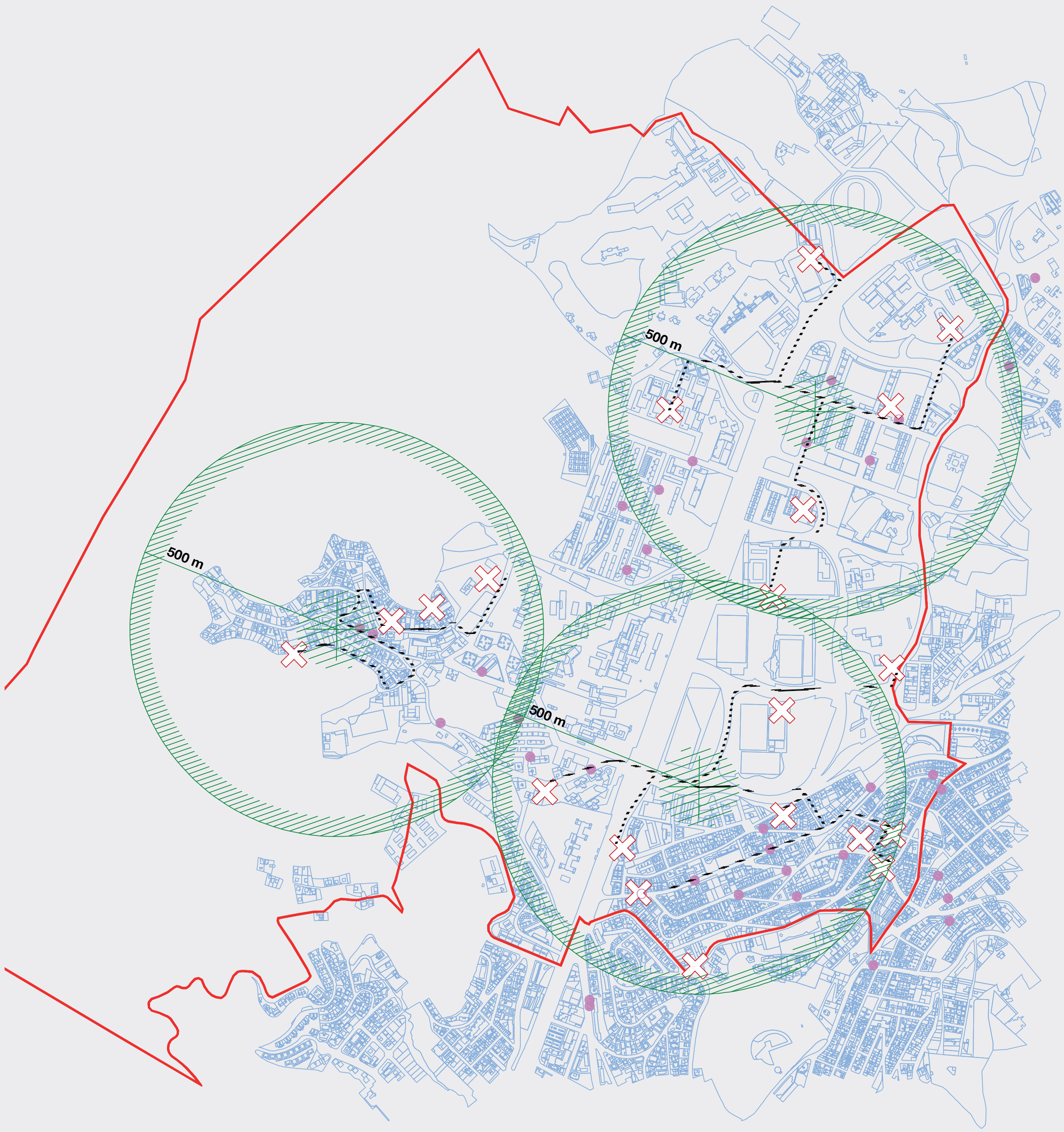


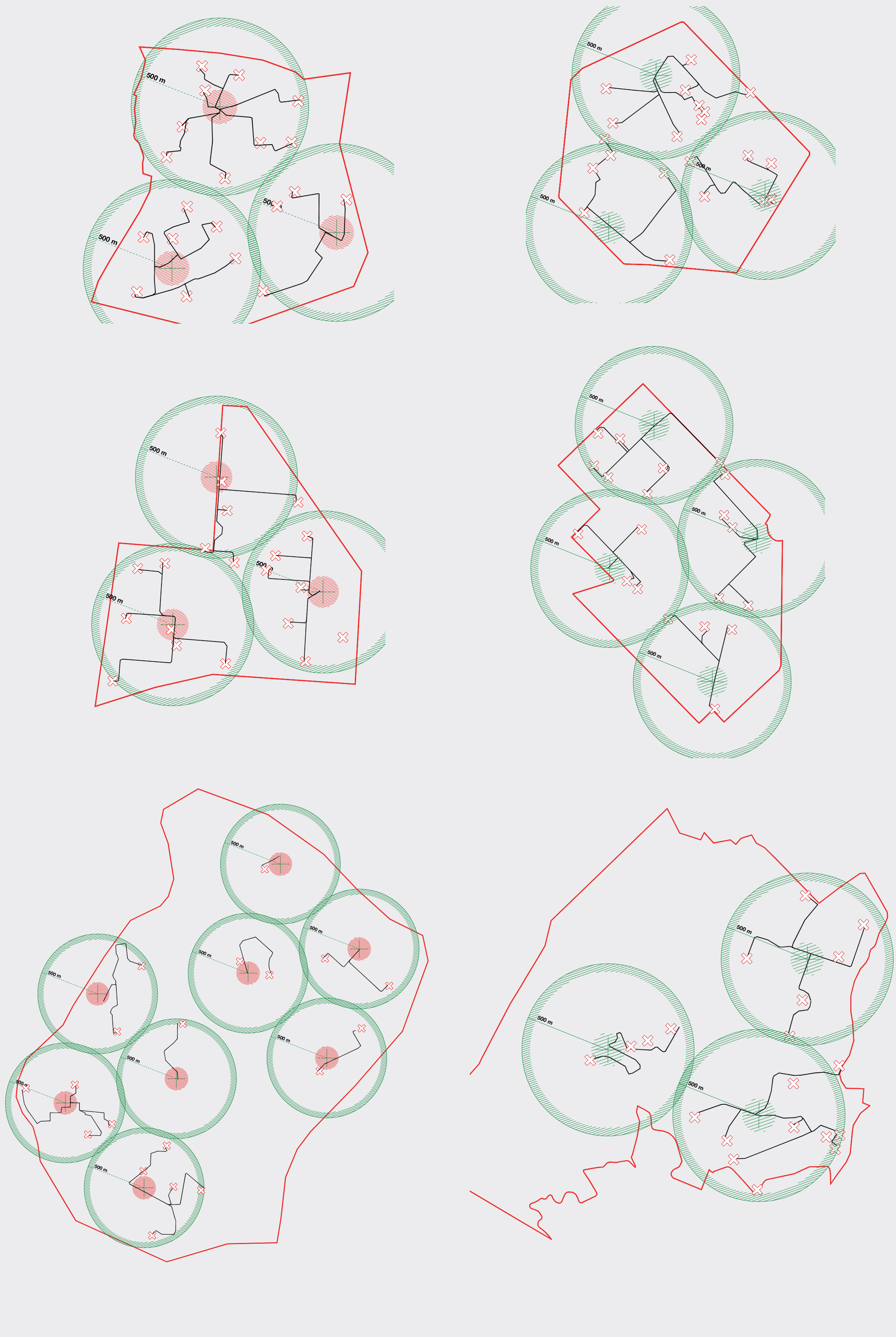
Barcelona
scale 1:15.000

- Unloading area
- Stop / Delivery
- Zone Boundary
- Pick Up



MicroHub Reach



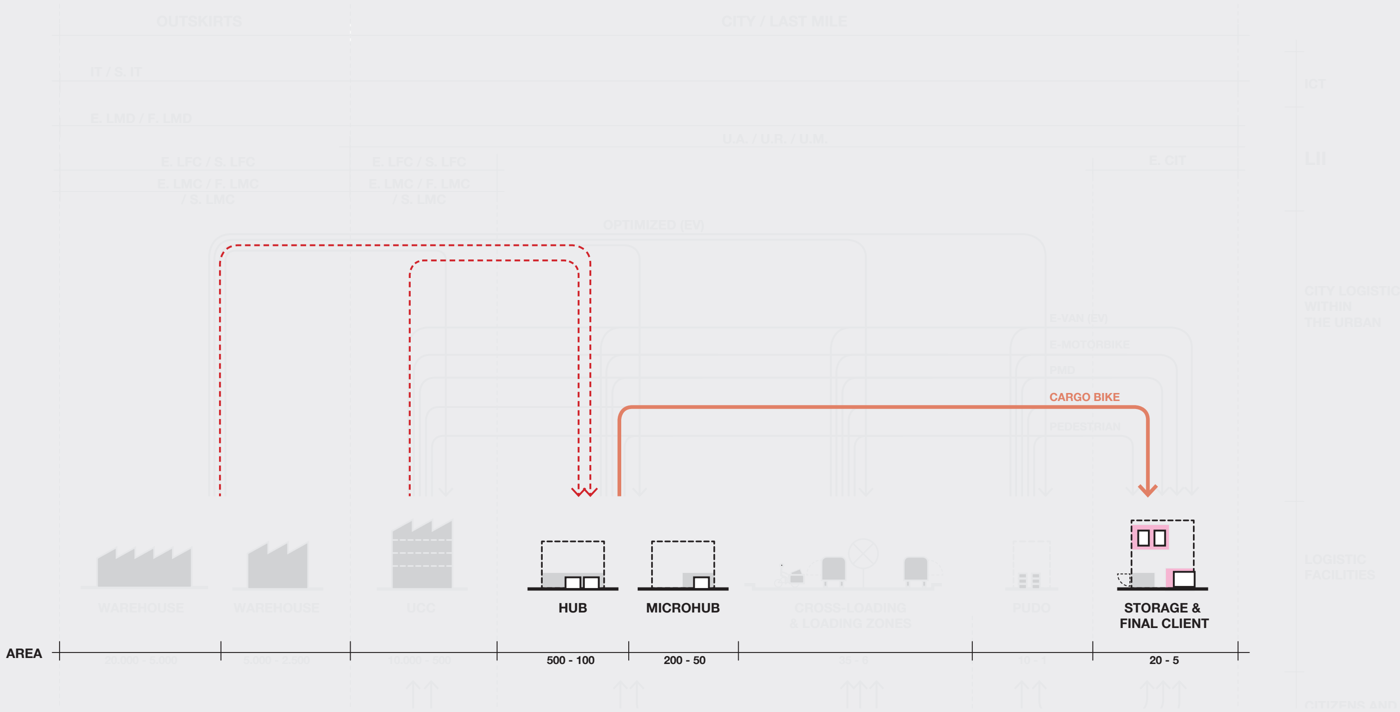

500 m

Micro-hubs with pick-up
Conclusions:

Bringing the parcels inside the cities to strategic and well-distributed locations and allowing clients to organize their own pickup near their homes, helps to engage with the local community while having a positive impact on the environment and neighborhood. New and active services increase the well-being of an urban area and contribute to viewing logistics in a positive light. For the client, the flexibility it adds to the "order and delivery" process is an added value.

Further study is needed concerning the physical characteristics of Micro-hubs and how they will be supplied with parcels. They may be spaces managed by a person or automated storage boxes. In both cases, the decisions should be based on density and availability of space as each model could produce different impacts. We believe that this scenario is completely feasible in the denser areas of both Madrid and Barcelona.

The availability of land at the outskirts of cities and the lower density of means that micro-hubs at the outskirts would be less efficient or less used. This could support the conclusion these areas may be more appropriate for automated boxes rather than managed spaces.



6. Micro-hubs with bike delivery Scenario

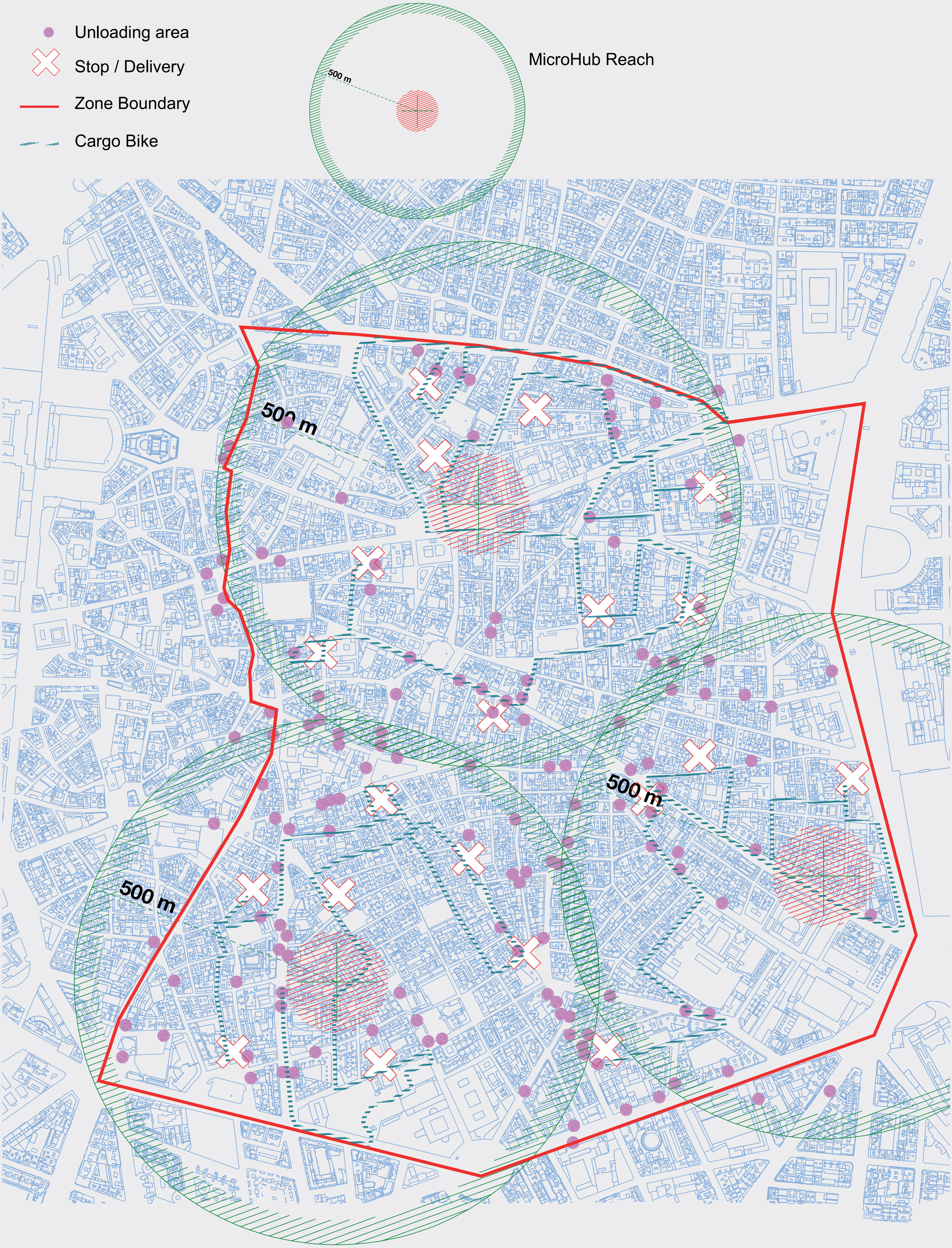
7.3. Proposed scenarios
7.3.6. Micro-hubs with bike delivery

Developing further on the proposal of Micro-hubs strategically placed throughout city neighborhoods, this scenario looks at door-to-door delivery from the hubs to their final destination via human-powered cargo bike. As previously explored in the scenario of optimized route with cargo-bike (Scenario 3), the environmental costs are zero, as is the intrusion at the street level, both in terms of traffic flow and from the perspective of a pedestrian or a resident.

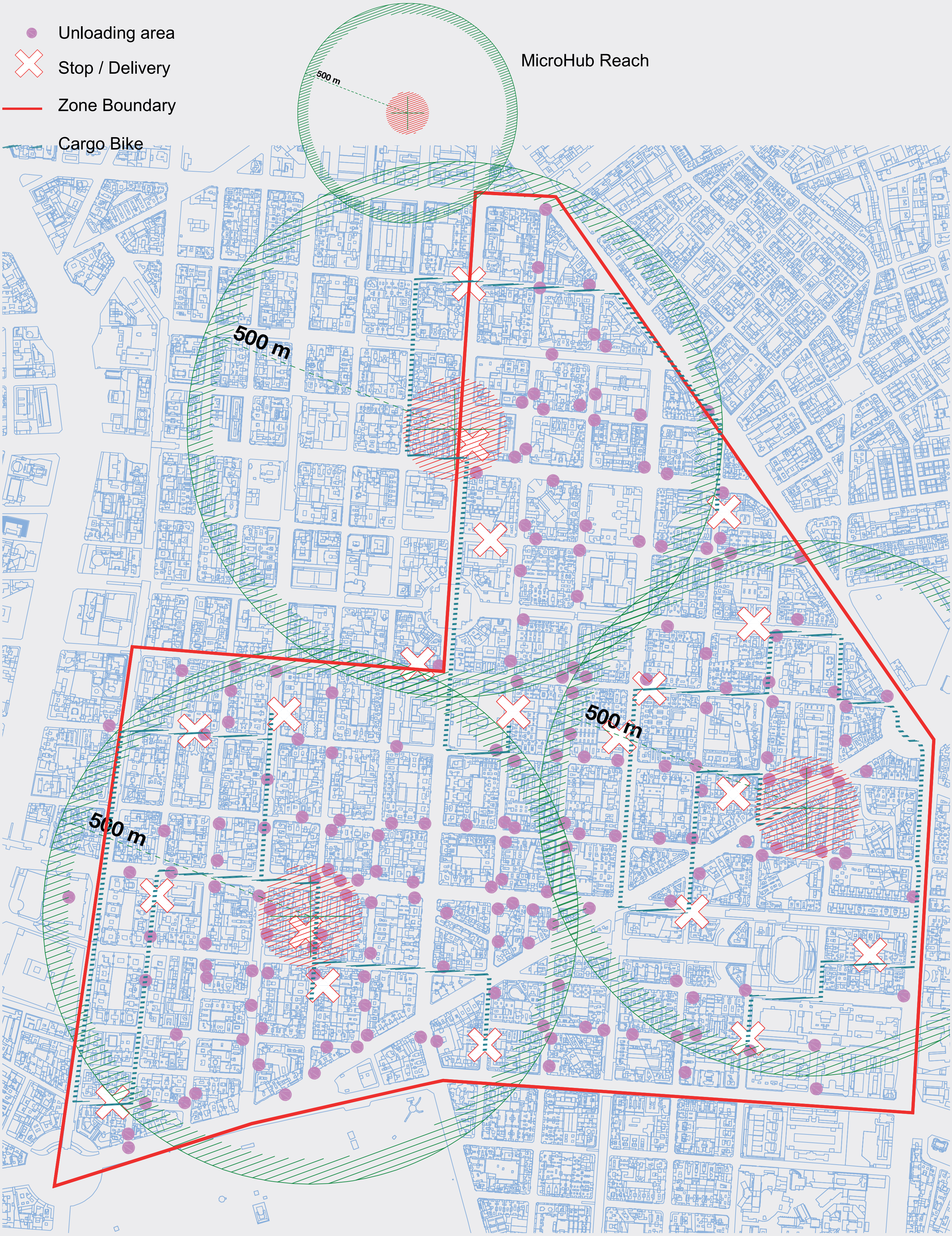
Each micro-hub location would deploy one cargo bike that serves a 500-meter radius. Within the 20 delivery stops that have been analyzed throughout this report, one individual hub in the center would serve on average, 30% of those deliveries. The 500-meter radius means that this facility can deliver to any point within that radius in two minutes. When adding more stops to that route along with the time necessary to prepare the parcels and reach new points on the route, the hub could easily satisfy the growing popularity of the one-hour delivery time, provided that the hub is well supplied. Supplying the hub itself must be considered and then related to the scenarios explored in chapter 5. Different options for different vehicles and times (ICE Vans during high traffic hours, Electric Vehicles during high traffic hours, Electric Vehicles during low traffic hours, and Electric Vehicles at night) arriving at the selected urban area should be considered. And these options should be further analyzed in combination with Optimized route with Electric Van (Scenario 1) and Consolidation Centers (Scenario 9) scenarios.
However, for the current scenario of micro hubs with bicycles, supply is not factored in and only the movement of the parcels within the urban area is calculated. The data of all hubs within one urban area, using the same parameters of 20 deliveries per neighborhood, are added together resulting in a sum that allows performance evaluation across all the other scenarios

We propose that these micro-hubs also offer pick-up services, but this was not taken into consideration in the present scenario’s evaluation.

Madrid
scale 1:10.000

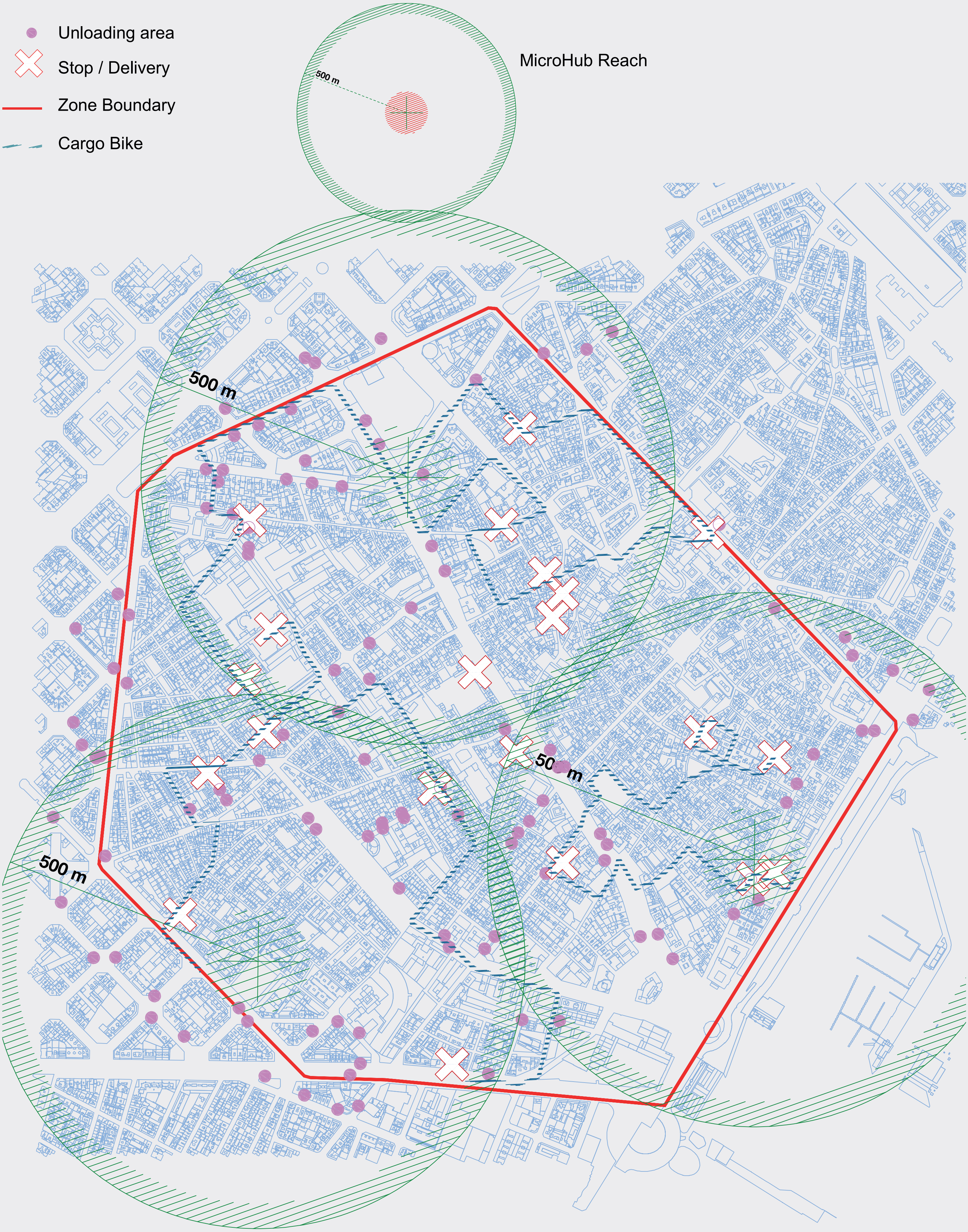


Madrid
scale 1:10.000

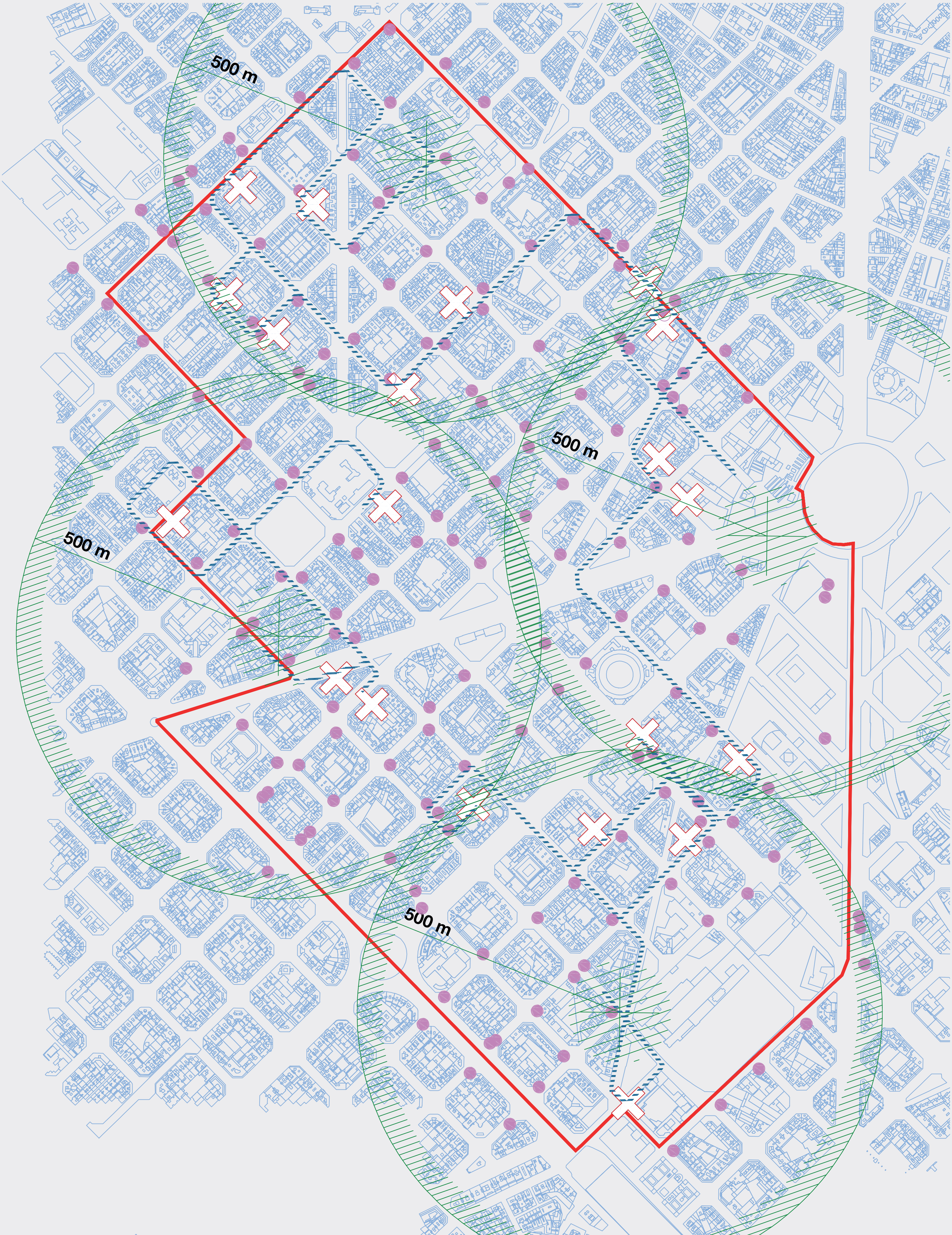


Madrid
scale 1:20.000

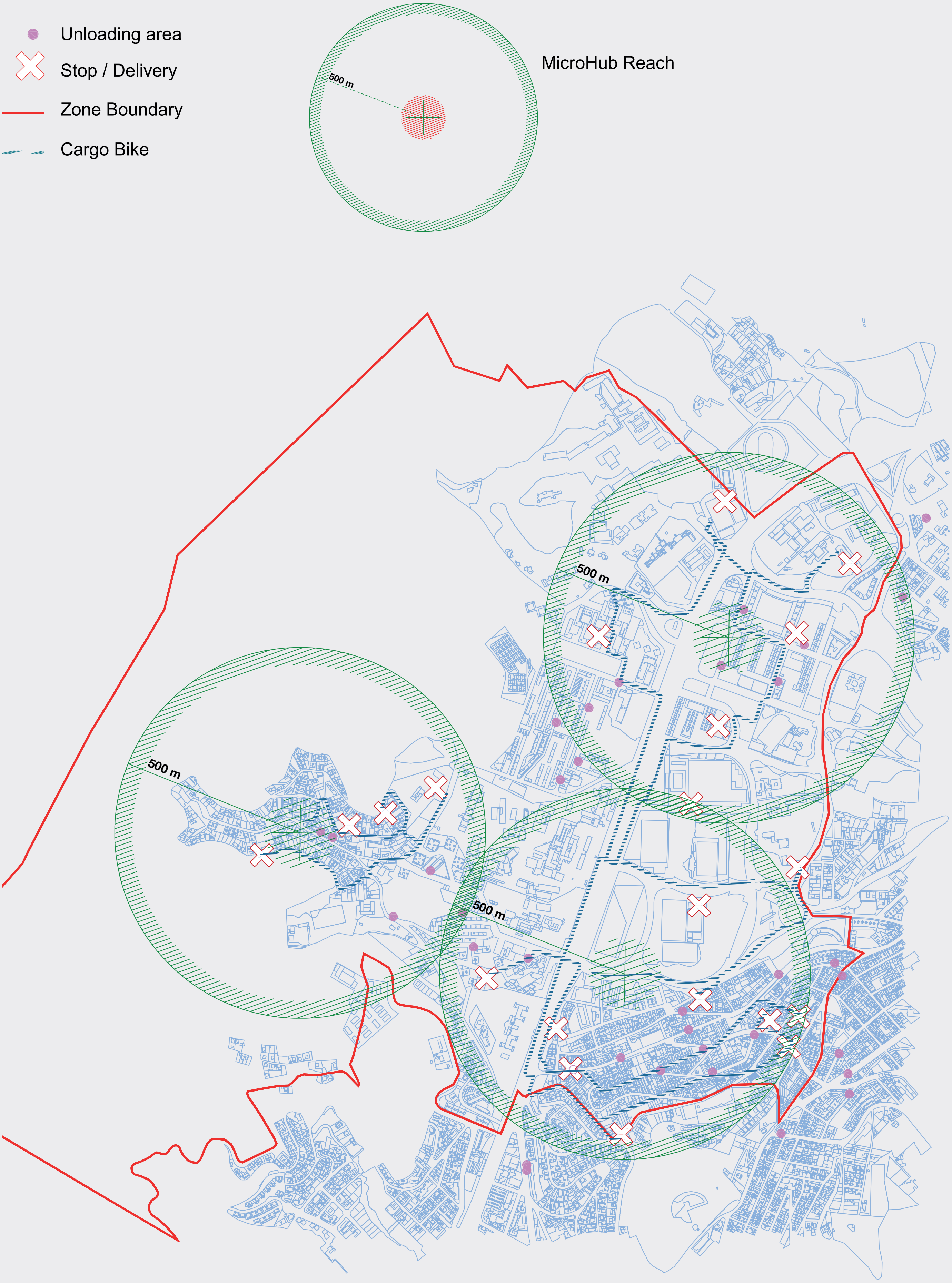
Barcelona
scale 1:10.000

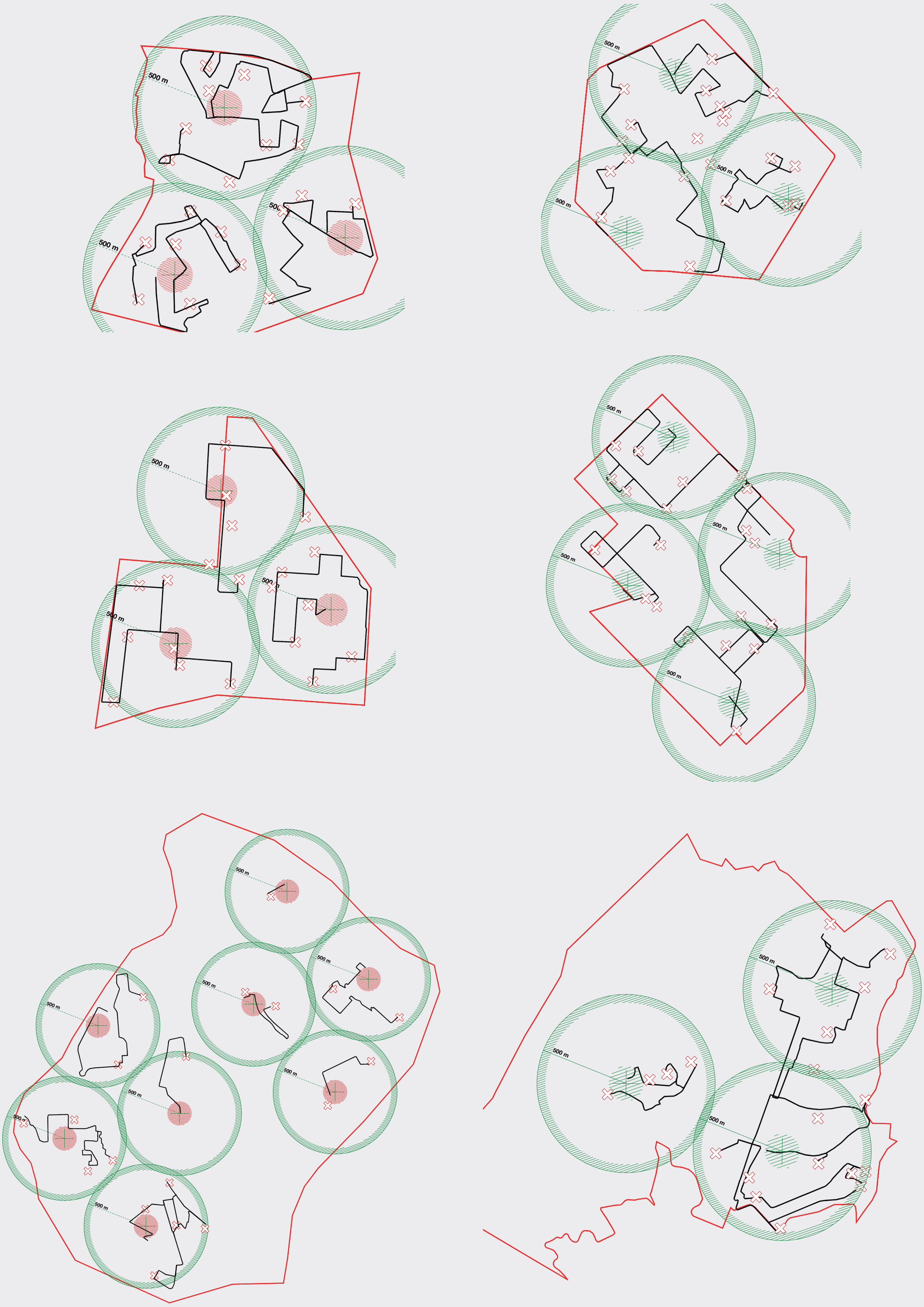


Barcelona
scale 1:10.000



Barcelona
scale 1:15.000

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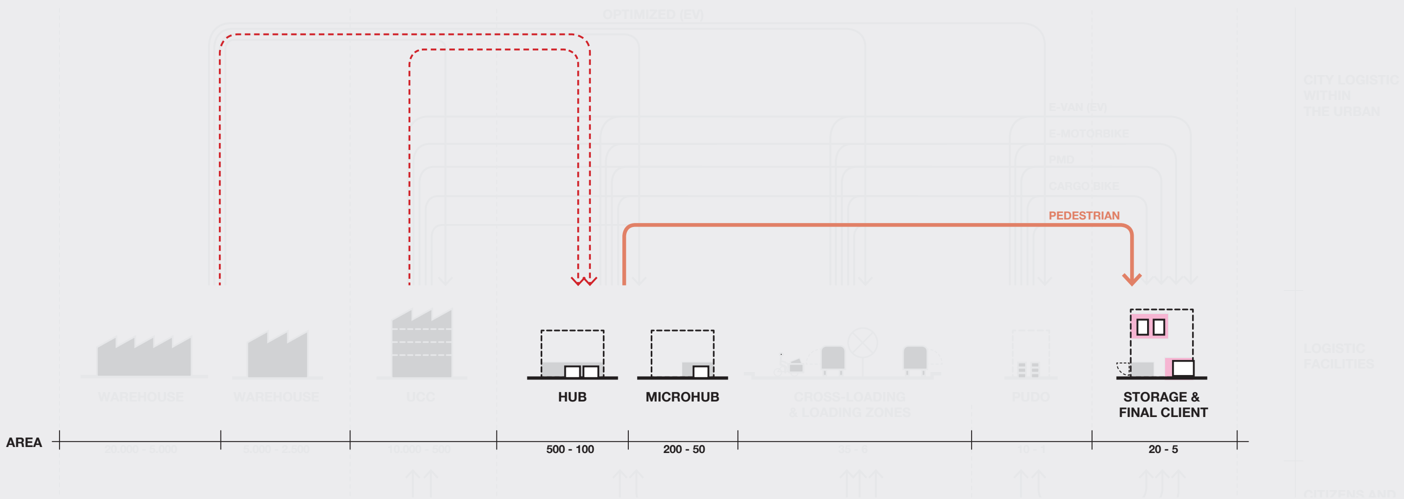
Micro-hubs with with bike delivery
Conclusions:

Depending on the strategy chosen for the supply of these micro-hubs, this scenario has the potential of becoming the most time-efficient and eco-friendly of all. Bike delivery has almost universal access at street level, zero emissions, and near-zero noise contamination. It is becoming increasingly popular. Micro-hubs could form agreements with external bike delivery companies and thereby create a chain of local connections and mutual empowerment.



7. Micro-hubs with pedestrian delivery Scenario

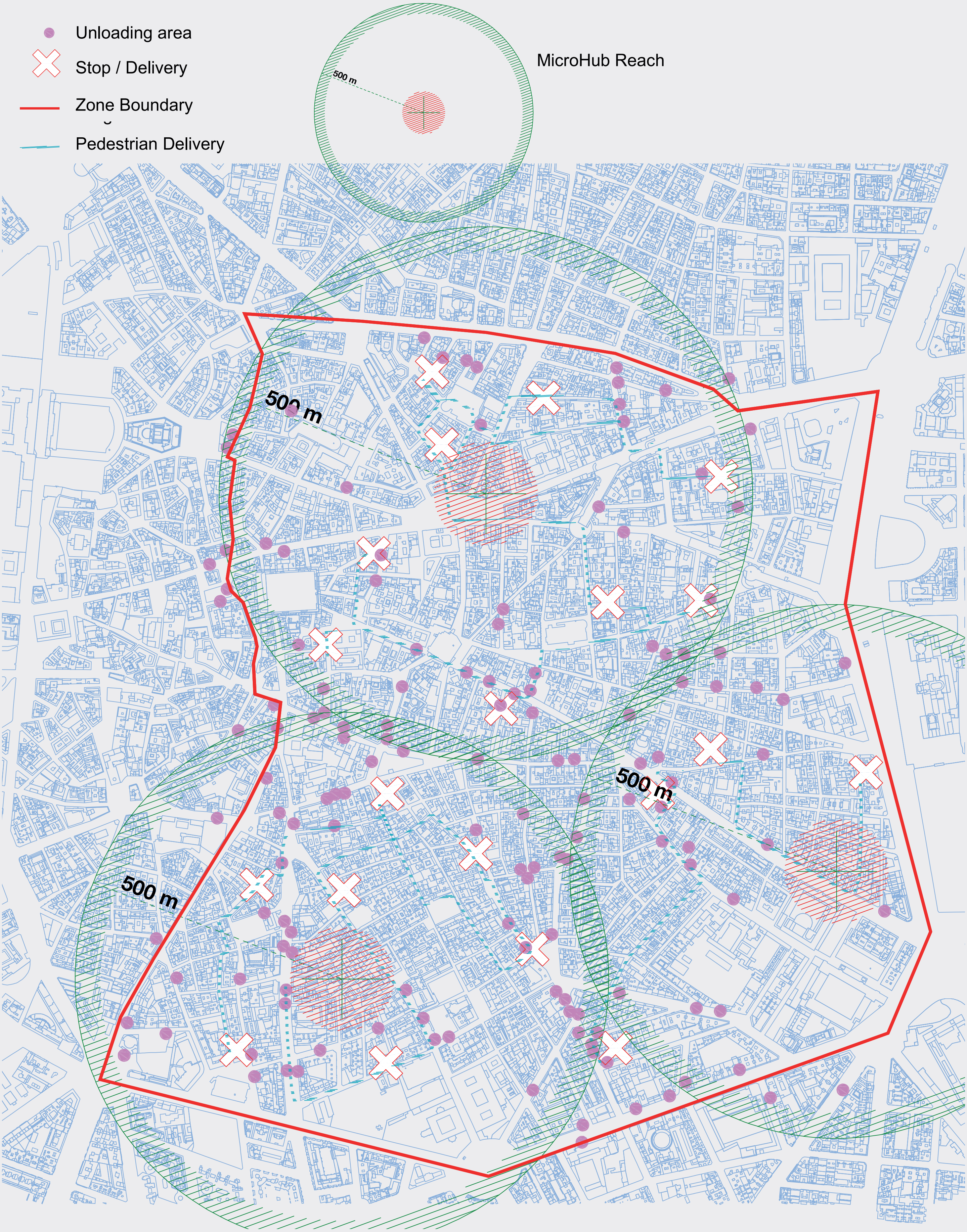
7.3. Proposed scenarios
7.3.7. Micro-hubs with pedestrian delivery

This scenario is a mixture of Micro-hubs with pick-up (Scenario 5) and Optimized route with Pedestrian delivery (Scenario 4) We have not taken into account the movement of the package from the last warehouse to the micro-hub. We have only modeled the impact from the micro-hub to the final destination

Much like in Micro-hubs with pick-up scenario, micro-hubs are distributed throughout the urban areas serving a 500-meter radius. Given the limited capacity to carry a large volume of packages, this radius guarantees a ten-minute walk for delivery and re-supply, if needed. The data for 20 deliveries were collected to facilitate the performance evaluation in the Logistics Impact Index.

We propose that these Micro-hubs also offer pick-up services, but this was not taken into consideration in this scenario’s evaluation.

Madrid
scale 1:10.000



Madrid
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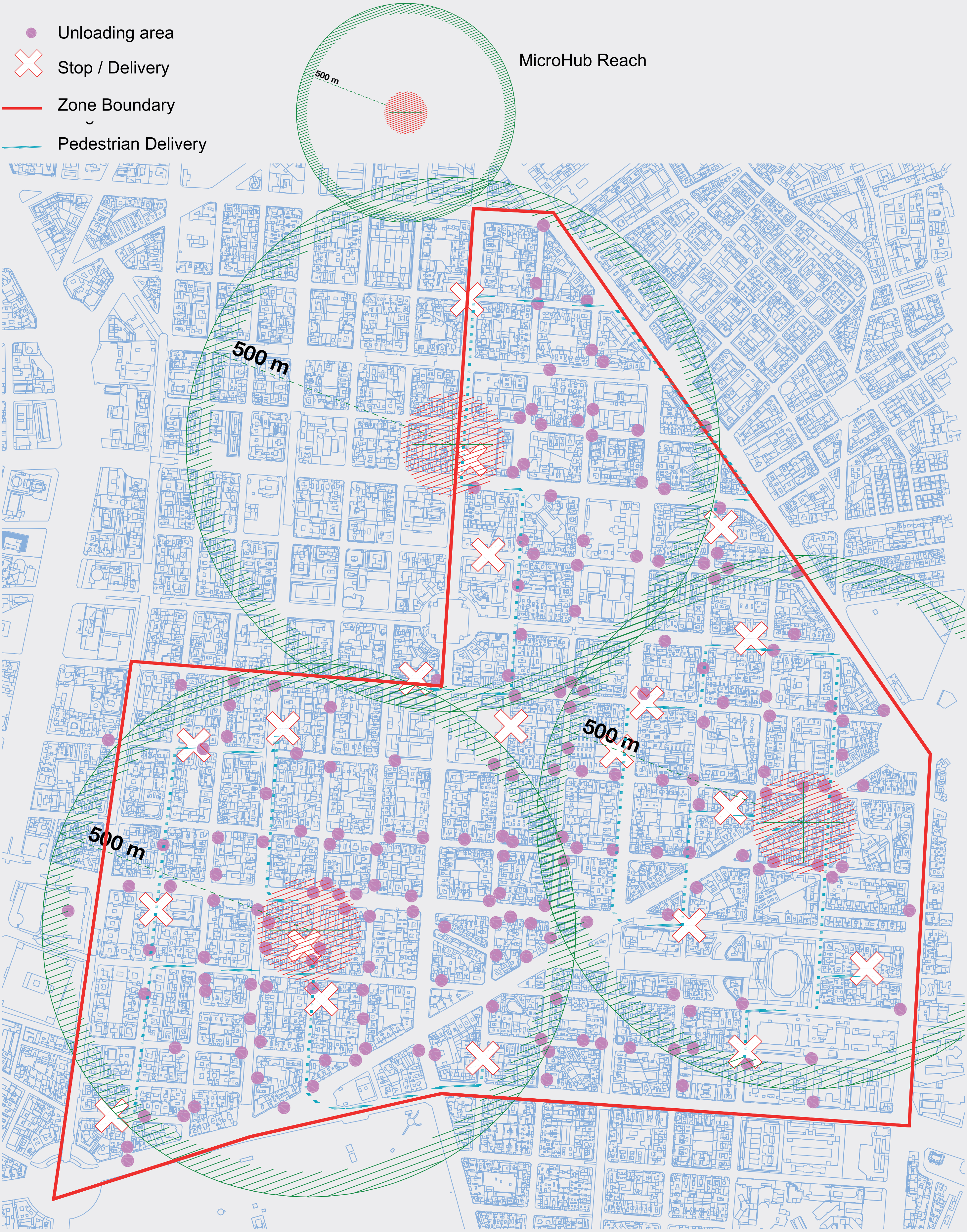
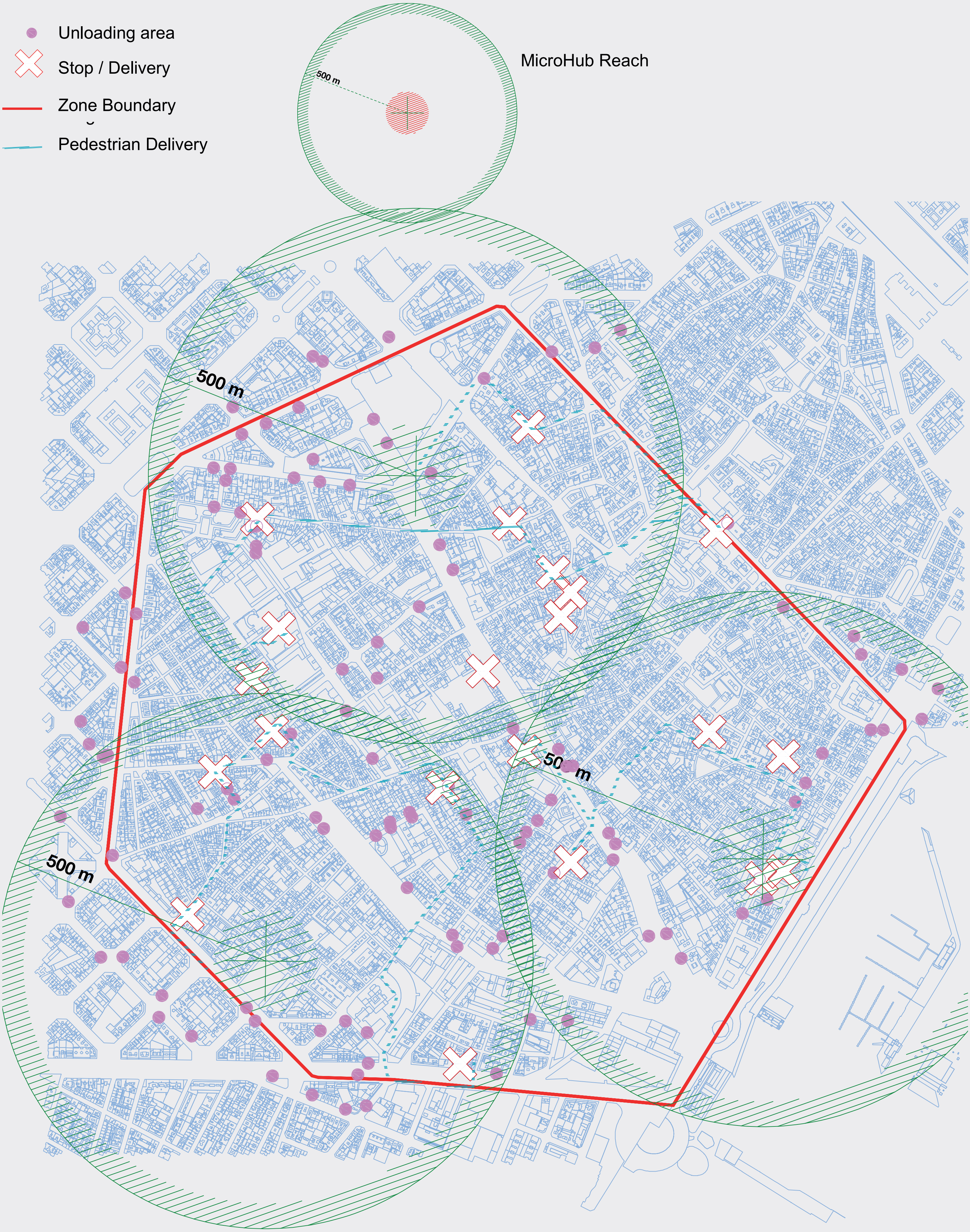
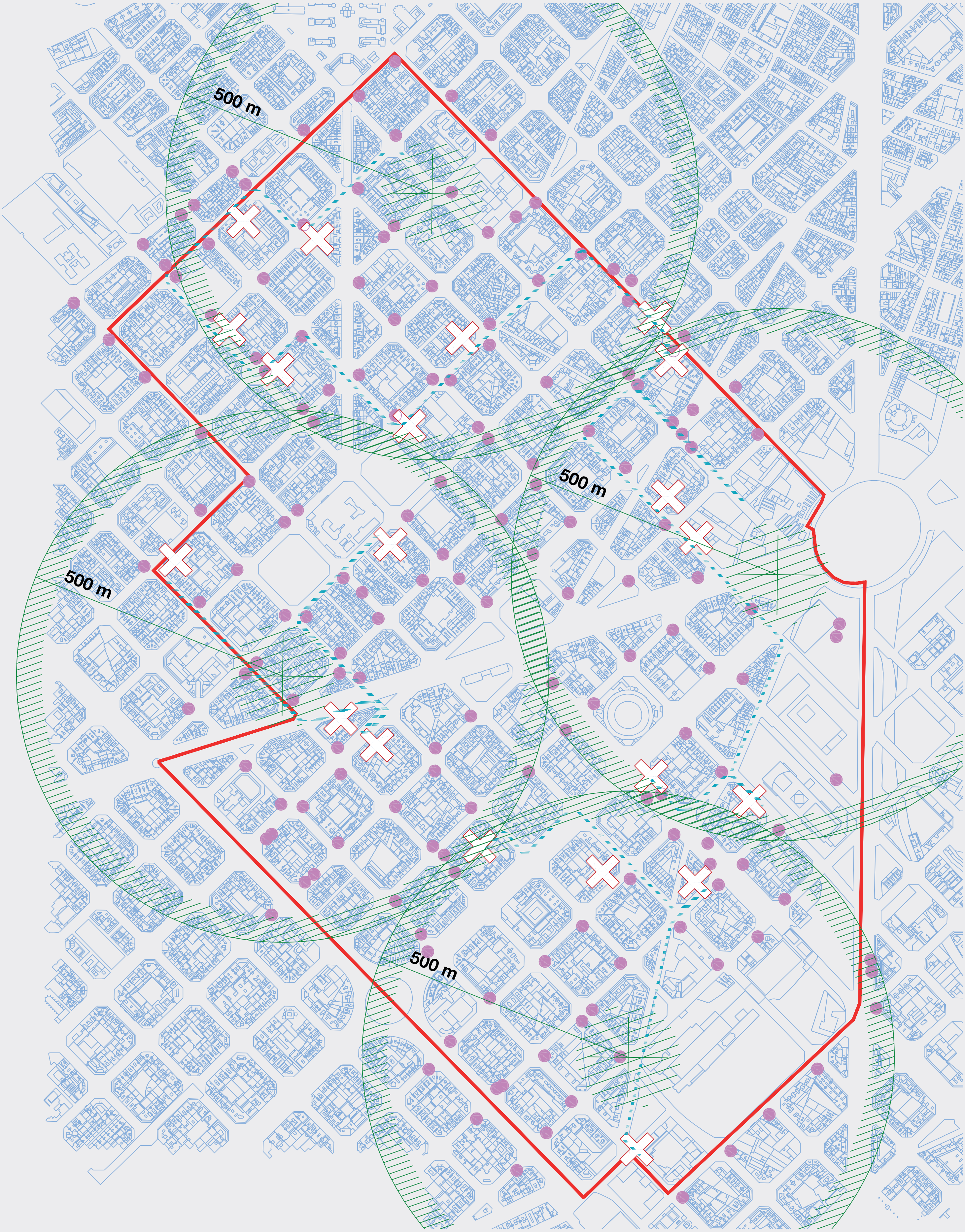


Madrid
scale 1:20.000

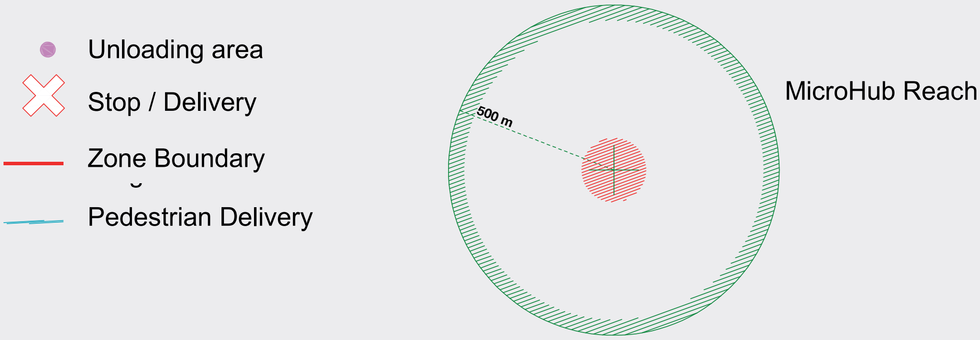
Barcelona
scale 1:10.000

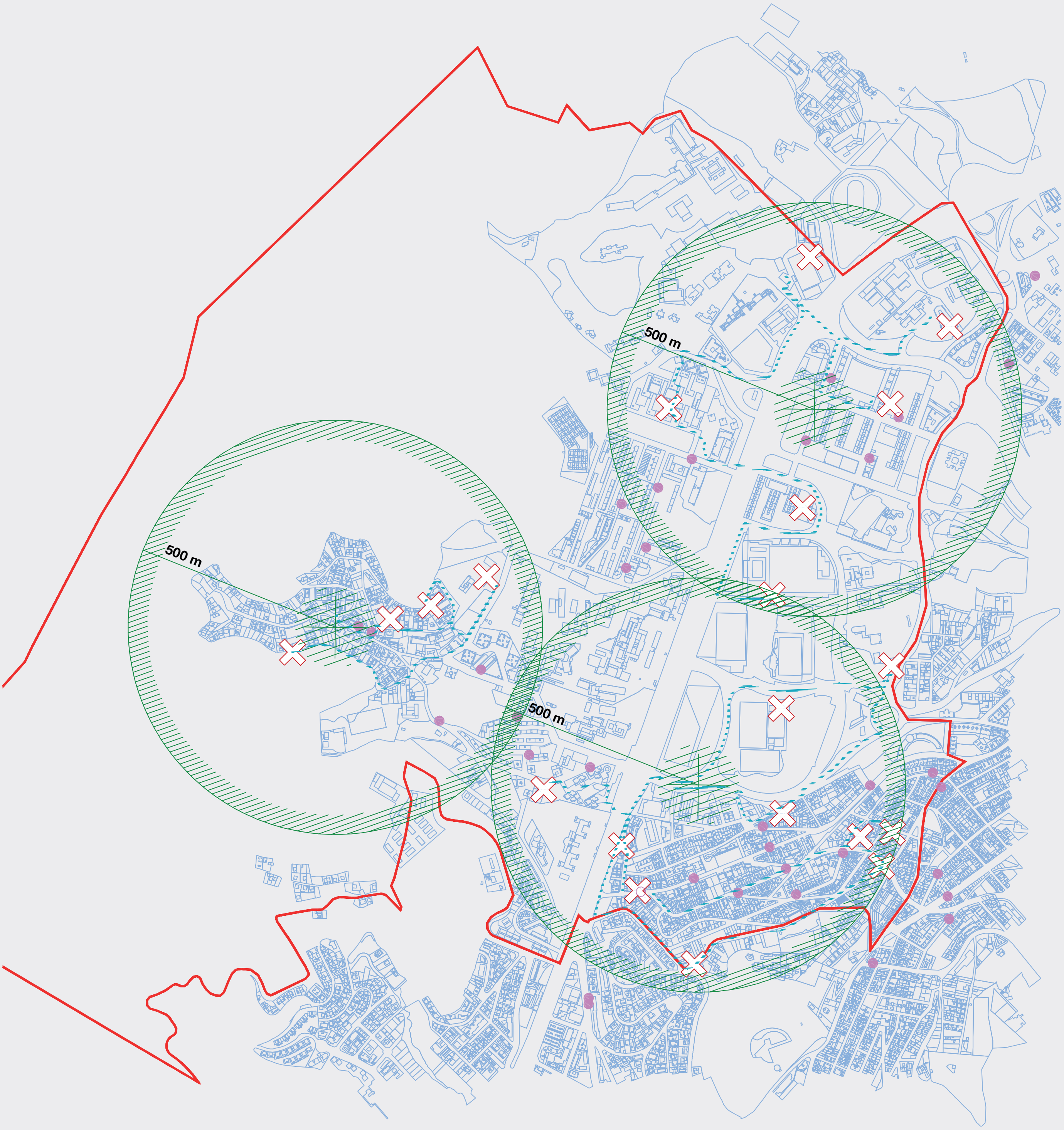


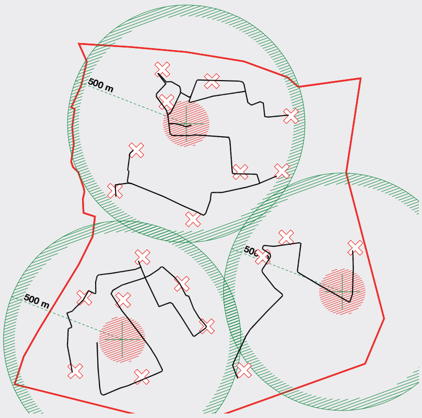
Barcelona
scale 1:10.000



Barcelona
scale 1:15.000



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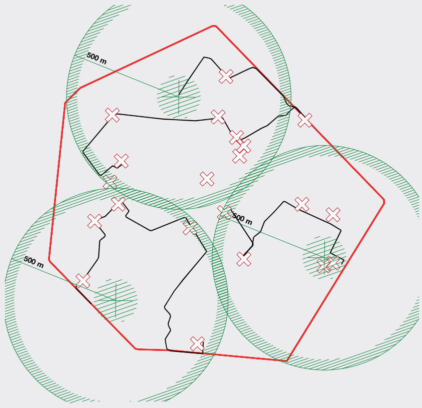
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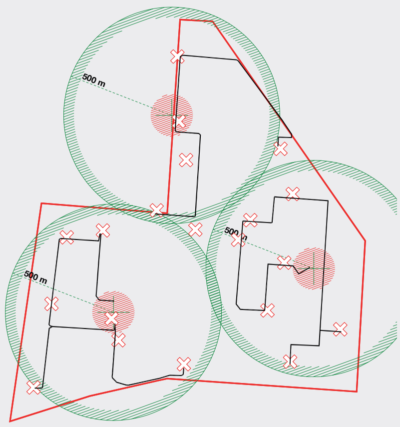
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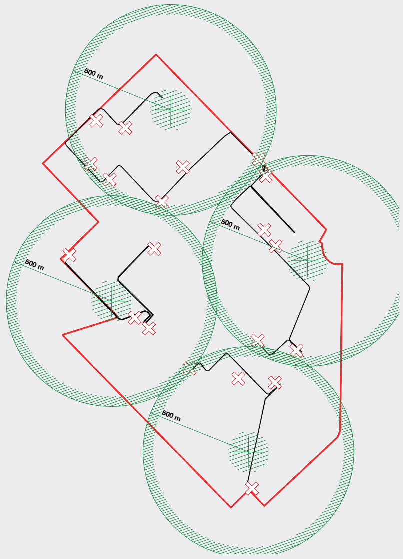
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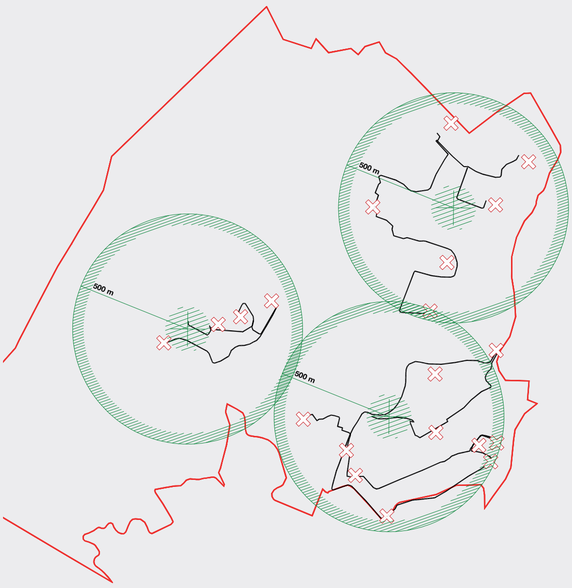
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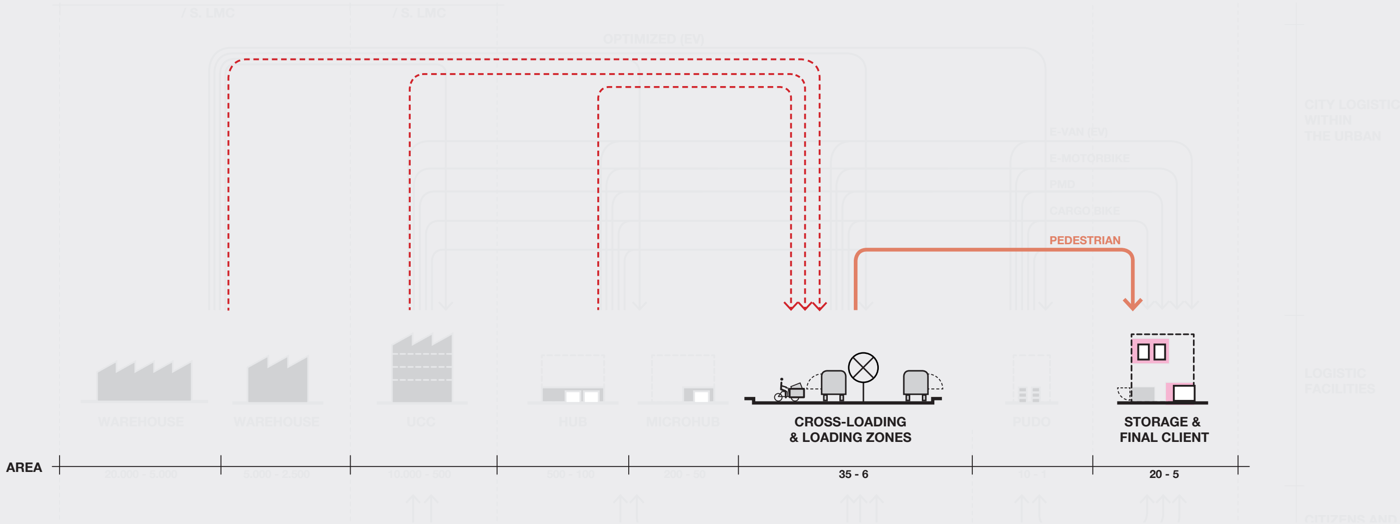
Micro-hubs with with pedestrian delivery Conclusions:

This scenario has one of the highest positive social impacts because it can create a neighborhood-based service and add a mobile representative of that service that eventually becomes a recognizable collaborator in the urban area. In addition, the dense distribution of these micro-hubs resolves the lack of efficiency that the pedestrian delivery had in the. Optimized route with Pedestrian delivery Scenario 5.

As we have seen so far, the lower density areas are less suited for pedestrian deliveries because of the large distances that need to be traveled. However, in high-density areas, the freedom of movement of a pedestrian becomes extremely efficient, especially in areas that are especially suited and planned for pedestrian traffic.



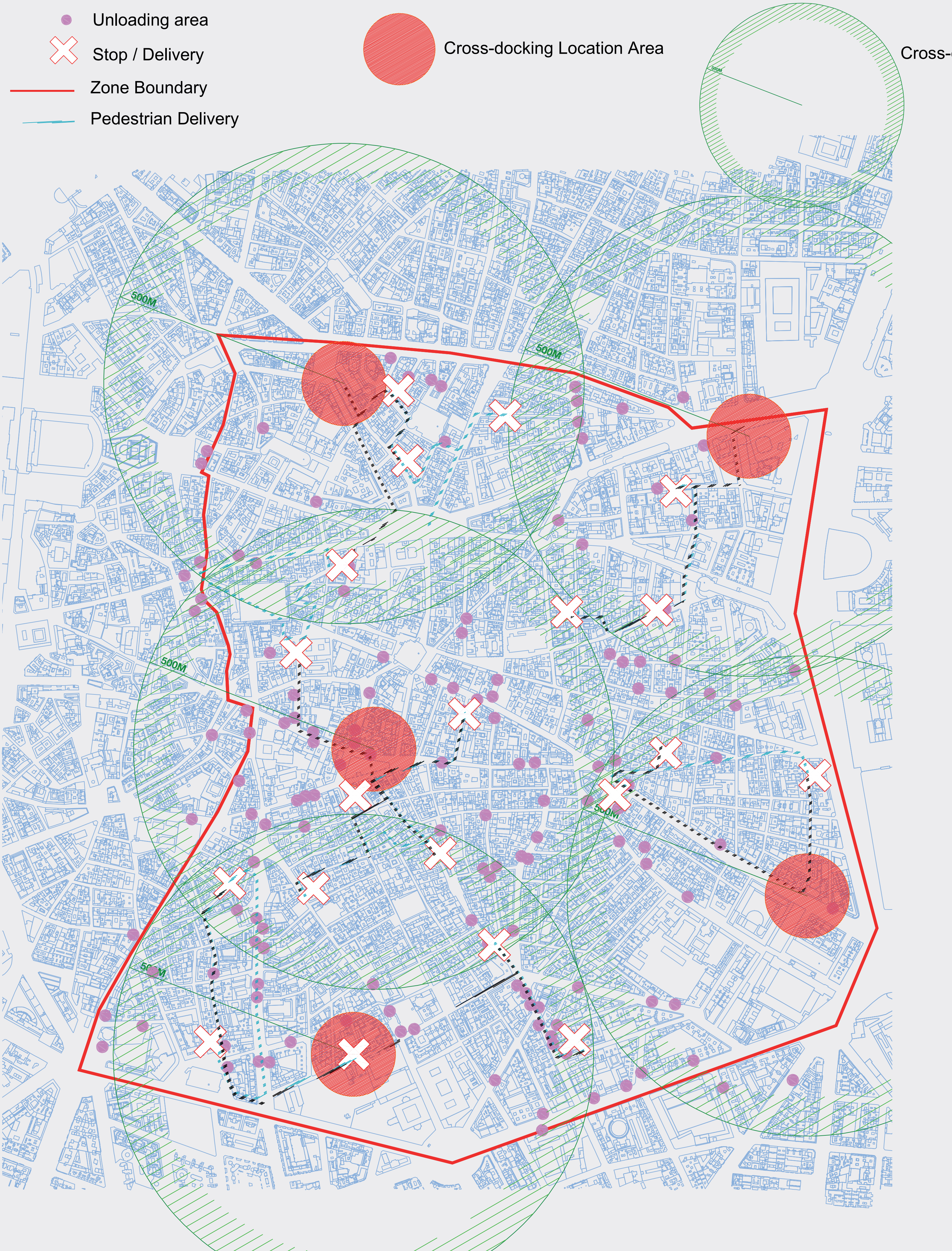
8. Cross-loading/unloading with pedestrian delivery Scenario

7.3. Proposed scenarios
7.3.8. Cross-loading/unloading with pedestrian delivery

This scenario proposes using loading and unloading zones as temporary nano-hubs from which the driver completes his/her deliveries. It is a kind of open-air cross-docking. Essentially an electrical van that arrives from the warehouse is parked for a longer amount of time and temporarily becomes a storage space from which pedestrian delivery may be completed. Parking spaces are strategically determined in order to efficiently deliver within a 10-minute pedestrian radius. This would mean that each stop would have a duration between 20 and 30 minutes, depending on the amounts of deliveries in the area. The driver would make more or fewer stops depending on the size and density of the urban area.

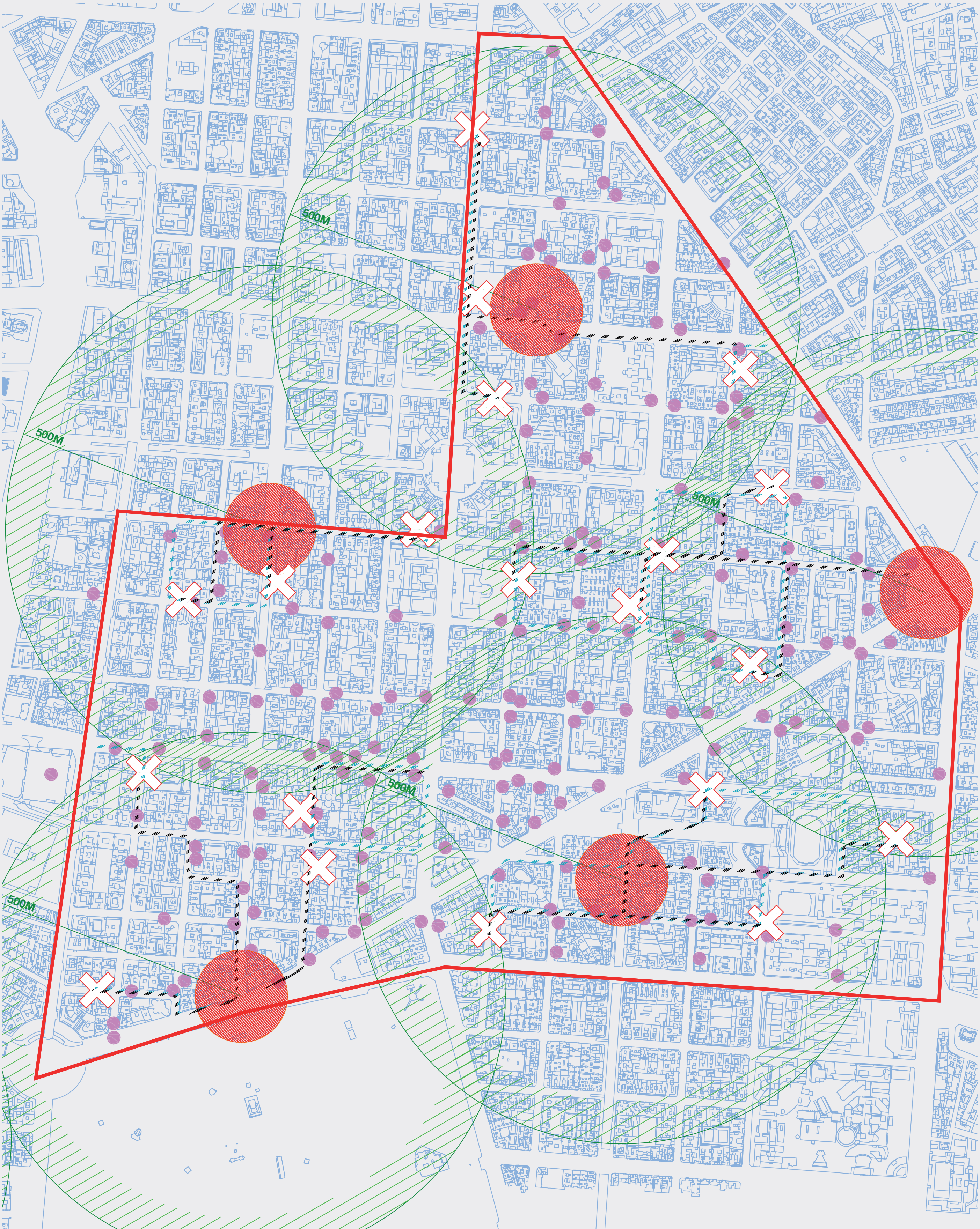
This scenario was evaluated including the time and distance traveled from the warehouses to the urban areas and between parking spaces. We believe that impacts could be further reduced if combined with the scenario of Consolidation Centers (Scenario 9).

Madrid
scale 1:10.000

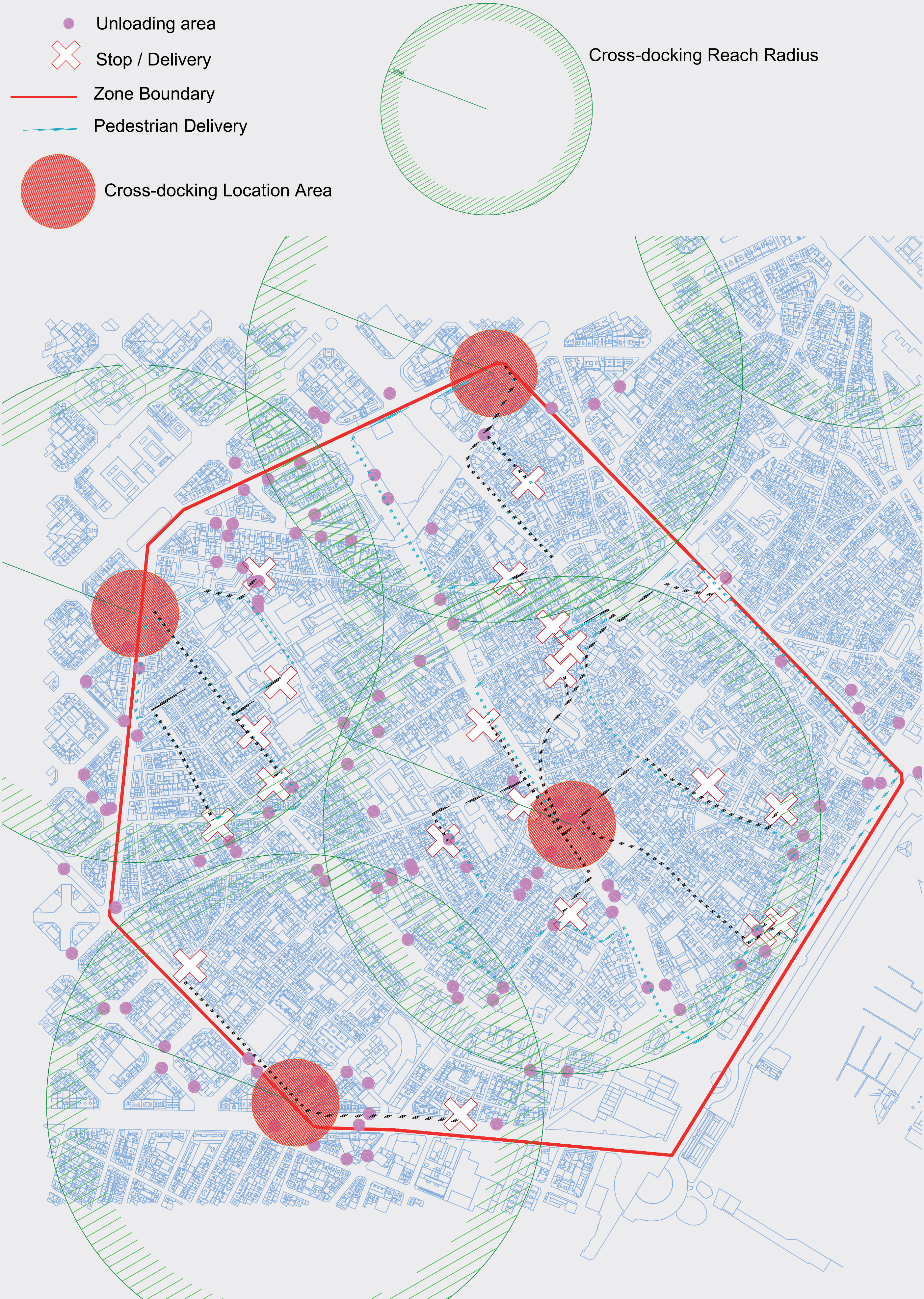


Madrid
scale 1:10.000

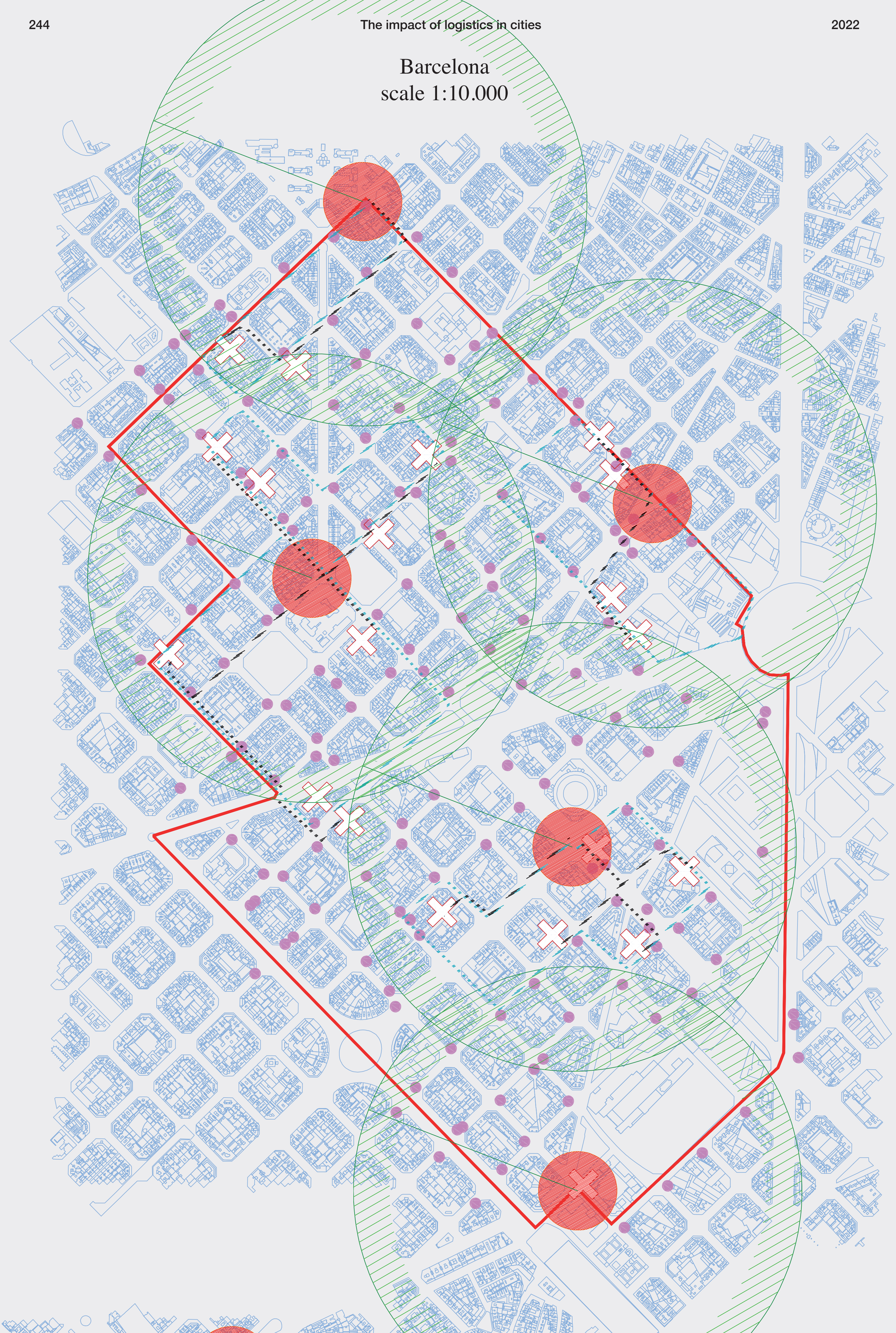
docking Reach Radius



Madrid
scale 1:20.000


Unloading area
Stop / Delivery
Zone Boundary
Pedestrian Delivery
Cross-docking Location Area
Cross-docking Reach Radius

Barcelona
scale 1:10.000



Barcelona
scale 1:15.000

Unloading area

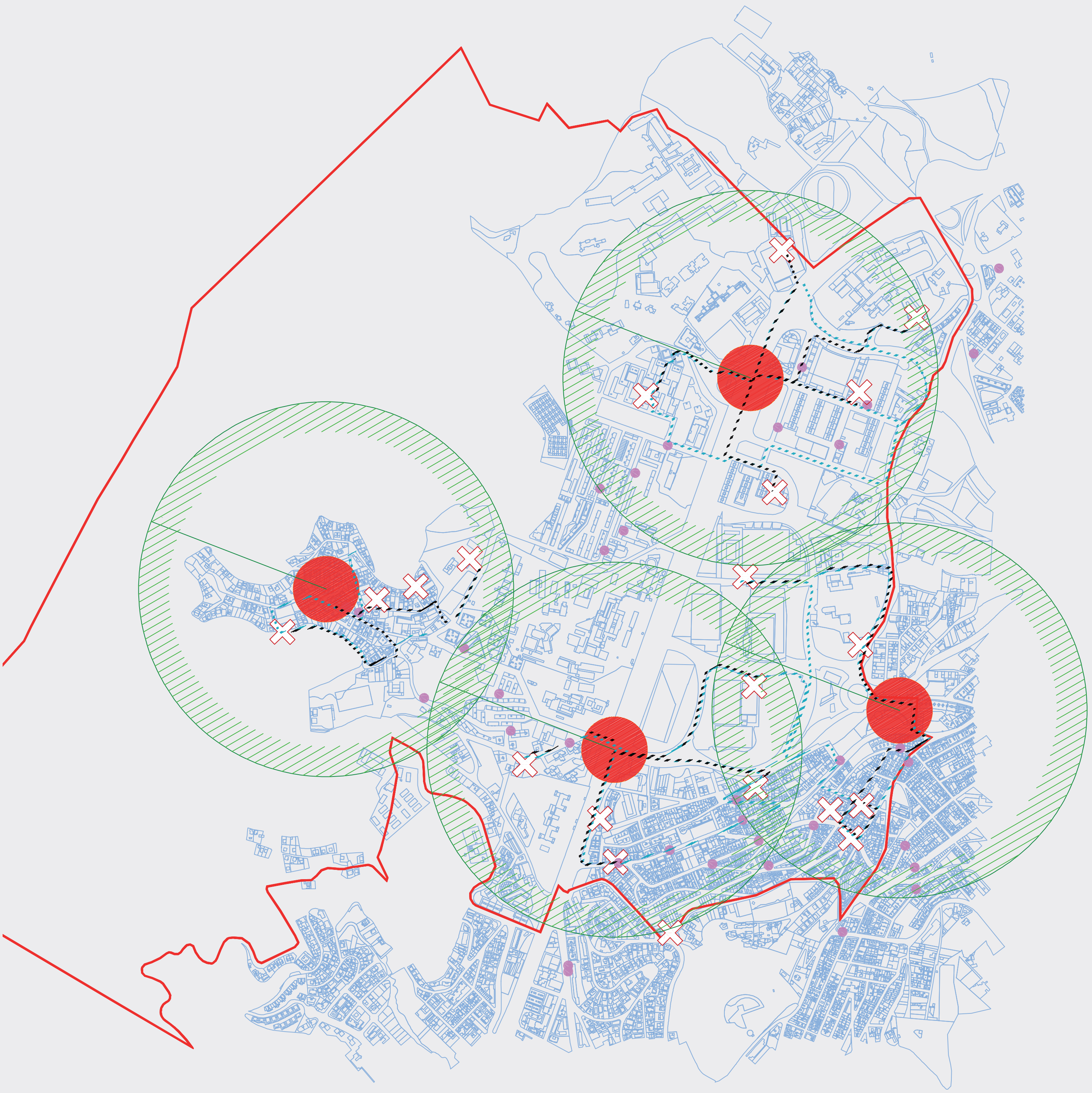
Stop / Delivery

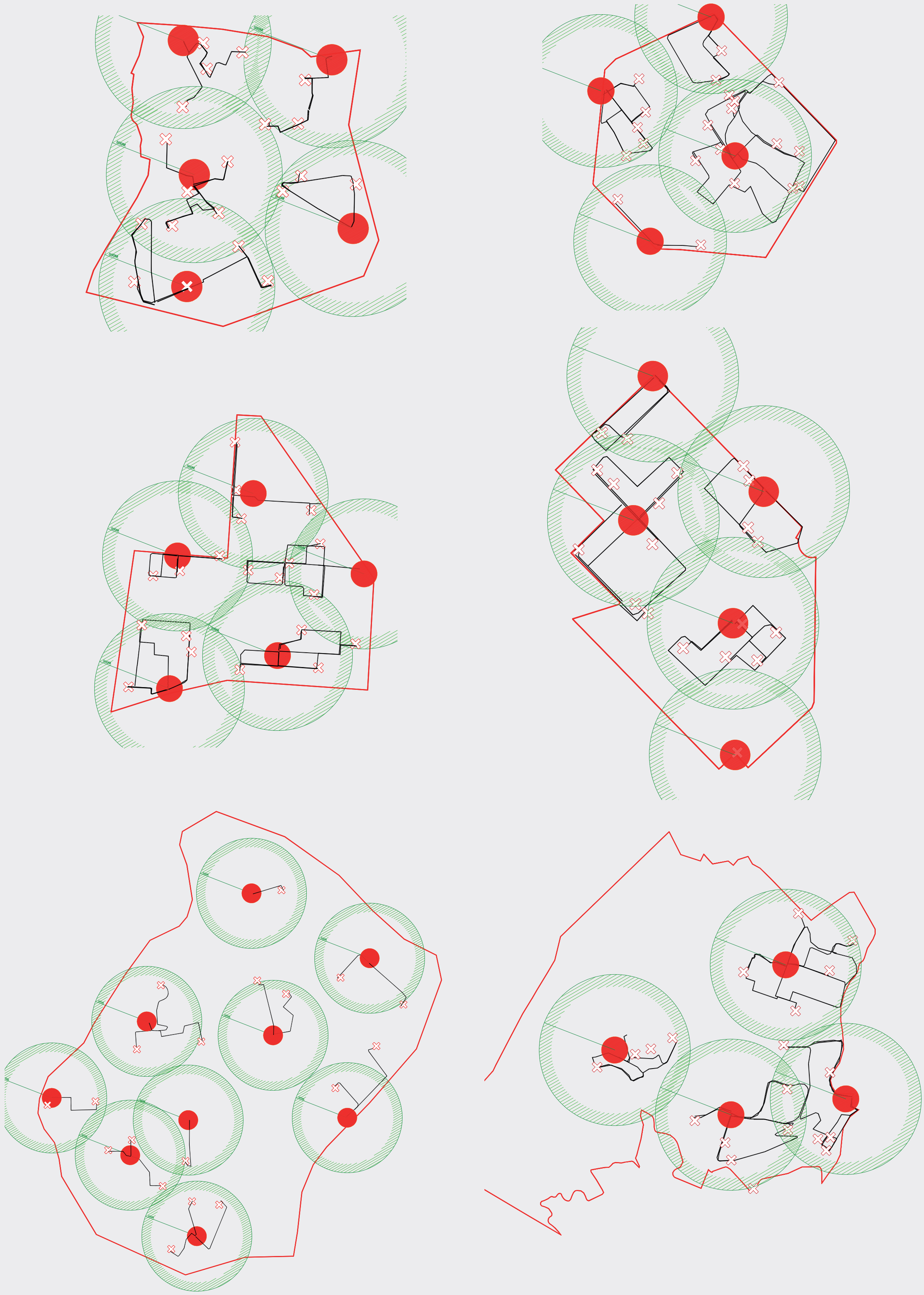
Zone Boundary

Pedestrian Delivery

Cross-docking Location Area

Cross-docking Reach Radius



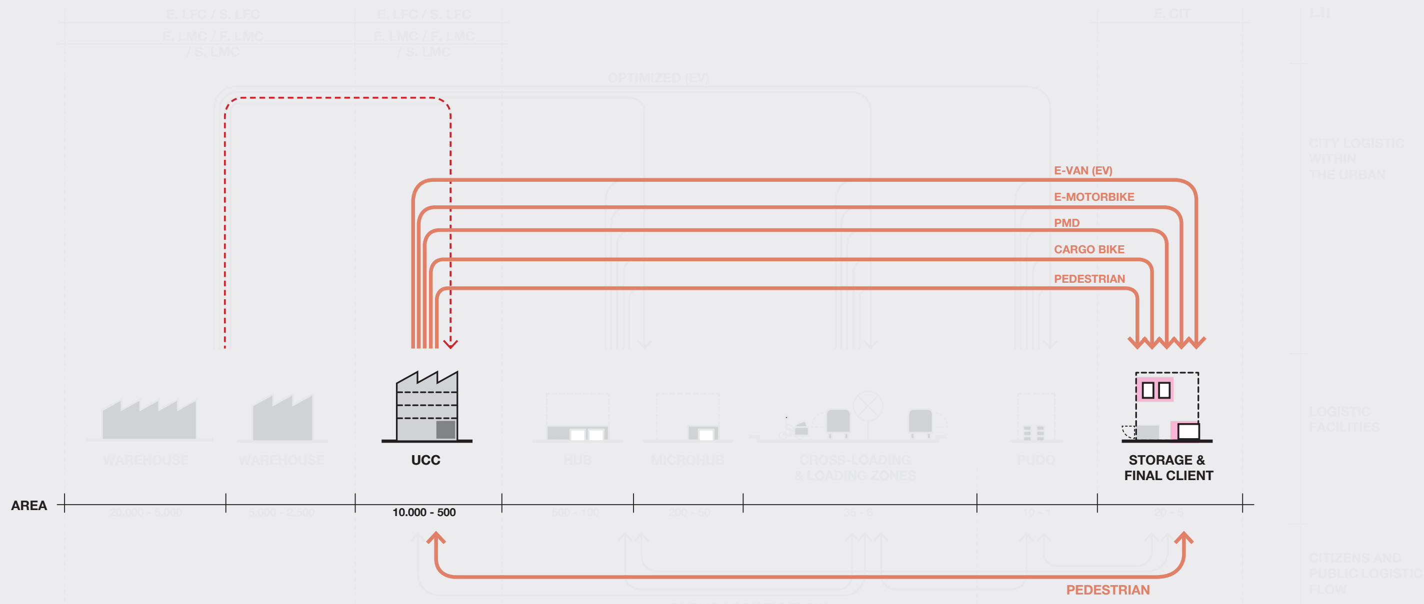


Cross-loading/unloading with pedestrian delivery
Conclusions:

Using loading and unloading zones as temporary hubs removes the necessity of managing more real estate, without greatly affecting the efficiency of the delivery process.

However, it does imply that changes need to be done from the city administration side regarding, first the extension of the stationary time limit legislation in a loading and unloading zone and, second, increase the availability of loading and unloading spaces either by creating systems that temporarily convert other available parking spaces into loading zones or adding new ones altogether. The negative aspect of this scenario is that for it to be fully efficient, fully loaded vans must transit the city. Even if using an electrical van means having less environmental and noise impact, its physical size still counts as an important presence in traffic and occupying parking spaces.

In addition, the spatial and landscape quality of the loading and unloading areas must be reconsidered, and it is an opportunity to redesign these public spaces, granting them a more positive impact on the environment.



9. UCC. Urban Consolidation Centres Scenario

7.3. Proposed scenarios
7.3.9. UCC. Urban Consolidation Centres

Based on the BAU model and the five performance scenarios outlined above for the three areas, the next obvious proposal for the last mile is to consider the insertion of a Consolidation Center in the city. If such a center were strategically placed within the city, able to cover the last mile radius, it would translate into two consolidation centers in Madrid and only one in Barcelona.
Two main flows were analyzed: input (feeding the consolidation center with the packages that need to be delivered within a determined time frame) and output (the process of delivering the packages).
In the input analysis the following possibilities have been explored:

- Moving the packages from larger warehouses at the outskirts of the city consolidation center in ICE Vans at peak traffic hours.
- Moving the packages from a larger warehouse at the outskirts of the city consolidation center in EV in between peak traffic hours.
- Moving all transport operations at night with EV.

The input level would benefit greatly from the optimization platforms that would ensure efficient use of the fleet and cargo space for all of the above parameters considered.

The ICE van at peak hours is the costliest one from an environmental standpoint. However, a consolidation center implies that the overall trips made by an ICE van on a typical day will be significantly reduced., In comparison to the BAU model, this is superior. The EV follows the same path, gaining points for its 0 emissions impact and faster delivery time by avoiding peak hours.
Supplying the consolidation center during the night with an EV vehicle results in the fastest and cleanest choice. By avoiding all-day traffic, the time is reduced to nearly a third of the previous models. However. night operations are regulated for noise, and while EVs have lower noise emission, vehicles are only one part of the equation, and the unloading operations on the street and inside the consolidation center would have to have special conditions and practices, and very likely the space would require soundproofing and other protocols.
At an output level, this scenario can work alone and also in combination with previously analyzed scenarios. Simply implementing a consolidation center reveals a great change in impacts at various levels.

At a one-kilometer radius from the consolidation center, a 15-minute walking time to any location in that radius could be guaranteed. This is a hybrid scenario in which nearby deliveries may be undertaken by pedestrians. The consolidation center itself could become a pick-up point for citizens living in that area. This pick-up scenario

has a double advantage. Not only does it reduce the emissions to zero, but also converts the consolidation center into a local asset for the neighborhood. This could lead to a more positive perception of the overall process of logistics and increase the satisfaction of neighborhood residents. This positive impact at a neighborhood level can only be guaranteed if the operations are optimized for noise reduction and reduced flow of supply vans.

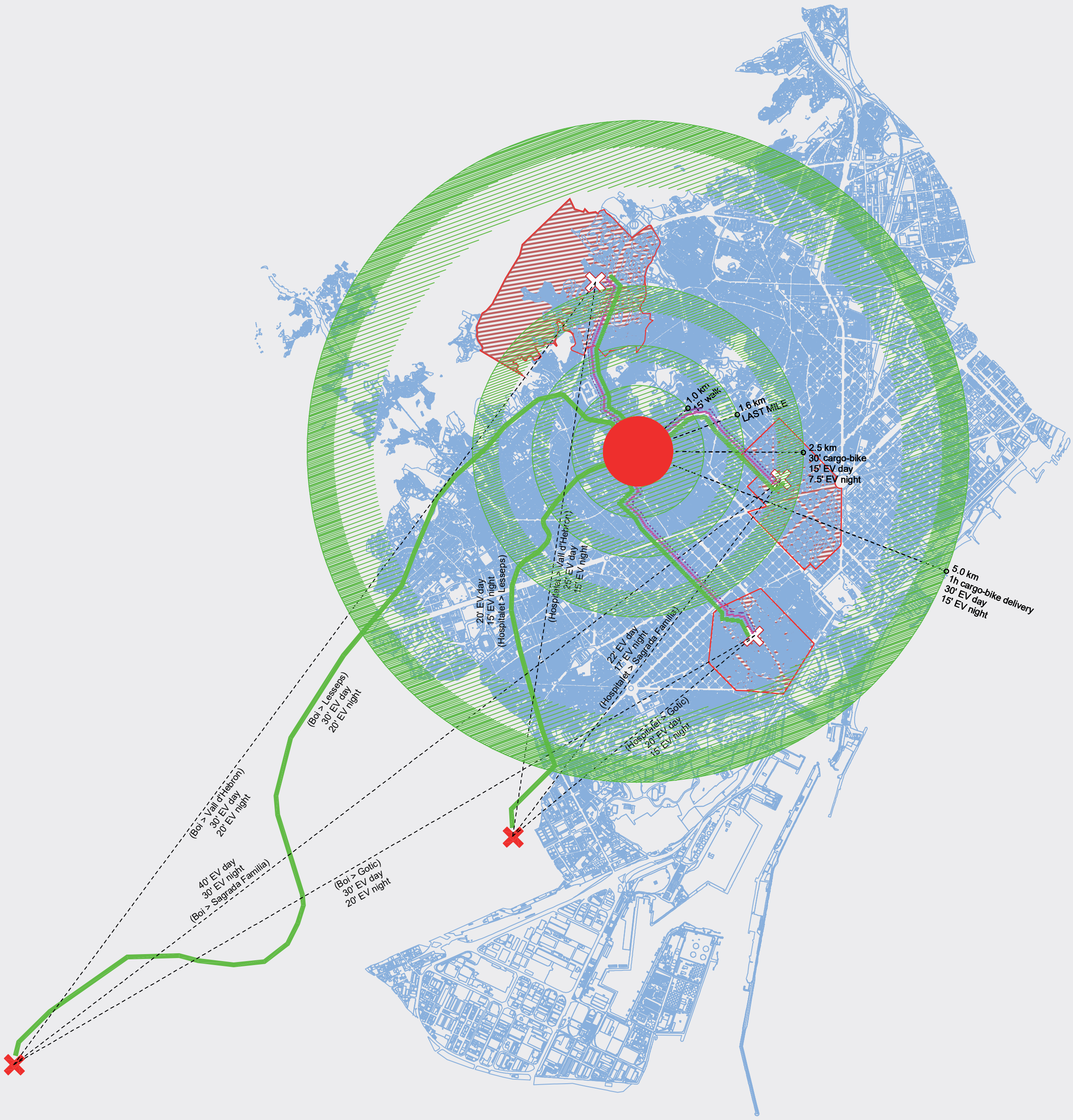
The next level of impact is at a 2.5-kilometer radius a 30-minute delivery time guaranteed by cargo bike or a 15-minute delivery time guaranteed by a motor vehicle (preferably EV). At night, if the consolidation center supplies a series of micro or nano-hubs throughout the city, it could do so within this radius within seven minutes.
Another level of the direct impact comes from a five-kilometer radius, which guarantees a one-hour delivery time via cargo bike or a 30-minute delivery time by a motor vehicle, lowers the CO2 impact to zero, and contributes to a positive effect on the public's perception of logistics. As before, if the UCC has supply points within the five-kilometer radius, the delivery time at night would be only 15 minutes via a motor vehicle.
A consolidation center can reduce that delivery time to an average of 20 minutes when compared to the BAU model using times between warehouses and the three urban typologies examined is 30 to 45 minutes. The most notable difference is evident in high-density areas that experience high traffic and circulation restrictions, where a consolidation center could be reached faster by using a more adaptable fleet.
The proximity of a consolidation center to likely delivery points also means that the increasing popularity of the "same-day delivery" or "1-hour delivery" options could be satisfied with significantly less impact on the environment and traffic.

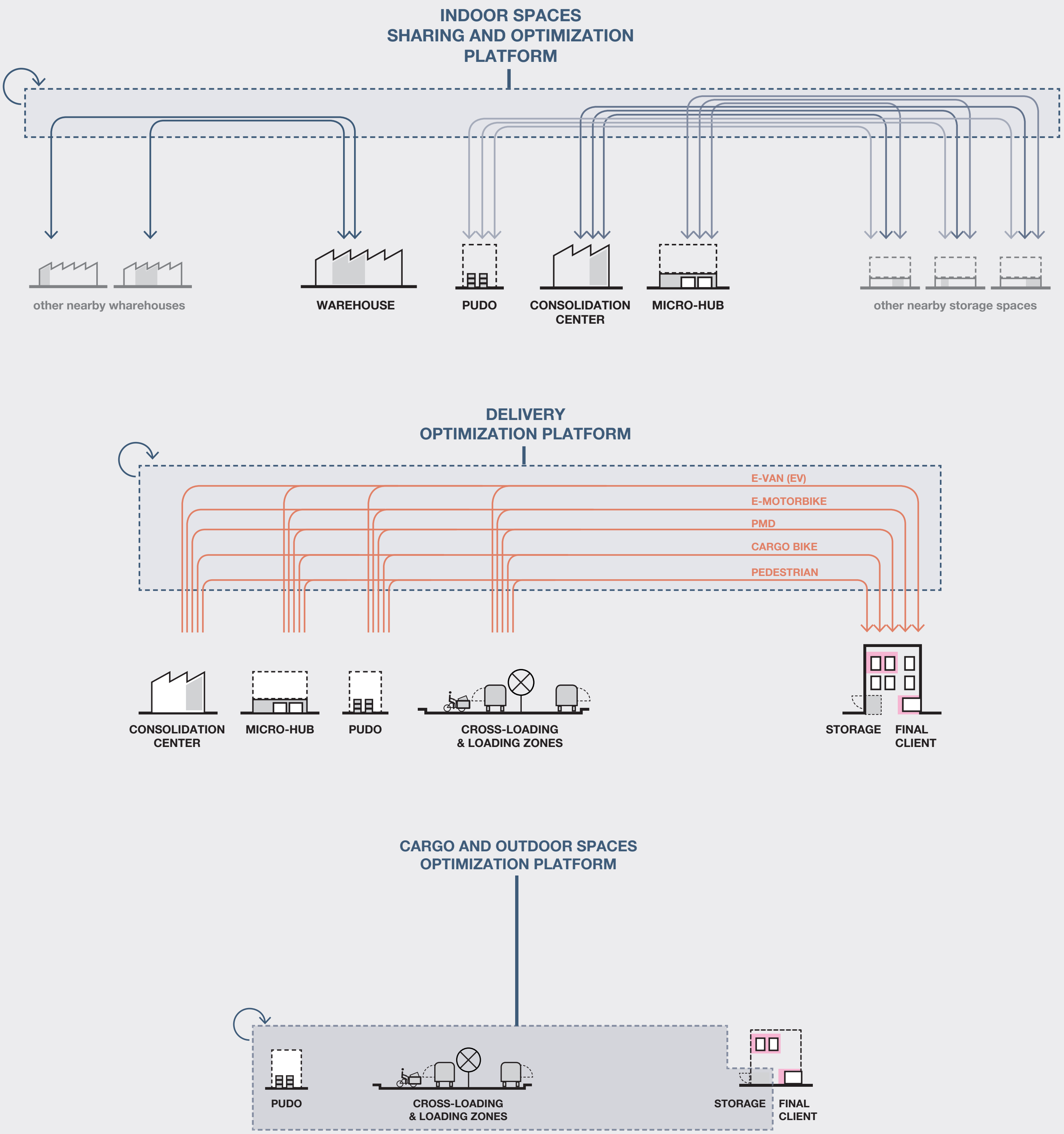
Conclusions.

Penetrating the city and bringing parcels closer to the delivery point means a significant reduction in time and kilometers traveled. The establishment of a consolidation center greatly improves the performance of all scenarios discussed previously. An urban consolidation center implies a larger initial investment from the managing company, the performance value it adds to a dense city will amortize it quickly.
The design, systems thinking, and services offered by a consolidation center are crucial to be accepted as a positive insertion in the community. It has the potential to create a lively new facility in the city, but it also has a risk of becoming obscure and closed to the public (like the new Amazon Prime 3000sqm center opened recently in the South of Madrid).

Madrid
scale 1:100.000

Barcelona
scale 1:100.000





10. Optimisation Platforms Scenario

7.3. Proposed scenarios
7.3.10. Optimisation Platforms

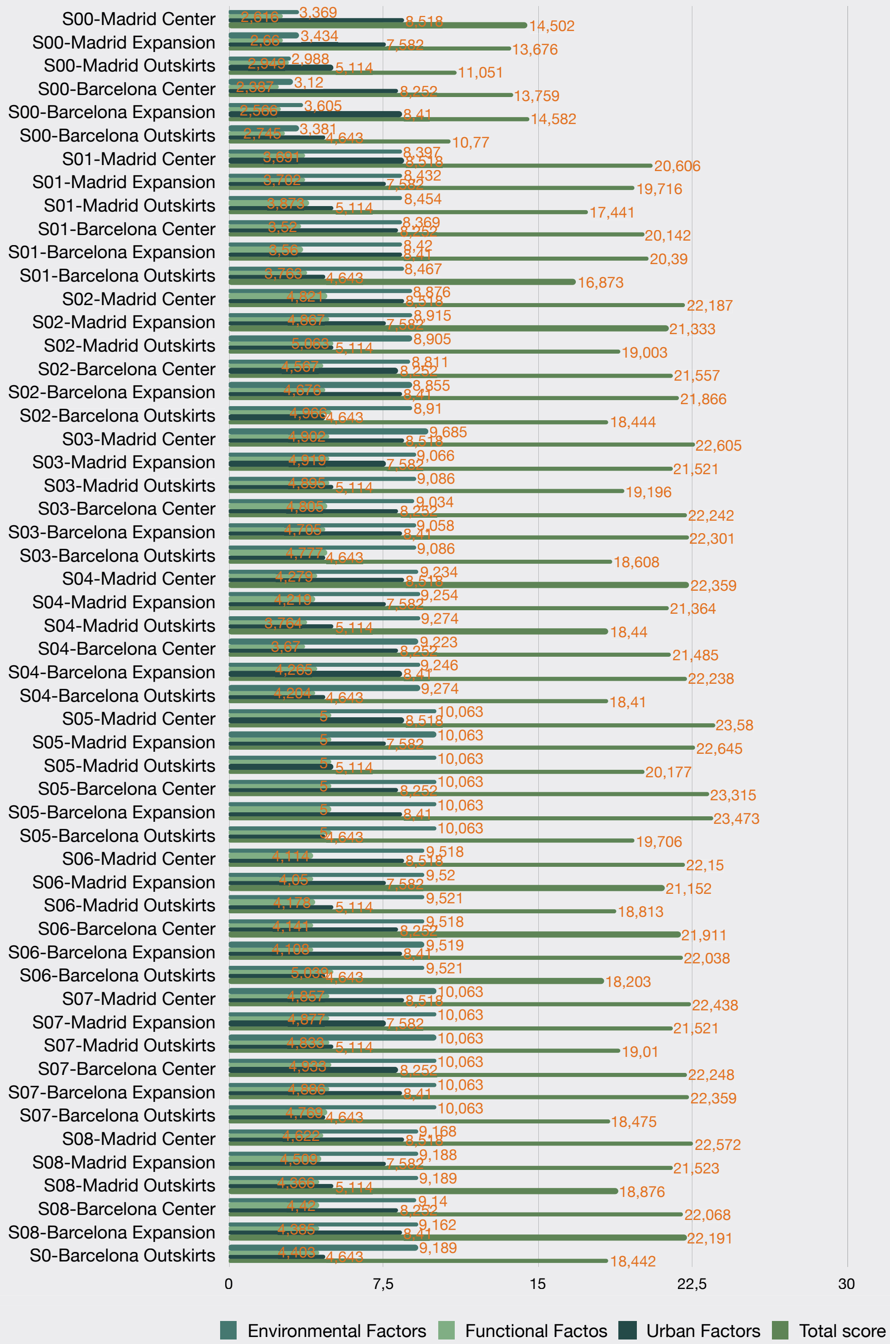
This report recognizes three opportunities for the implementation of technology within the logistics process based on the circuit, vehicle loading capacity, and storage capacity of logistic facilities.

Circuit. The first and most urgent measure is the optimization of each driver's circuit. This refers to the creation of a delivery route for each driver which ensures the minimum presence (time and obstruction of traffic) of the vehicle on the street. This is achieved through optimizing the order of deliveries concerning the point of departure, resulting in fewer kilometers covered and less time between deliveries. Optimization has a positive ecological impact, as we know that there is a relation between longer distances and a higher CO2 footprint, and more refills needed overall. Citizens' perceptions of logistics may be improved by having vehicles present for less time in the city.

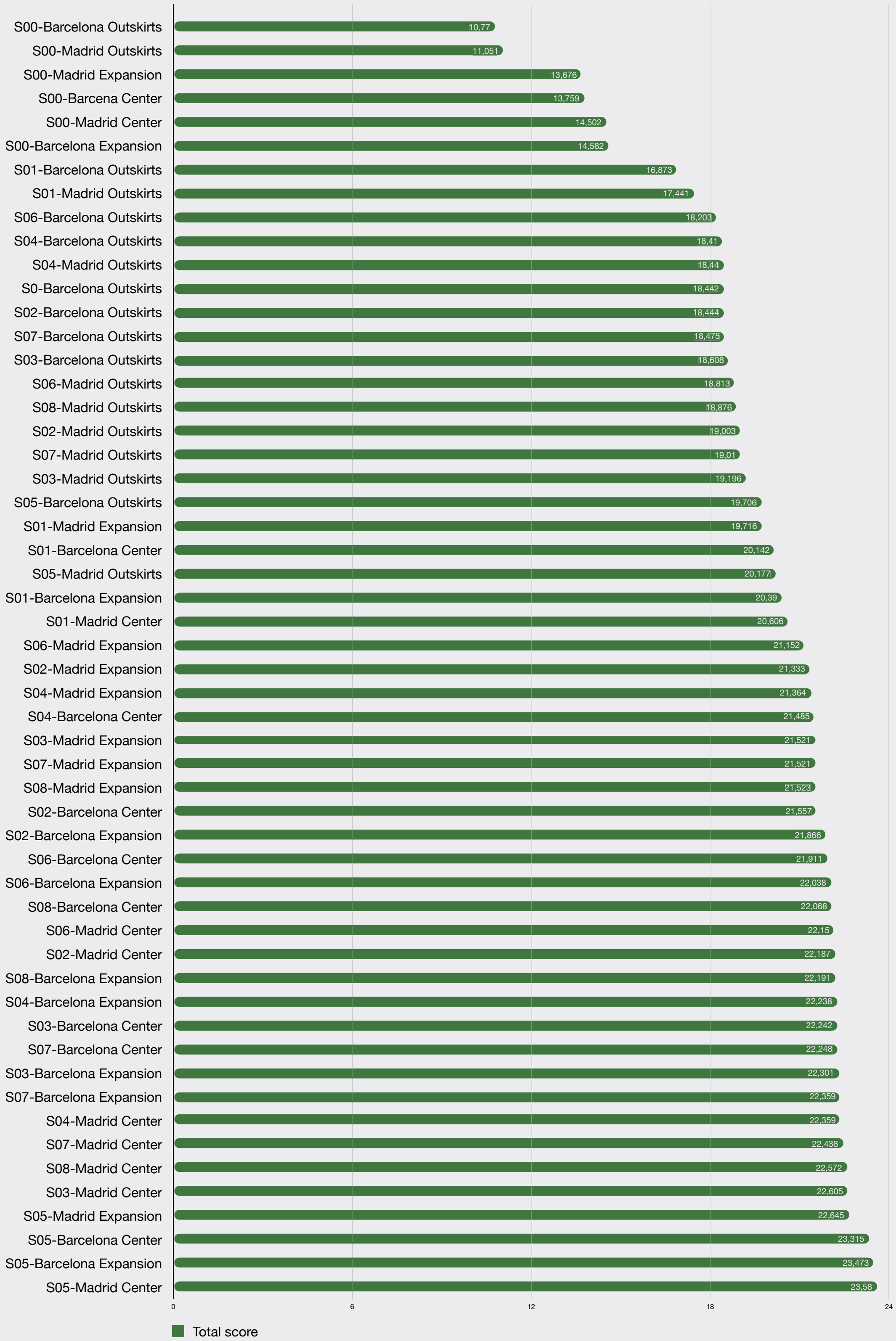
Vehicle Load Capacity. A second optimization opportunity is recognized within the vehicles themselves. Currently, in the BAU scenario, drivers load vans at only 15-20% of their capacity with no criteria regarding package order. Vehicles are not prepared to protect or take special measures to care for packages, facilitate access to packages during delivery, or use the vehicle capacity space to the fullest. Following the first optimization proposal that would generate an order of packages to be loaded, van space could be improved with the installation of a structure or other elements to improve the capacity, organization, and care of packages.

Logistic Facility Storage Capacity. Thirdly, the case studies have revealed that the capacities of logistics storage and cross-docking spaces are not uniformly used over time. In other words, there are recognizable peak periods of the year where activity increases or decreases. These fluctuations, while converging around important national holidays, vary from client to client, meaning that while one client is suffering because of lack of space for storage and operation, another client may be at 20% capacity. The opportunity here is to create a platform of short-term space-sharing among clients to collectively use the built space more efficiently and to compensate for activity fluctuations (from a storage standpoint for one client and an economical one for another). This space-sharing platform could work on different scales, from the scale of the warehouse to the van, allowing more clients to use the same driver for common routes.

The consequences of implementing optimization technologies are mainly positive and can enhance a collaborative network of city logistics. In contrast to the financial effort to build and implement these platforms, we must remember that digital technology can contribute value, efficiency, and sustainability by effectively taking advantage of available resources, increasing overall sustainability, and offering more flexibility to the clients.


S00-Madrid Center 3,369 8,518 14,502
S00-Madrid Expansion 3,434 7,582 13,676
S00-Madrid Outskirts 2,988 5,114 11,051
S00-Barcelona Center 3,12 8,252 13,759
S00-Barcelona Expansion 3,605 8,41 14,582
S00-Barcelona Outskirts 3,381 4,643 10,77
S01-Madrid Center 8,397 8,518 20,606
S01-Madrid Expansion 8,432 7,582 19,716
S01-Madrid Outskirts 8,454 5,114 17,441
S01-Barcelona Center 8,369 8,252 20,142
S01-Barcelona Expansion 8,42 8,41 20,39
S01-Barcelona Outskirts 8,467 4,643 16,873
S02-Madrid Center 8,876 8,518 22,187
S02-Madrid Expansion 8,915 7,582 21,333
S02-Madrid Outskirts 8,905 5,114 19,003
S02-Barcelona Center 8,811 8,252 21,557
S02-Barcelona Expansion 8,855 8,41 21,866
S02-Barcelona Outskirts 8,91 4,643 18,444
S03-Madrid Center 9,685 8,518 22,605
S03-Madrid Expansion 9,066 7,582 21,521
S03-Madrid Outskirts 9,086 5,114 19,196
S03-Barcelona Center 9,034 8,252 22,242
S03-Barcelona Expansion 9,058 8,41 22,301
S03-Barcelona Outskirts 9,086 4,643 18,608
S04-Madrid Center 9,234 8,518 22,359
S04-Madrid Expansion 9,254 7,582 21,364
S04-Madrid Outskirts 9,274 5,114 18,44
S04-Barcelona Center 9,223 8,252 21,485
S04-Barcelona Expansion 9,246 8,41 22,238
S04-Barcelona Outskirts 9,274 4,643 18,41
S05-Madrid Center 10,063 5 8,518 23,58
S05-Madrid Expansion 10,063 5 7,582 22,645
S05-Madrid Outskirts 10,063 5 5,114 20,177
S05-Barcelona Center 10,063 5 8,252 23,315
S05-Barcelona Expansion 10,063 5 8,41 23,473
S05-Barcelona Outskirts 10,063 5 4,643 19,706
S06-Madrid Center 9,518 8,518 22,15
S06-Madrid Expansion 9,52 7,582 21,152
S06-Madrid Outskirts 9,521 5,114 18,813
S06-Barcelona Center 9,518 8,252 21,911
S06-Barcelona Expansion 9,519 8,41 22,038
S06-Barcelona Outskirts 9,521 4,643 18,203
S07-Madrid Center 10,063 8,518 22,438
S07-Madrid Expansion 10,063 7,582 21,521
S07-Madrid Outskirts 10,063 5,114 19,01
S07-Barcelona Center 10,063 8,252 22,248
S07-Barcelona Expansion 10,063 8,41 22,359
S07-Barcelona Outskirts 10,063 4,643 18,475
S08-Madrid Center 9,168 8,518 22,572
S08-Madrid Expansion 9,188 7,582 21,523
S08-Madrid Outskirts 9,189 5,114 18,876
S08-Barcelona Center 9,14 8,252 22,068
S08-Barcelona Expansion 9,162 8,41 22,191
S0-Barcelona Outskirts 9,189 4,643 18,442
0
7,5
15
22,5
30
Environmental Factors
Functional Factos
Urban Factors
Total score

7.4. Logistic Impact Index Evaluation.



7.5. Conclusions

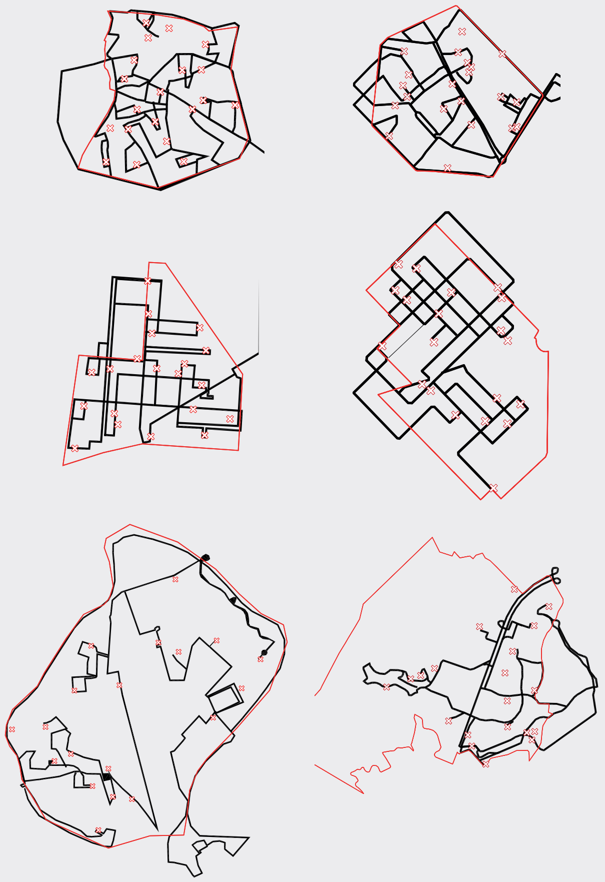
The scenarios built and analyzed show the following key findings that can be tackled for maximum results:

1. Introduction of technology via optimization. This allows for efficient use of resources and less time and kilometers traveled. Introduction of technology also means opening up possibilities for collaborations and agreements within the clients of the same logistics facility.

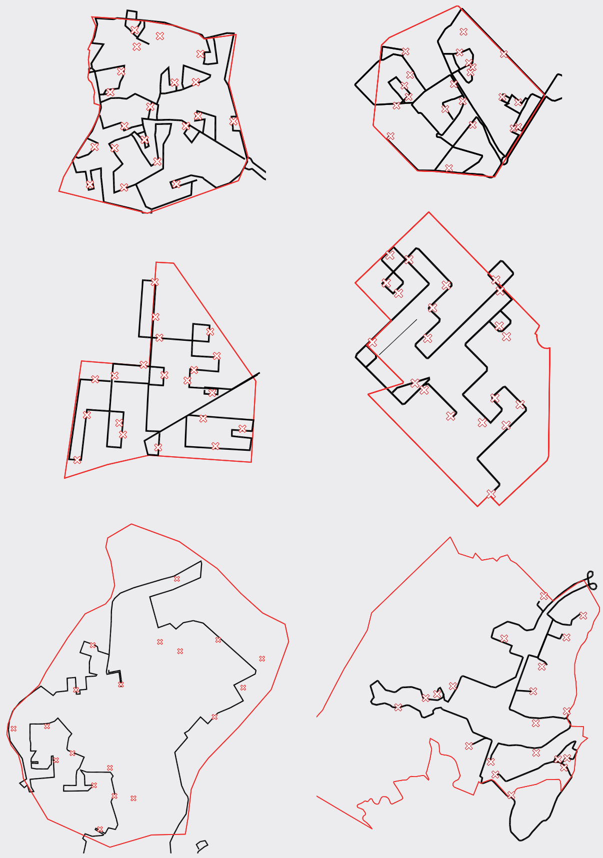
2. Diverse and sustainable fleet. Delivery vehicle choice is important because of the impact it has on the environment and also on the perception of logistics. Some vehicles are more appropriate than others depending on the urban morphology, but the rule of thumb is regarding performance and impact resulting from the analysis is: the higher density the smaller and quieter vehicle choice the better.

3. Implementation of hubs inside or close to the denser areas of the city has positive effects on performance and perception, by reducing distances traveled and offering new local services. More than that, they have the potential of starting agreements with small local delivery companies, solidifying their presence as an active community player.

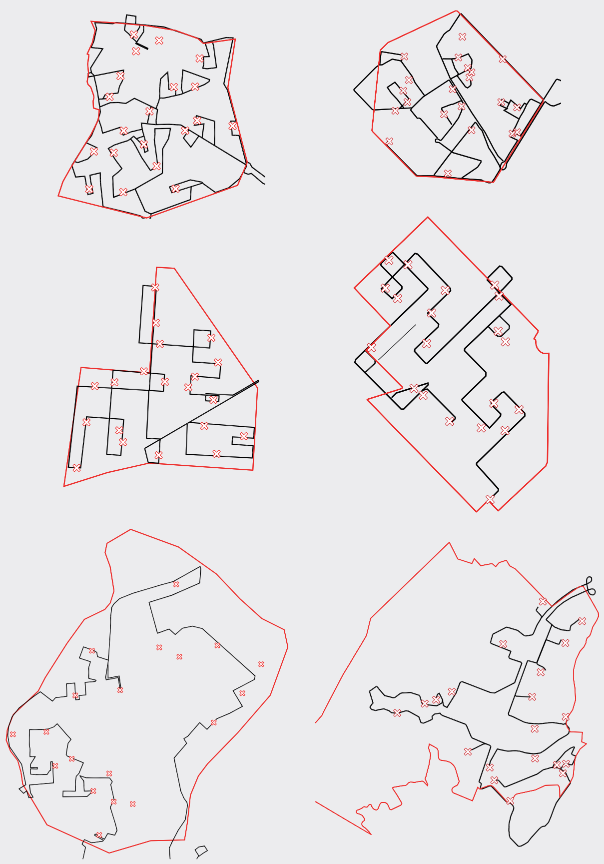
0. BAU



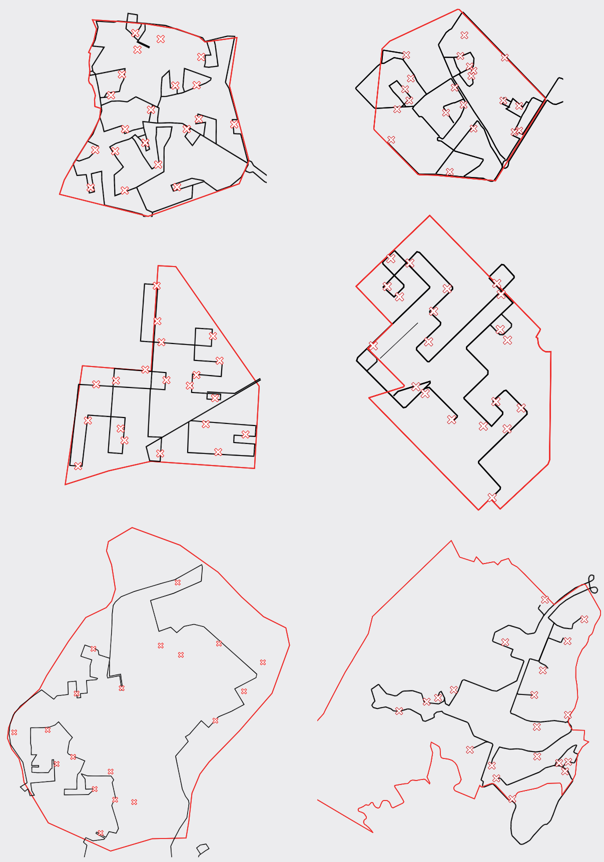
1. Optimized E-van



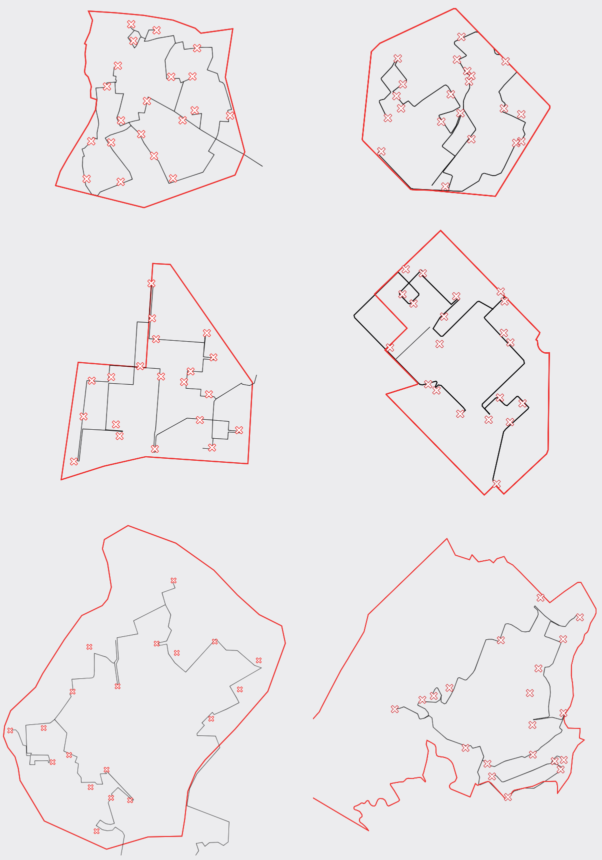
3. Optimized E-motorcycle



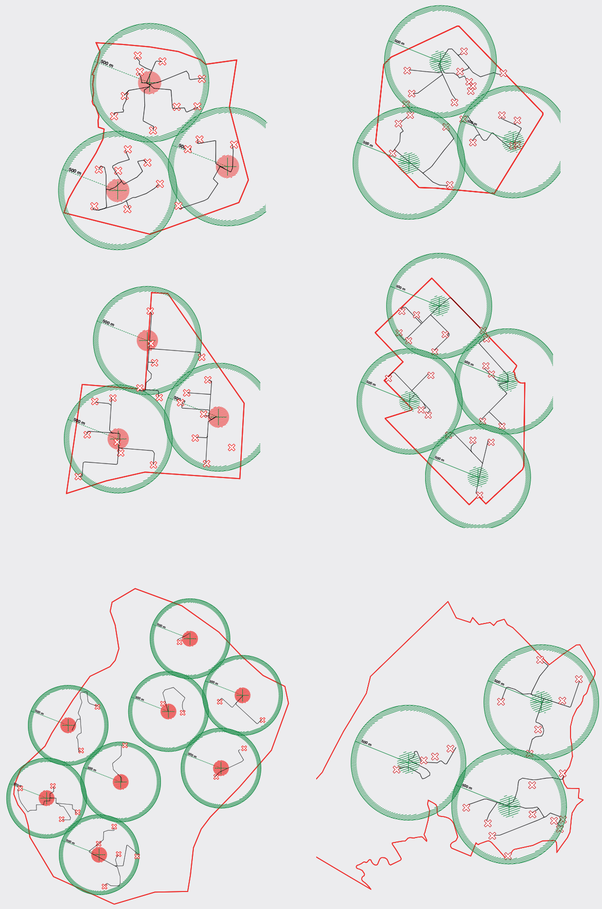
4. Optimized cargo bike



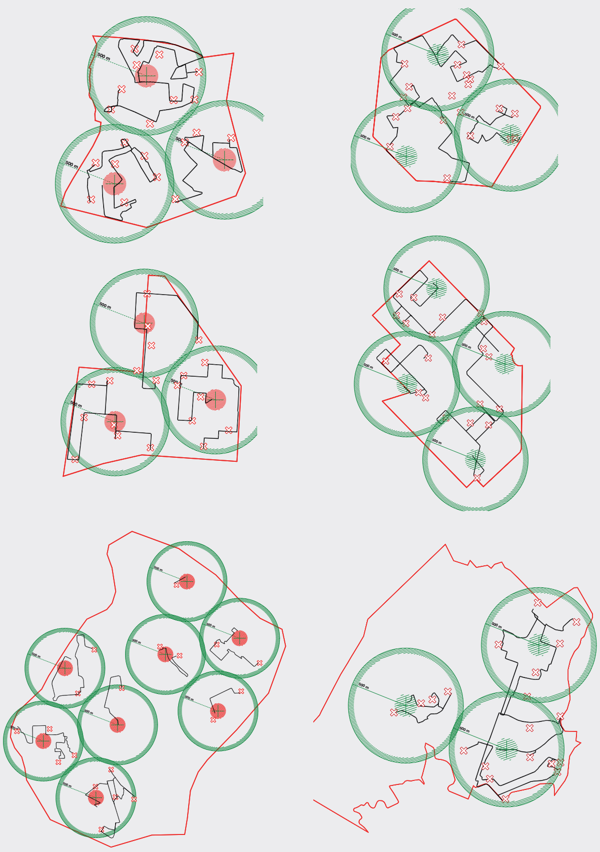
5. Optimized pedestrian



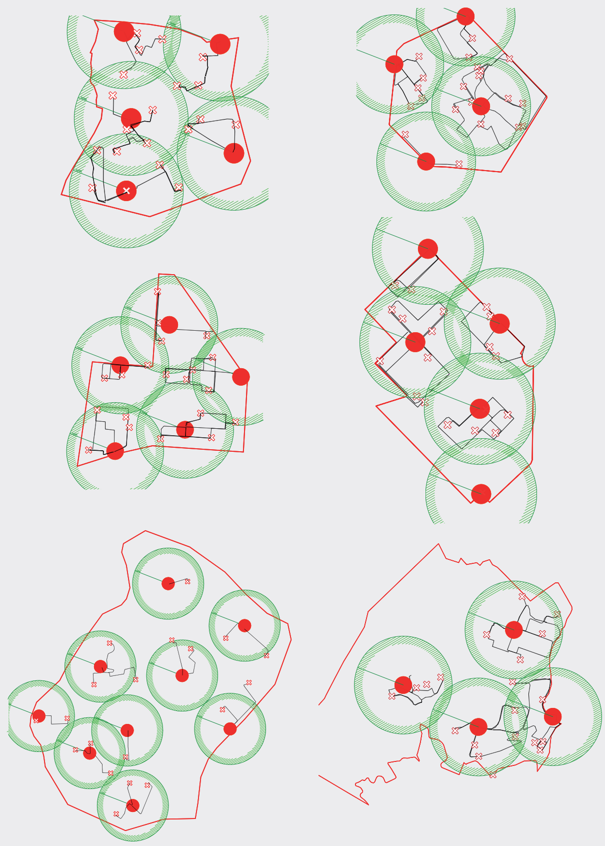
8. Microhub with pickup



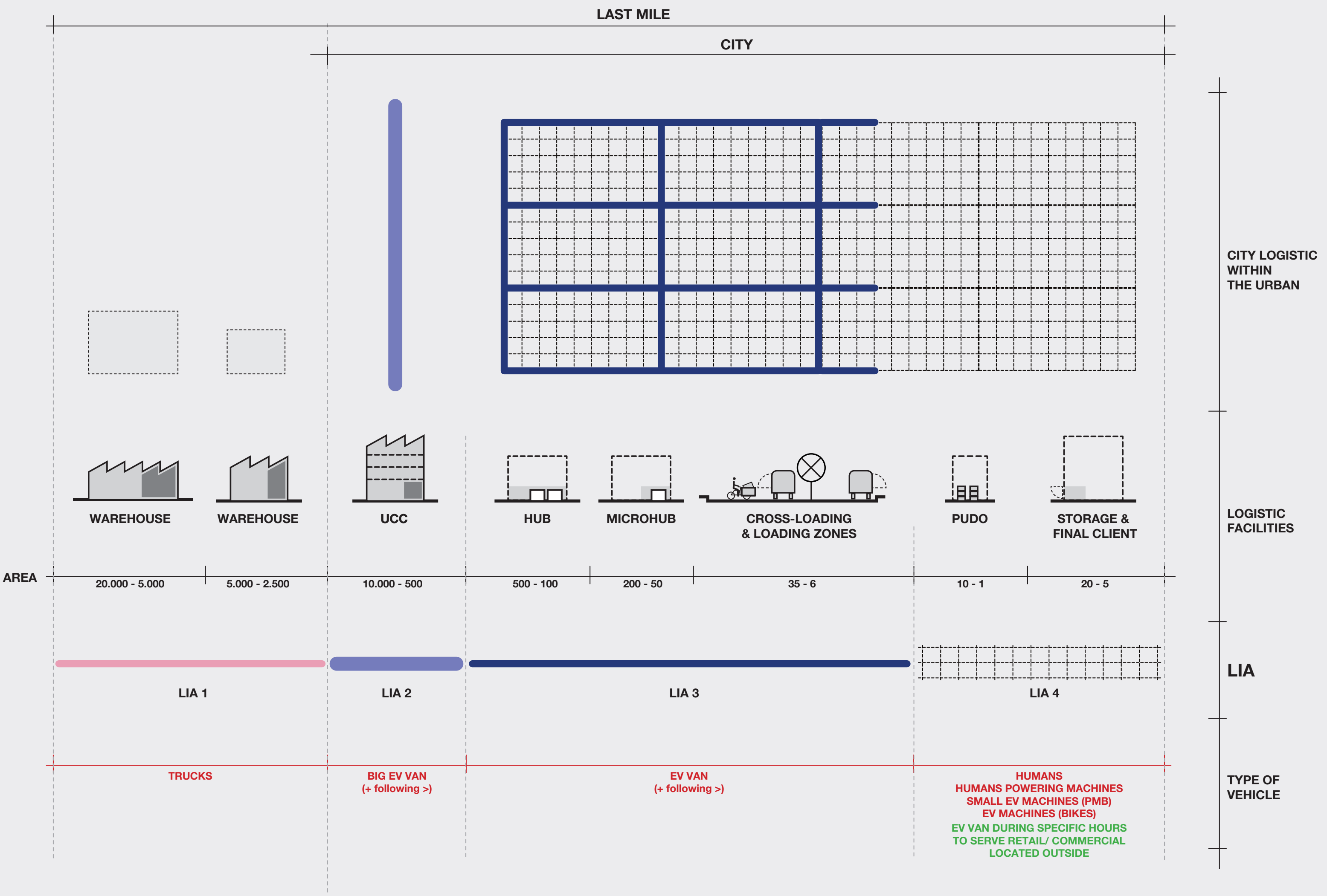
6. Microhub with cargo bike delivery



7. Microhub with pedestrian delivery



08: LIA



Logistics Intensity Areas Criteria

8. Logistics Intensity Areas

The scenarios analyzed in the previous chapter, although they are probably the most representative, are just a small number of the multiple possibilities of last-mile delivery options and processes. Based on the Logistic Network diagram, there are 175 possibilities for deliveries, while current BAU models mostly work with one standard option. There are alternatives in terms of types of vehicles, size and energy sources, logistics facilities, and stakeholders' involvement. The combination of these parameters results in different impacts on the city, according to the Last Mile Logistic Impact Index.

The LM-LII can be an efficient tool to evaluate the impact of last-mile delivery alternatives. However, the objective of the index is not just to measure the last-mile delivery impacts, but rather to provide strategies and actions to avoid, reduce, or cushion negative impacts. In other words, the LM-LII is analytical, but at the same time, it was designed with a proactive aim.

Cities need to provide different physical spaces for the last-mile delivery, both indoors and outdoors. From the large scale of the last warehouse to the small locker of a PUDO, storage spaces can range from 2,.000 square meters down to just to 1 square meter. Between both, there are many options and new solutions in our cities. It is important to clarify that for the purpose of the present research, that storage spaces are measured in square meters, while in general for city logistics they are measured also in cubic meters Usually, the warehousing of goods uses vertical systems of shelves or racks to optimize the volume of the storage spaces. Recent robotic storage systems, such as the Ocado Smart Platform (Ocado Group, 2022 are improving the usable volume of warehouses.). Later in this study, the vertical dimension will be included to establish a relationship with building typology.
The diagram on the left page shows a classification of the most representative storage spaces in city logistics, grouped by their area in square meters. The surface assigned for each space is an approximate reference.

Classification of storage spaces according to size:

Storage space	Surface area (sqm)
Last Warehouse	20.000-5.000
Last Warehouse	2.500-5.000
UCC	500-10.000
HUB	100-500
Micro-HUB	50-200
Cross-docking (storage space in the interior of the vehicle)	5-35
Storage room in building private space.	5-20
PUDO	1-10

8.1. Planning policies and city logistics.

Cities are responding in a different way to the global supply network. While Paris is limiting city logistics to improve the quality of life of its residents, others such as Chicago, Los Angeles, or Shanghai are becoming major world hubs. Chicago is a major rail hub for North America, Los Angeles a gateway for East Asia, and Shanghai the largest cargo port in the world.

Some cities have developed specific actions to promote more sustainable urban freight distribution. In Copenhagen, there are specific areas for the unloading of commercial trucks. In Stockholm, Urban Distribution Centers are located outside the city to reduce the size of trucks entering the city. In Stockholm, Gothenburg, Malmö, and Lund, trucks older than eight years cannot enter the city. In Barcelona, there are separate lanes for loading and unloading 5-7 PM (Averkyna, 2017). In 2016, the city of Paris updated the Local Urbanism Plan to include a global logistic strategy for the city. It was one of the first times that city logistics was recognized as a necessary service for citizens and an important economic agent, just as any other public facility. The Plan developed the network of Urban Logistics Spaces (ELU) which subsequently was divided into four logistics scales. Most of the restrictions of city logistics are usually focused on the type of vehicle and delivery, while not on the logistic facilities. Some authors have made a classification of roads and streets, according to regulations and restrictions, which limit logistic deliveries, in order of the restrictive regulatory measures level (Den Boer et al., 2017):

1 Public roads
- *a. no other regulations*

2 Geo-fencing
- *a.for instance based on emission class*
- *b.or with time windows*

3 Routed geo-fencing
- *a.as 2, but with addition of prescribed/ limited routes to (un)loading zones*

4 Slotted and routed geofencing
- *a.as 3, with the addition of allocated timeslots for entry and (un-)loading-zones*
- *b.assumes advanced ITS systems that create 'green-flow' with priority, and managed unloading zones (reserved, with flexibility in trading slots between users)*

5 Restricted.
- *a. for designated modes of transport and designated routes only*

There is a lack of planning activities and long-term planning approaches for city logistics, which has led to a shortage of spaces for logistics activities in cities (Lukic, 2017). City logistics needs opportunities and options to perform last-mile delivery sustainably.
Most of the planning policies are based on the dichotomy of restrictions and permits, to avoid

negative impacts on the urban environment. The present research proposes a different approach. On the one hand, the objective is to reduce the negative impact of logistics, and on the other hand, to enhance positive impacts. It is a two-way process, which reduces the intensity of the impact and intensifies a path towards a sustainable environment.

8.2. How to define a LIA (Logistic Intensity Area)?

Nowadays, cities are setting different types of restrictions for the last mile delivery. To date, these restrictions are mostly based on accessibility and GHG emissions. The definition of any type of urban regulation to restrict or limit certain activities should be approached from different perspectives. It should not be an isolated norm because it usually creates collateral problems. From this point of view, urban regulations require a holistic approach that includes not only environmental and social concerns but also functional and economic demands.
Most current urban regulations do not include any detailed recommendation, support, or restriction on the location of storage spaces for the last mile delivery. This lack of regulation is producing a negative impact both on the delivery process and on the city. If we were to recognize the flow of goods as a public service, as we understand the flow of citizens, then public authorities would be required to provide the infrastructure that logistics requires. City logistics would then be considered a public service (EIT Urban Mobility, 2021).
The proper location of storage spaces for the last mile delivery is an important factor that can contribute to lowering the impact of city logistics. As facilities get closer to the city center, there is a reduction in the size of storage spaces for city logistics. There are several reasons behind this, but it is mainly a matter of the cost per square meter, the availability of appropriate space within the city center, environmental concerns, and restrictions and regulations on logistic warehouses.
The objective of the present chapter is to define the criteria for the location of storage spaces for city logistics, responding to the different types of delivery according to the urban structure. The present approach is based upon the results of the scenarios created in chapter 7. We aim to establish a positive relationship between city logistics and the urban structure.

Our scenarios show that there are much better options than current BAU models. Rather than a direct delivery from the last warehouse to the final client by an ICE vehicle, it is recommended that there be a gradual transition between different types of vehicles and storage spaces. In other words, the parcel must pass through different hands before its final delivery. Initially, this matter can seem less efficient in terms of time and productivity, but if handled properly, it could be more efficient with

less impact.
There is a need for different types of storage spaces within the city limits to allow for the transition of a parcel through different situations. Cities should be more flexible and able to adapt to fast-evolving changes. Unfortunately, this is not always the case. Specifically, city logistics has been undergoing a radical transformation in recent years. The availability of opportunities for new spaces together with the right choice of vehicle will support a positive impact on the last-mile delivery.
The objective of the Logistic Intensity Areas (LIA) is to set different intensity levels for city logistics, to strike a balance between efficiency and optimization of city logistics and its social and environmental impacts. With this in mind, the LIA aims to define urban areas, where the intensity of city logistics will be the lowest. Outside of these areas, the restrictions will gradually disappear. Each LIA's level defines specific limitations for city logistics. The LIA is not only a restrictive set of guidelines, rather it is a dynamic tool that requires a proactive approach from all stakeholders.
Thus, the LIA involves all stakeholders in a continuous feedback process to optimize the last mile delivery and to promote sustainable practices for the urban environment. The LIA is both restrictive and proactive. It allows specific logistics activities in urban areas while requiring active involvement in the neighborhood. The objective of the LIA is to reduce the environmental impact and to produce positive impacts.

8.3. Background.

As said above, cities have taken a standard approach to limit traffic and certain types of activities within the city center mainly, because of environmental and social concerns, which include air and noise pollution. The old town, the city center, or neighborhoods in cities all over the world have restricted access to certain types of vehicles and have prohibited specific noxious activities. However, we can see another precedent for Logistic Intensity Areas, based on grouping individual urban blocks into a bigger urban structure. Since 2001, Barcelona has been gradually transforming the city into the revolutionary "Superblocks". Salvador Rueda, director of the Urban Ecology Agency of Barcelona until 2019, was the person behind this initiative to cluster together city blocks into groupings of 400 meters by 400 meters. (Ecology Agency of Barcelona, 2019)

Perhaps superblocks couldn't have happened in any other city except Barcelona. There are historic precedents as early as 1932's the Plan Macià (Le Corbusier, 1955) and the blocks designed by MBM architects for the Olympic Village in 1992 (Martorell, et al., 1991), which grouped several blocks in one bigger structure. (Bohigas, 2021)
The Plan Macià for Barcelona, designed by Le Corbusier and Pierre Jeanneret together with the GATCPAC group, planned the construction of huge blocks of 400x400 meters. Almost four times

the standard size of a traditional Barcelona block defined in the Cerdà Plan (113.5x113.5 meters.). Even though superblocks have different densities and typologies, they have the same dimensions as the Macià Plan blocks, formed by a grid of 9 blocks (3x3 blocks). “Casa Bloc” was the only realized block of Plan Macià, although it was half the size. When considering present-day urbanism, it is interesting to understand the idea of prototype as reflected in Casa Bloc and other past initiatives. At the time of the Barcelona Olympics, architects MBM intended to build larger groupings consisting of 3 blocks connected to open spaces. In fact, the projects were called super units, a clear precedent of the later superblocks (Martorell, et al., 1991). Images of Plan Macià and Villa Olimpica blocks from MBM.

The first prototype of a Superblock in Barcelona was built in Poblenou in 2016, by joining nine blocks, in a grid of 3x3. This first initiative was followed by the superblocks of Sant Antoni and Gracià. Vehicle speeds are limited to 50 km/h outside the superblock, while in the interior, to the maximum is 10 km/h. Residents’ private vehicles (or official service vehicles) are the only ones allowed in the interior of the superblocks. Thus, the interior streets of the superblocks are designed as a shared space for vehicles and people, with people having priority over vehicles. Additionally, some new squares (open spaces) were developed at the intersection of the interior streets. The main objective was to remove some of the vehicles from the street, to recover spaces for citizens, and to promote biodiversity.

Although the size of the superblocks is smaller than the Logistics Blocks proposed by the LIA, the spirit is similar. The highest level of the LIA has the most stringent restrictions in terms of vehicles and storage spaces. The LIA and the Logistics Blocks are congruent with the superblocks plan for Barcelona. The PMU 2013-2018 set DUM areas outside the superblocks, which are regulated as follows: (Ayuntamiento de Barcelona, 2022):

The objective of the places regulated as Urban Goods Distribution (DUM) is to provide service on weekdays from 8 AM to 8 PM, to all vehicles that need to distribute goods very close to the destination point during a limited time of 30 minutes. e This time limit has the objective of giving maximum rotation to these places to serve the maximum possible number of trucks and vans that perform these operations every day.

The LIA aims to move one step forward and to incorporate different levels of intensity for city logistics, where different types of storage spaces and delivery methods may have their place in the urban structure producing a positive impact.

In addition, LIA can be easily implemented within current planning policies. It is aligned not only with the concept of superblocks but also with the 15-minute city. Both promote and reinforce urban livability, through a process of decentralization and humanization of the scale of the city.

<table>
<tr><th colspan="4">LOGISTIC INTENSITY AREAS</th></tr>
<tr><th></th><th colspan="2">Impact Intensity Reduction</th><th rowspan="2">Intensification of Positive Impact</th></tr>
<tr><th></th><th>Storage Spaces allowed.</th><th>Vehicles allowed.</th></tr>
<tr><td>Level 1- Industrial Areas.
Maximum distance to delivery point:
20-30 km.
Duration:
45’ 1 h EV day</td><td>Warehouse</td><td>Trucks
EV Machines (big Vans)</td><td rowspan="4">Resources Community (energy + water + carbon):
Energy Community
EV chargers
Water storage
Irrigation
Carbon sequestration

Improvement of the Natural environment:
Parks (ground and other levels, including roof)
Biodiversity
Regeneration
Draining pavement

Community Involvement:
Public spaces
Social spaces
Social actions
Prosumer attitude</td></tr>
<tr><td>Level 2- UCC.
Maximum distance to delivery point:
5 km.
Duration:
1 h cargo bike
30’ EV day
15’ EV night</td><td>Urban Consolidation Center (UCC)
Hubs and micro-hubs.
Cross-docking
PUDO
Storage room (inside buildings)</td><td>EV machines (big Vans)
EV machines (Medium Vans)
EV machines (bikes)
EV machines (PMD)
Humans powering machines
Humans</td></tr>
<tr><td>Level 3- Exterior of Logistic Blocks.
Maximum distance to delivery point:
2,5 km.
Duration:
30’ min. cargo bike.
15’ min. EV</td><td>Hubs and micro-hubs.
Cross-docking
PUDO
Storage room (inside buildings)</td><td>EV machines (Medium Vans)
EV machines (bikes)
EV machines (PMD)
Humans powering machines
Humans</td></tr>
<tr><td>Level 4- Interior of Logistic Blocks.
Maximum distance to delivery point:
1,6 km (1 mile)
15 walking.</td><td>PUDO
Storage room (inside buildings)</td><td>EV machines (Medium Vans)- (Only specific hours and due to requirements to be close to delivery point)
EV machines (bikes)
EV machines (PMD)
Humans powering machines
Humans</td></tr>
</table>

LIA Levels according to the impact intensity reduction and intensification of the positve impact

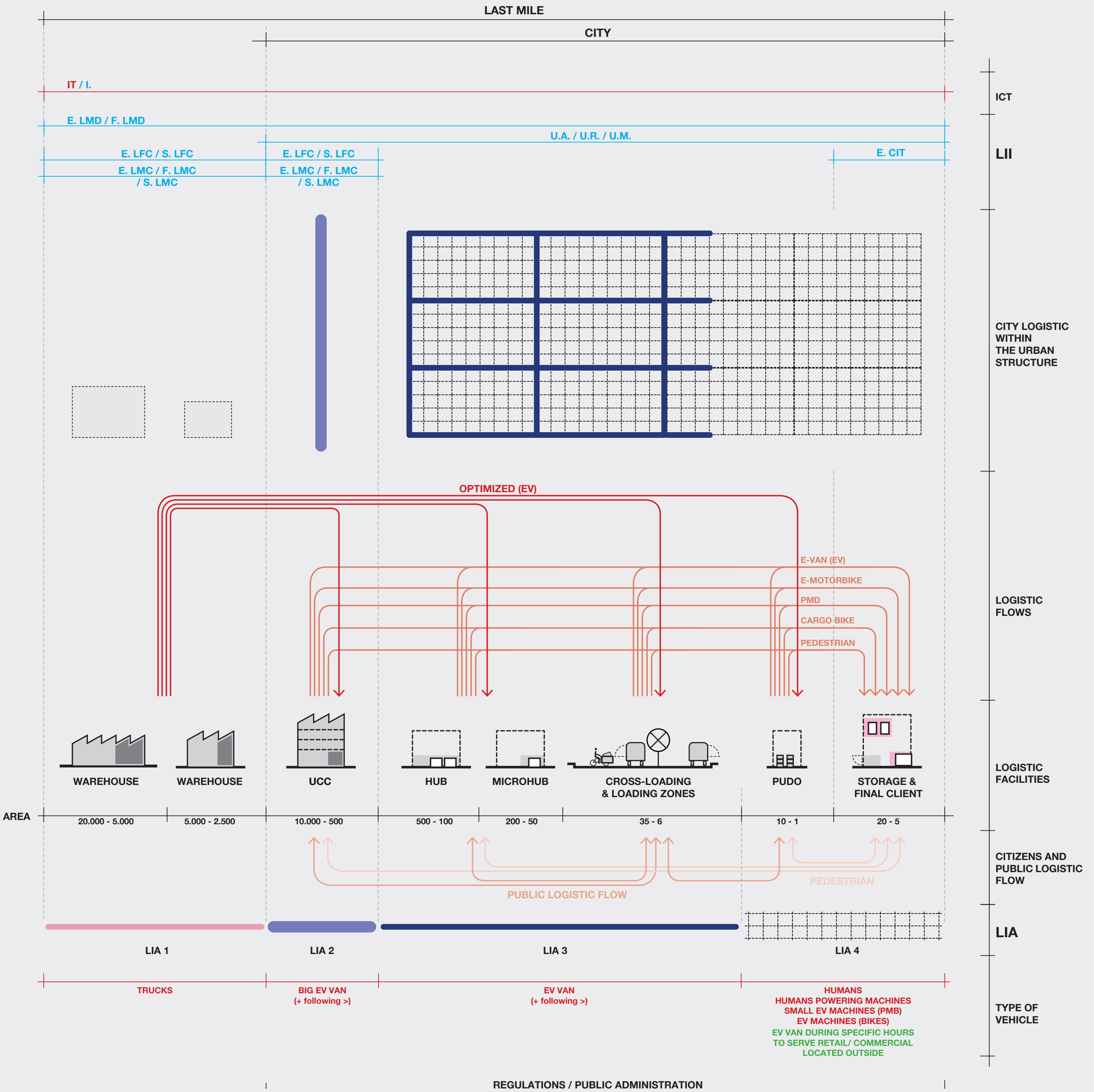
8.4. Logistic Intensity Areas (LIA):

Establishing Logistics Impact Areas is a planning policy based on two steps: a first step is to reduce current negative impacts and a second step is to enhance positive ones. The concept of intensity refers to a bidirectional process, where the impact of logistics infrastructure in an urban area is reduced, and at the same time, it promotes beneficial relationships within the neighborhood. In other words, the LIA cushions the intensity of the current negative impacts and simultaneously intensifies a healthy environment.

The diagram on the left page reflects the main features of the LIA. It should be read both horizontally and vertically. At the center are located the principal types of storage spaces, classified from the largest to the smallest. The surface areas or sizes are meant as just a guide. The upper part is a plan of a generic urban structure formed by a grid of blocks.

The city plan is related to the storage spaces and the delivery systems throughout all levels of the LIA. The levels from 1 to 3 are located within the city limits, while level 4 is placed at the outskirts. The Logistics Blocks are defined by the red rectangle, which groups together several blocks. Level 4 has the highest level of restrictions within Logistic Blocks. Level 3 defines the exterior of the Logistic Blocks, marked by the red line, while Level 2 is the principal infrastructure that connects several Logistics Blocks.

The table on the left page shows how the logistic facilities and permitted vehicles reduce the intensity of the impact in each level and the strategies to improve positive impacts. From the lowest intensity level to the highest, there is a gradual increase on restrictions and limitations in terms of logistic facilities and vehicles. The Logistic Blocks aim to protect the environment within the blocks in terms of pollution, noise, congestion, and stress, while at the same time providing efficient and optimal delivery services.



Logistics Network with LM-LII and LIA Levels

8.5. Impact Intensity Reduction

A delivery can pass through different LIA levels to provide opportunities and options for city logistics. It is a flexible system that can adapt to different requirements of efficiency and time. The principal types of deliveries are outlined below, incorporating the transitions from one level to another:

From Level 3 to Level 4: from the exterior to the interior of the Logistic Blocks. (See Diagram).
Hubs and Micro-hubs, as well as spaces for loading and unloading areas, can be located outside of Logistics Blocks. From these storage spaces, the final delivery will be realized with EVs, such as bikes, PMD, or machines powered by humans. It is also possible to walk to a delivery point, as the maximum distance to the final client of less than one mile.
During specific hours small vans may enter the logistic blocks when required to deliver big or special goods closer to the final point. The speed limit is 10 km/h.

From Level 2 to Level 3: from the UCC to the exterior of the Logistic Blocks. (See Diagram).
The UCC can feed the hubs, micro-hubs, and cross-docking spaces. These deliveries will be undertaken with EV vehicles, such as medium-size vans, bikes, or PMD. Delivery to the exterior of the Logistic Blocks will be possible by bike or walking depending on distances and time requirements.

From Level 1 to Level 2: from the industrial areas to the UCC. (See Diagram).
Preferably, the delivery from the last warehouse to the UCC will be done at night. The industrial areas will feed the UCCs by EVs such as fully loaded big vans. The location of the UCC must be carefully selected to avoid a negative impact on the surrounding environment. The UCC must be outside levels 3 and 4 and close to a main infrastructure to improve efficiency and reduce impacts.

The UCC must have interior parking to allow cross-docking. This facility could be a warehouse where the vehicles can be loaded and unloaded on the interior., Due to the high cost of land within the city limits, the facility will probably have to intensify its uses in terms of surface area and floor levels. Within the city, the UCC will be probably located in an existing building rather than a new one. It could, for instance, be an underground parking garage connected to upper levels of storage, or a parking garage with storage both above and below ground. Finally, it could be part of a mixed-use building, such as offices that are empty at night.
In some ways, big supermarkets with underground parking, located on the ground floor of a residential building, are not too different from a UCC. Usually, the goods are delivered and stored at night or early morning. Obviously, this model does not need cross-docking where goods are transferred

to another vehicle. But, in terms of environmental impacts, it isn´t too different from a logistics facility.

In Madrid, some examples that take advantage of existing parking spaces inside an office building or mix-used building are already occurring. In the case of an office building, the parking area, empty at night, is used for cross-docking purposes. (Cadena de Suministro, 2021). Recently, a group of private and public stakeholders has begun promoting a network of urban hubs in Madrid, to find their proper location within the city limits (Gutierrez, 2020). Santiago Bernabeu Stadium, currently undergoing a massive transformation, will accommodate a UCC in the parking garage. (Ezquiaga, 2022).

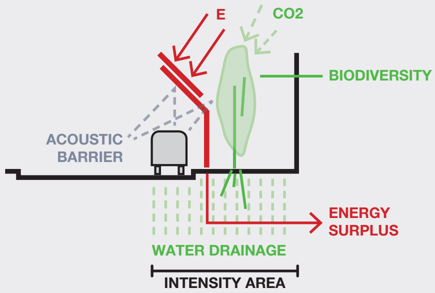
In Barcelona, UCCs are being developed inside shopping malls. (Cadena de Suministro, 2021). Apart from the environmental impact, a barrier to logistic facilities within city limits is the high cost of the rent that impacts their desired profit margin. This is one of the reasons why hubs or UCCs are being implemented in underused spaces, or during specific times, usually at night, when a building is underutilized. The result is that urban logistic facilities are increasingly becoming hybrid and occupying shared spaces.

From Level 2 to Level 4: from the UCC to the interior of Logistic Blocks. (See Diagram).

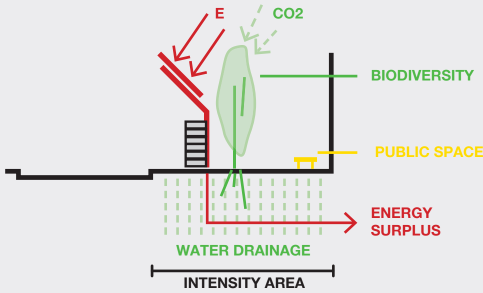
It is possible to deliver from the UCC to the interior of blocks if the distance allows the use of EVs such as bikes and PMDs, bikes powered by humans, or by walking. As mentioned previously, small vans can deliver directly from the UCC to the interior of the logistic blocks when required to deliver big or special goods close to the final destination.

From Level 1 to Level 4: from the warehouse to the interior of Logistic Blocks. (See Diagram).
This is the current BAU model. ICE vans deliver directly to the final point in the interior of the Logistic Blocks. Only in specific cases, due to the size or to the special requirement of the goods, (for temperature control, for example), will be possible to make the delivery from the last warehouse to the final delivery point by EVs, such as small vans.

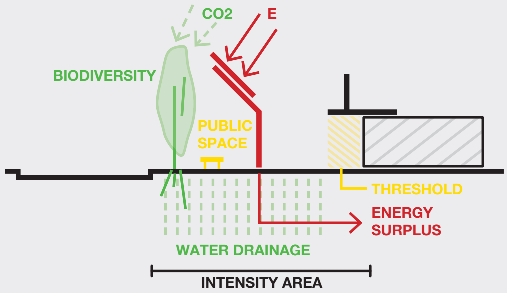
LOADING + UNLOADING



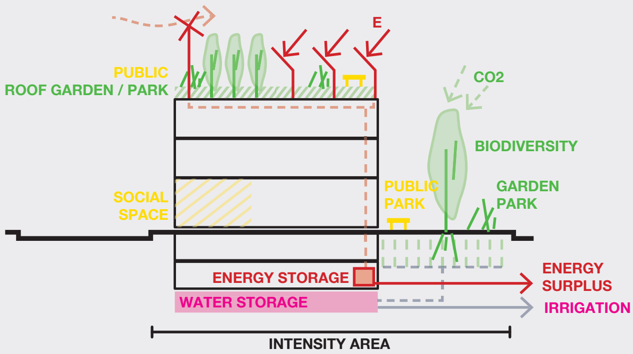
PUDO



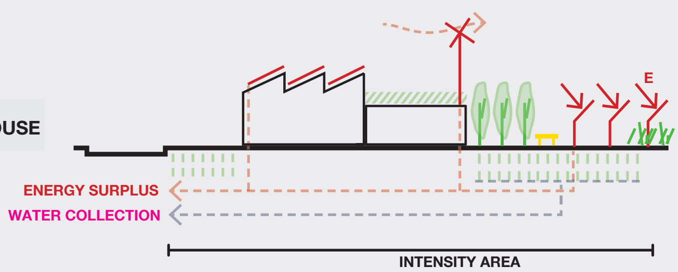
HUB



UCC



WAREHOUSE



	COLLABORATIVE RESOURCES	IMPROVEMENT OF THE NATURAL ENVIRONMENT	COMMUNITY INVOLVEMENT
LOADING + UNLOADING	- PHOTOVOLTAIC PANELS - CO2 SEQUESTRATION - EV CHARGING	- DRAINAGE PAVEMENT - BIODIVERSITY	- PARTICIPATORY DESIGN - ACOUSTIC / VISUAL BARRIER
PUDO	- PHOTOVOLTAIC PANELS - CO2 SEQUESTRATION - EV CHARGING	- DRAINAGE PAVEMENT - BIODIVERSITY	- PUBLIC SPACE (BENCH...) - PARTICIPATORY DESIGN
HUB	- PHOTOVOLTAIC PANELS - CO2 SEQUESTRATION - EV CHARGING	- DRAINAGE PAVEMENT - BIODIVERSITY	- PUBLIC SPACE (BENCH...) - PARTICIPATORY DESIGN
UCC	- PHOTOVOLTAIC PANELS - WIND TURBINES - CO2 SEQUESTRATION - WATER STORAGE + WATER SURPLUS - ENERGY STORAGE + ENERGY SURPLUS - EV CHARGING	- DRAINAGE PAVEMENT - BIODIVERSITY	- PUBLIC SPACE (BENCH, PARK, ROOFTOP, PLAYGROUND...) - PARTICIPATORY DESIGN - SOCIAL SPACE - SOCIAL ACTIVITIES
WAREHOUSE	- PHOTOVOLTAIC PANELS - WIND TURBINES - CO2 SEQUESTRATION - WATER STORAGE + WATER SURPLUS - ENERGY STORAGE + ENERGY SURPLUS - EV CHARGING	- DRAINAGE PAVEMENT - BIODIVERSITY	- COLLECTIVE SPACE (BENCH, PARK, ROOFTOP, PLAYGROUND...) - PARTICIPATORY DESIGN - SOCIAL SPACE - SOCIAL ACTIVITIES

Actions and strategies for enhancing positive impact

8.6. Intensification for positive impact

The LIA offers the opportunity to redesign the logistics infrastructure as a network of flows, where the logistics facilities work as interconnected nodes, that promote a beneficial relationship with the urban environment across different intensity levels. Using a biological metaphor, the LIA establishes a symbiotic relationship between logistics and the city.
Understanding and approaching city logistics beyond infrastructure, but as a network is a theoretical framework that helps to build a new type of relation with the environment. Thus, the architecture and landscape of the network can be redesigned as a hybrid system, based on three strategies: sharing resources, improving our environment, and community involvement.
The logistics network can share its resources with the city. If the network is not only self-sufficient but net-positive, it could generate more resources than needed and share the surplus with the city. This means that the logistic network can become a Resources Community infrastructure (RCI) that can supply and store resources while restoring the environment. The RCI supplies and stores energy and water and has also the capacity to capture carbon.

The RCI is an evolution in the concept of Energy Community, which are “collective actions of citizens coming together to participate in the energy system, taking ownership of their energy
City logistics can also play a role in enhancing general health and biodiversity, through the design of ecosystems such as parks, gardens, or habitats for natural organisms. In addition, city logistics can promote the regeneration of degraded areas.

The third strategy promotes community involvement in the logistics network through the development of a participatory design, social actions, and the supply of public and social spaces. Finally, the final client of the network should have a proactive and sustainable role in the logistics network, especially in the final delivery stage.
These three strategies can be developed at different scales ranging from simply draining the pavement for the loading and unloading areas, or the creation of a public park located at the rooftop of an Urban Consolidation Center. Moreover, visual impact and noise pollution can be reduced by implementing these and other responsible strategies.

8.7. Implementation of the positive impact.

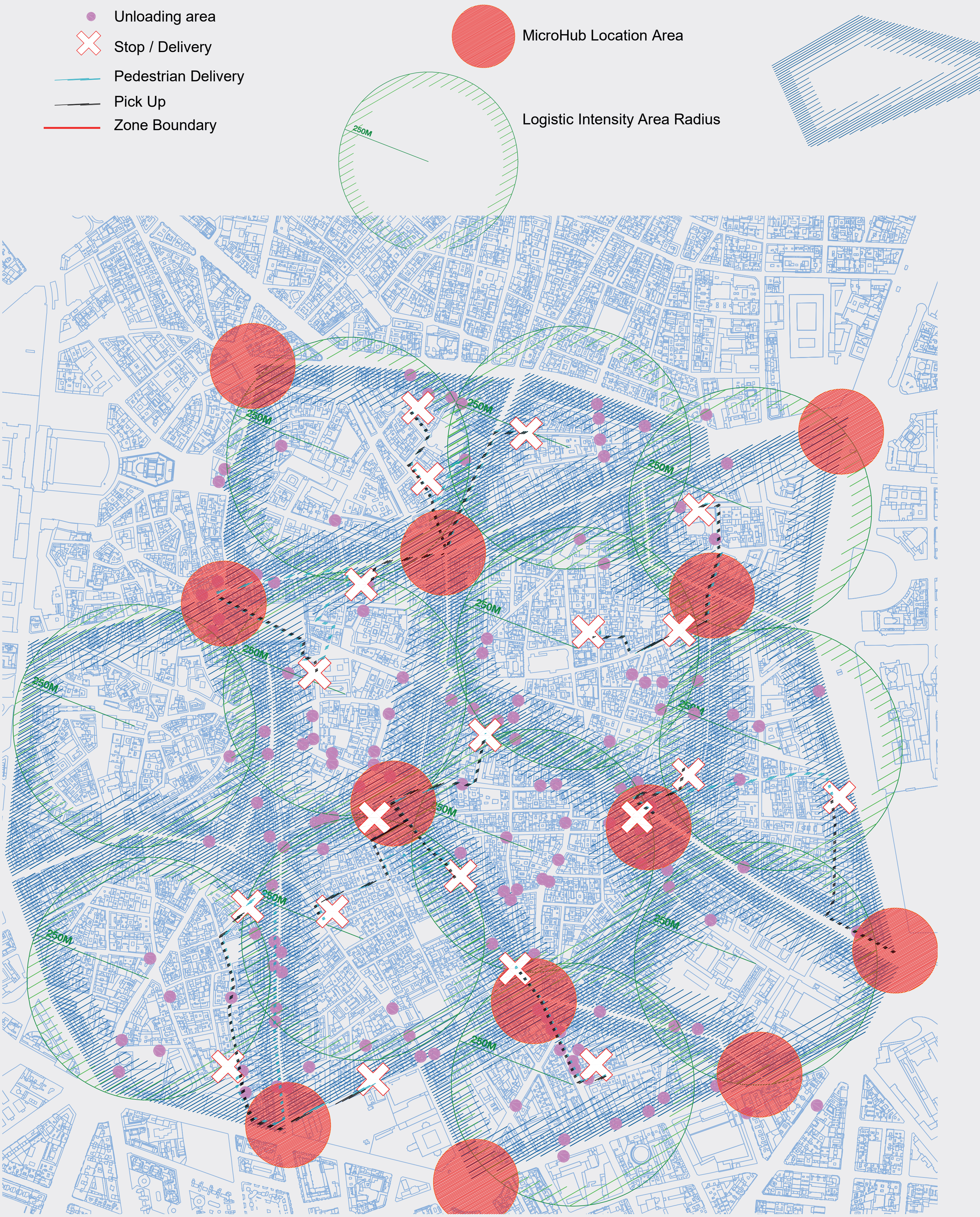
The table on the left page illustrates some examples of how to implement strategies such as sharing resources, improving the natural environment, and community involvement in the logistics network to intensify a positive impact in the urban environment. According to the urban structure, each logistics facility has an intensity area where these strategies should be applied.

Loading and unloading areas can be designed not only as physical spaces marked on the pavement but as the interconnection of different environments. The pavement can allow drainage and recycling of rainwater and vegetation can be planted in the surrounding areas to enhance biodiversity among other positive impacts. A canopy can accommodate photovoltaic panels to light the area or to provide surplus energy to the community, such as EV chargers. In addition, vegetation and canopies can function as visual and acoustic barriers and can help to capture the carbon dioxide from the atmosphere.

The PUDOs and hubs may have similar approaches as the loading and unloading areas. In the case of the PUDOs, the integration of the physical elements such as the smart locker with the photovoltaic canopies is desirable. A canopy designed with vegetation can provide shade and a comfortable environment that may include a public space with benches or a playground. In the case of a HUB or micro-hubs the threshold between the exterior and interior forms a potential place to ease the flow of people for pick-up and return of parcels.
The Urban Consolidation Centers have the most complex programs. Due to its higher impact on the city, the potential for positive impact is also higher. Usually, a UCC is a multi-story, hybrid building that can accommodate interior parking for cross-docking, storage areas, offices, and other functions to support the community. The surrounding area consists not only of the ground floor but also the roof-top and other exterior levels. It is possible to include collaborative resources such as photovoltaic panels, wind turbines, and water collection systems in these spaces. Both energy and water can be stored or be used to supply the community. In the case of naturalization, the vegetation and natural organisms can overrun the surrounding areas to enhance biodiversity and to support public activities like playgrounds, sports, or leisure areas. The UCC can provide social spaces for the neighborhoods including co-working areas and meeting rooms for elderly people. In addition, the management of the UCC can enhance social actions within the community.

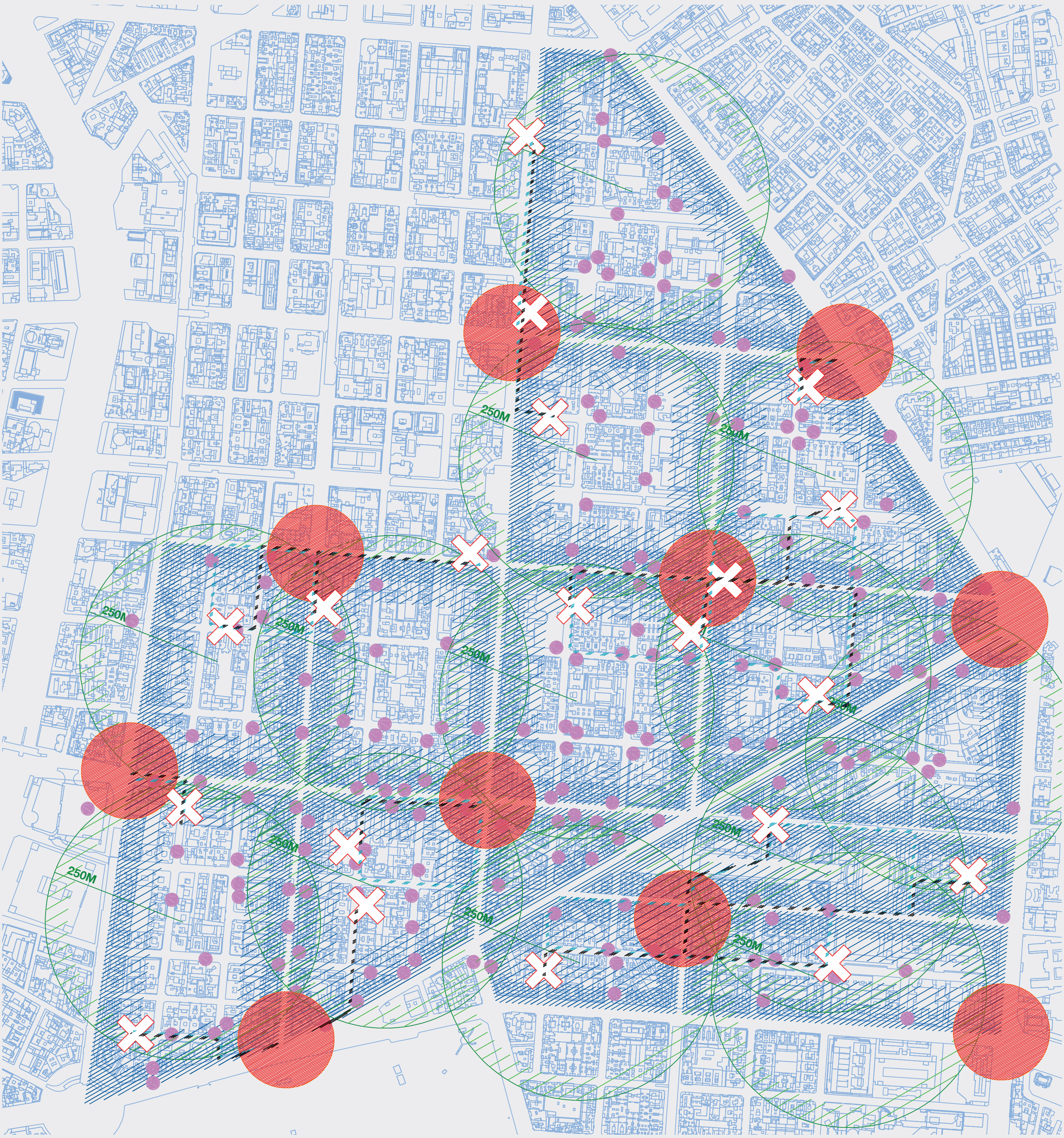
The location of warehouses outside the urban areas influences the definition of the type and degree of intensification for positive impact. In general, one to two-story warehouses are located in industrial areas of different densities and activities, Warehouses can implement intensification strategies similar to UCCs, but due to their size and the surface area of the plot, it is possible to develop other uses such as sports areas and parks. In the case of collaborative resources, the amount of surplus energy and water to supply other communities could be much greater. The lack of residential areas close to the warehouses requires other types of strategies for community involvement. First, the warehouse needs to be accepted and embraced by the community and second, interaction with other warehouses within the industrial area needs to be enhanced. Social activities, such as those sports, club activities, or training programs are options..

Madrid
scale 1:10.000
Logistics Intensity Area Distribution



Madrid
scale 1:10.000
Logistics Intensity Area Distribution

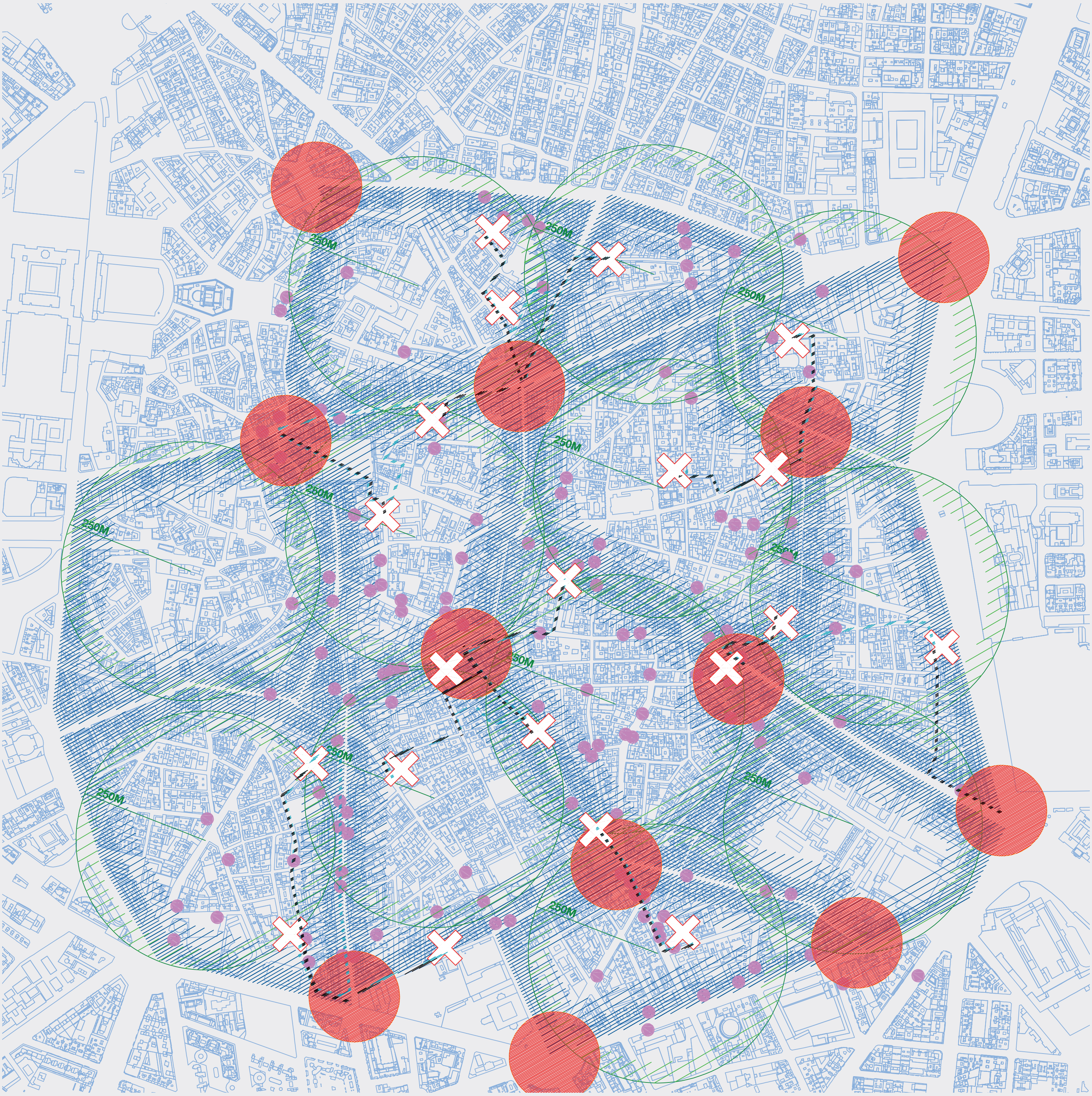
Logistic Intensity Area Perimeter



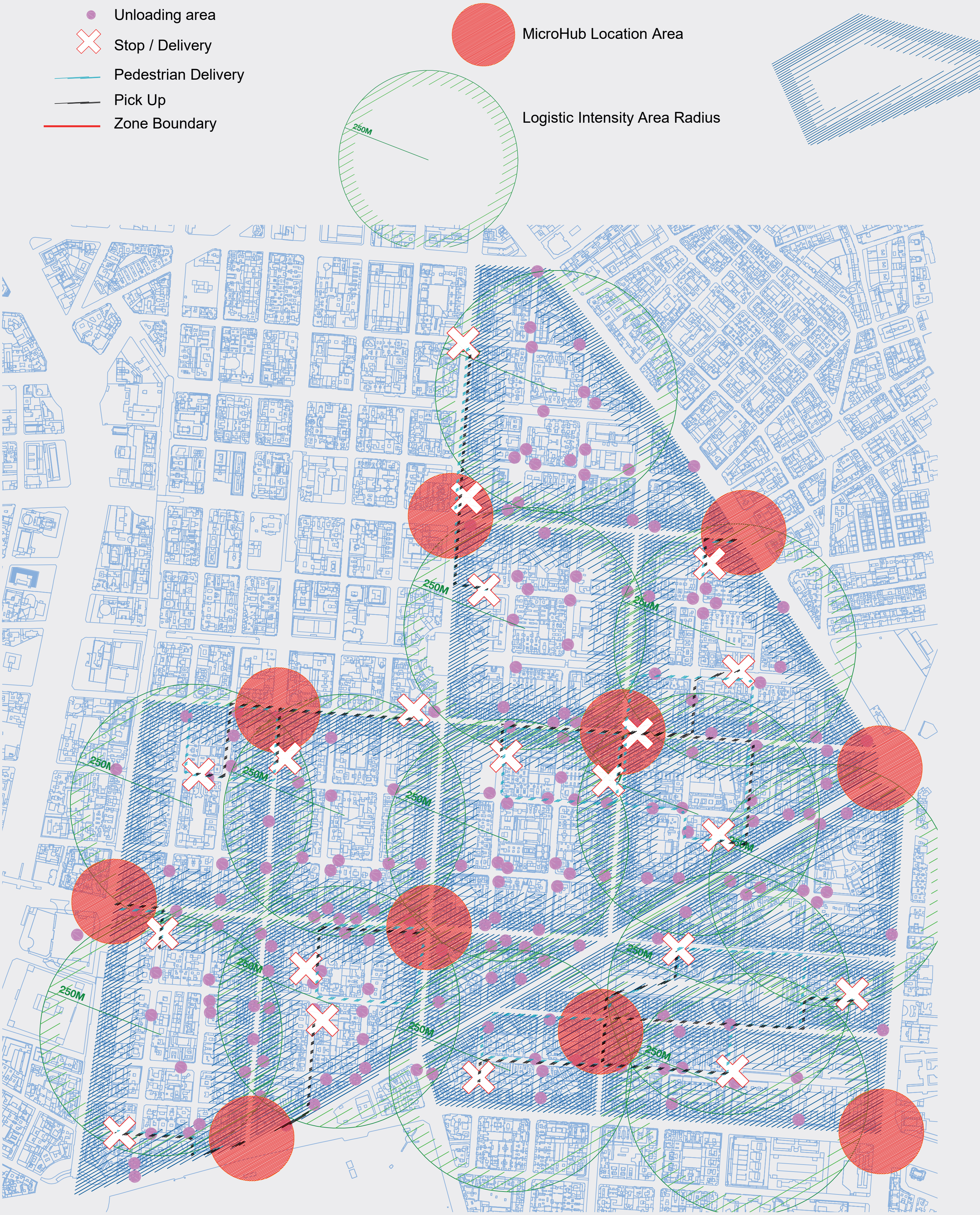
Madrid
scale 1:20.000
Logistics Intensity Area Distribution

Barcelona
scale 1:10.000
Logistics Intensity Area Distribution

Logistic Intensity Area Perimeter



Barcelona
scale 1:10.000
Logistics Intensity Area Distribution



Barcelona
scale 1:15.000
Logistics Intensity Area Distribution

Logistic Intensity Area Perimeter

09: Conclus

ions

Conclusions

This work has been structured in four interconnected parts: analysis, modeling and simulation, evaluation, and proposals. The data collected from the analysis phase helped build the models and to perform the simulations for the scenarios. Later these scenarios were evaluated by the Last-Mile Logistics Impact Index (LM-LII), a tool developed specifically for the present research. This tool is, we believe, is a realistic means to assist decision-makers in understanding and dealing with the evaluation of options for organizing and improving the logistics network.

The concept of Logistics Intensity Areas (LIA) was designed for a planning policy approach to promote the most sustainable and efficient logistics scenarios for a city. It supports. the key findings of the present research. Our work, seeking to be the most precise, useful, and verifiable, has been carried out in the cities of Madrid and Barcelona. Nevertheless, the tools and findings can be applied to other places that were specifically included in this study.

The authors of the present research have interdisciplinary backgrounds and have trained as urban and landscape designers, planners, architects, and mathematicians with experience in modeling and simulating cities as complex systems. Traditionally, research in the field of city logistics research has not been approached from the perspective of the urban designer, architect, or planner. We have placed the city at the center of this study, knowing that the characteristics of each city, including its layout, scale, organization, urban fabric, and a myriad of other factors are always interconnected and required for any understanding of logistics. Therefore, we did not analyze just the flow of goods, but the whole logistics network and its interconnection with the city.

The objective of the present research was to analyze and evaluate the impact of logistics in cities, and propose specific strategies, actions, and planning policies to enhance its positive impacts on the urban environment while maintaining the efficiency and functionality of the logistics network.

Evaluation tool: the Last-Mile Logistics Impact Index (LM-LII)

To evaluate the impact of the logistics network in the urban environment, the Last-Mile Logistics Index (LM-LII) was developed. This tool provides a quantitative measurement of the impact, based on environmental, functional, socioeconomic, urban, and information factors.

These factors are applied to the stakeholders, the logistic facilities, the delivery vehicles, and the urban fabric to evaluate their impact independently, and then together as a total sum. The LM-LII aims to standardize the evaluation criterion for the impact of logistics in cities. The LM-LII can be a certification system that measures the environmental impacts of the logistics network just as other certifications already do, such as those for product design, architecture, or urban design. Currently, there is no accepted tool to evaluate the logistics network. We believe that the LM-LII can fill this space.

Key findings from the evaluation of the scenarios

The results of the evaluation of the scenarios we defined showed that current Business as Usual (BAU) models, which are based on a direct delivery from the last warehouse to the final client, have the highest negative impact on the environment. The simulations showed that the parcels must pass through different hands before the final delivery if the goal is to reduce the negative impact on the urban environment. Thus, a network of logistic facilities inside the city for storage and cross-docking of goods is necessary.

Implementing simple route optimization software produces a significant decrease in time spent on the road by each vehicle. However, the tendency of customers to require prioritized delivery and the limited opening hours of private companies and commercial drop-off spaces disrupt the optimization process. These drawbacks could be avoided with the implementation of PUDOs, which free the driver from external schedules, especially to delivery points that have daily pick-up and drop-offs.

The scenario using cargo bikes loaded from Urban Consolidation Centers, micro-hubs, or vans parked in selected loading and unloading areas, have the smallest impact on the city while still being efficient, both ecologically and visually and in terms of public opinion. The presence of these friendly vehicles, with their zero emissions, near-zero noise impact, and small spatial footprint in the city, increases the sense of place in each neighborhood. Its human scale introduces a more digestible side of logistics versus the ICE vans, or those vehicles used in the BAU model.
However, the scenarios we modeled did not consider the limitations of cargo-bikes in the face

of extreme temperatures or inclement weather that leaves the driver exposed uncomfortable situations as may occur in Madrid and Barcelona (such as over 30 degrees weather and heavy rains).
While cargo bikes can use the automobile lane (and in some countries like Germany even the pedestrian paths), the lack of sufficient bike lanes inside a city can add to the level of danger to which each driver is exposed.

On the positive side, cargo bikes can be parked anywhere provided they do not block traffic, which significantly reduces the time spent on each delivery. In Madrid, there is no specific legislation regarding cargo-bikes and therefore it allows more drivers to access the emission-restricted city center. It is a vehicle it doesn't need any type of certification for the vehicle itself or rider, which opens the job market to a wider segment of the population.

The evaluation revealed that the most sustainable scenario is the combination of a Hub with the pick-up/drop-off option for the final client. The Hub could be either an Urban Consolidation Center, a micro-hub, or a Smart Locker. The Hub can be fed directly from the last warehouse by an Electric Vehicle (EV), preferably during the night. It could also be a combination of an Urban Consolidation Center fed at night from a warehouse, that delivers by bike or PMD to a micro-Hub. This scenario reveals that citizen play an important role in the development of a sustainable logistic ecosystem.

Pedestrian delivery is the least efficient in terms of time and load capacity, due to the average speed of a human being and their ability to carry weight. However, this method has plenty of advantages, too Pedestrian delivery is heavily linked to the quantity, location, and networks of logistics real-estate. The BAU model is completely unrealistic for humans and bikes because of the great distances between storage and final client. With the existence of carefully located consolidation centers, micro-hubs, or strategically parked fully loaded vans, the pedestrian model has a positive effect on the community it serves and opens the job market to a wider population, as well. At a community level, the street presence in both volume and noise is zero and contributes to the idea of a local service that strengthens the sense of place and trust in a neighborhood. The delivery unit is no longer perceived as a temporary intruder in an area, but more as a recognizable face, a "good neighbor," and part of the social fabric of the neighborhood it serves, which adds to stability and cohesion.

Implementation of a network of logistic facilities. The Logistics Intensity Areas (LIA).

The introduction of a network of logistics facilities within the urban environment, formed by Urban Consolidation Centers (UCCs), Hubs, Micro-Hubs, and PUDOs will provide flexibility to the overall system while improving the sustainability of several scenarios. This is possible by implementing direct delivery, preferably at night, from the last warehouse to the urban logistics facility, using an EV Van, optimized in terms of maximum load and circuit. The final delivery will be undertaken, depending on the distance, by bike or PMD, or walking from the urban logistics facility to the final client by bike or PMD. The flexibility of the logistics network opens up the possibility of multiple combinations of space, vehicles, and timing to find the most efficient and sustainable delivery.

Cities are required to provide opportunities. The implementation of a network of logistics facilities can promote several different options for stakeholders from the citizen to the transport operator, to find the most efficient and sustainable delivery method. The Logistics Impact Areas (LIA) approach leads to planning policies that regulate the location and features of the network of logistic facilities within the urban structure. The objective of the LIA is to synchronize an efficient logistics network with the design of a sustainable urban ecosystem.

The LIA introduces a two-way approach creating a symbiotic relationship between logistics and the city. On the one hand, it reduces the impact of the logistics flow in the urban environment, and on the other hand, it promotes positive impacts. The location of logistics facilities according to Intensity Areas, defined in accordance with the urban structure, is the first step in the strategy to reduce negative impacts. The Logistics Intensity Blocks (LIB) groups together in one area several blocks or buildings that will have the highest restrictions for types of facility and delivery vehicles of the Logistics Intensity Areas (LIA). The Logistics Intensity Blocks aim to promote a healthier environment in terms of GHG pollution, noise, congestion, visual impact, and stress. Outside of the limits of the Logistics Intensity Blocks, specific logistic facilities to support sustainable delivery are permitted. The restrictions established by the LIA decrease from level 4 of the LIB to level 1 for the last warehouse of the supply chain.

The LIA proposes a new type of logistics facility that is hybridized with other activities and facilities. Thus, logistics facilities are no longer just spaces for storage and cross-docking but are active buildings that can become integrated and responsive to the urban environment through community involvement, improvement of the natural environment, and collaborative

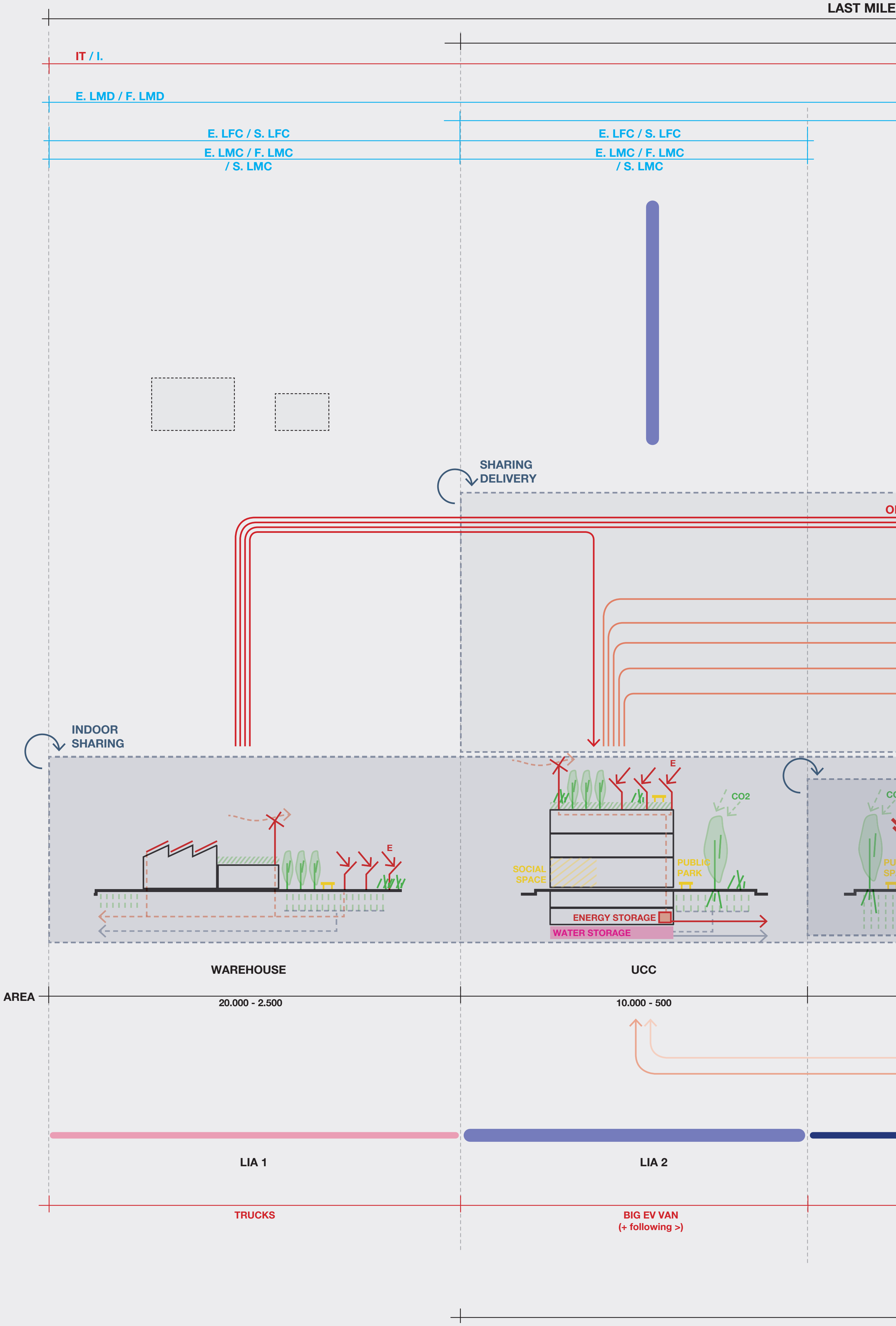
resources.

Collaborative resources are a very promising concept whereby the logistics network can share the supply and storage of resources, such as energy and water through the creation of new community infrastructure (Resources Community Infrastructure (RCI). Depending on the type of facility, the sharing capacity varies. In the case of improving the natural environment, urban logistics can enhance biodiversity, through the design and regeneration of ecosystems such as parks, gardens, or habitats for nature. Finally, community involvement is focused on participatory design, the promotion of social actions and activities, and the provision of spaces for the neighborhood.

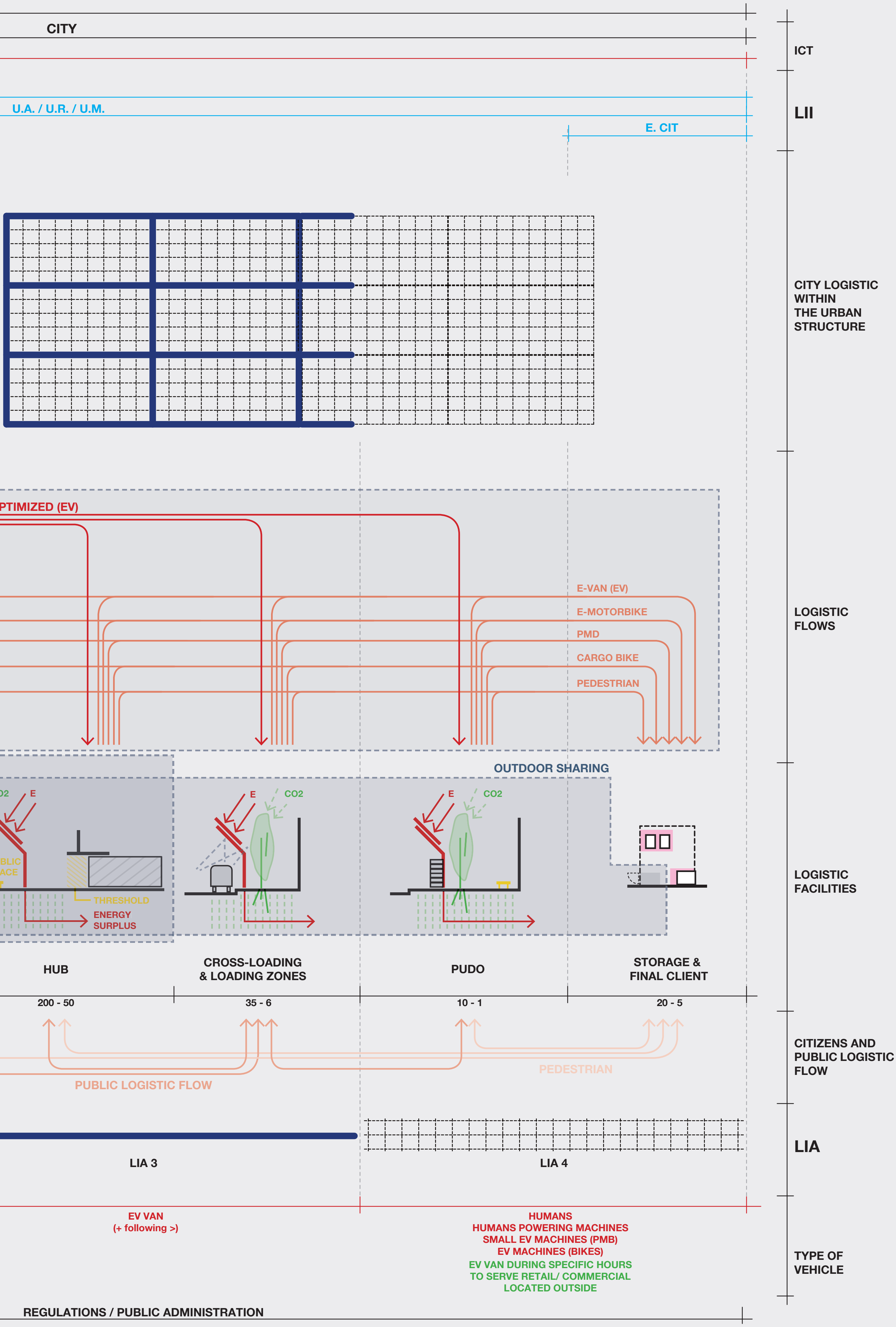
Further research and development.

This report proposes an evaluation tool and a planning policy to reduce the negative impacts of logistics and enhance a healthy urban environment. The Last-Mile Logistics Impact Index (LM-LII) helps to measure the impact of specific scenarios and realities, while the Logistics Impact Areas (LIA) synchronize the efficiency of the logistic network with the design of a sustainable urban ecosystem. This paper opens the path to the further development of the LM-LII and its implementation of the LIA. Although both are interconnected, they can be developed independently.

Public administrations, together with the stakeholders of the logistic ecosystem, must take the lead in setting the guidelines for the Logistics Impact Areas (LIA). the Last-Mile Logistics Impact Index (LM-LII) should be developed by an independent third party but include the participation of all logistics stakeholders. Our hope and recommendation would be to continue the work undertaken in this study through the creation an advisory team of researchers and experts to move forward. The IE the Center for Sustainable Cities is positioned to do so and would be pleased to work on the further development of the LM-LII and LIA to contribute to both the best logistics network and the most livable city.



Logistics Network including the Logistics Impact Index (LII), the Logistics Impact Areas (LIA) and the strategies and actions for enhancing positive impact


CITY
ICT
U.A. / U.R. / U.M.
LII
E. CIT
CITY LOGISTIC WITHIN THE URBAN STRUCTURE
PTIMIZED (EV)
E-VAN (EV)
E-MOTORBIKE
PMD
CARGO BIKE
PEDESTRIAN
LOGISTIC FLOWS
OUTDOOR SHARING
E
CO2
THRESHOLD
ENERGY SURPLUS
LOGISTIC FACILITIES
HUB
CROSS-LOADING & LOADING ZONES
PUDO
STORAGE & FINAL CLIENT
200 - 50
35 - 6
10 - 1
20 - 5
PUBLIC LOGISTIC FLOW
PEDESTRIAN
CITIZENS AND PUBLIC LOGISTIC FLOW
LIA 3
LIA 4
LIA
EV VAN
(+ following >)
HUMANS
HUMANS POWERING MACHINES
SMALL EV MACHINES (PMB)
EV MACHINES (BIKES)
EV VAN DURING SPECIFIC HOURS
TO SERVE RETAIL/ COMMERCIAL
LOCATED OUTSIDE
TYPE OF VEHICLE
REGULATIONS / PUBLIC ADMINISTRATION

10: Team

About

10.1 Center for Sustainable Cities

The Center for Sustainable Cities aims to integrate disciplines and knowledge associated with the city, to promote the understanding of the city as a complex ecosystem in permanent evolution and transformation. Our work and strategies, based on observation, data collection and analysis, aims to evaluate the real impact, in terms of sustainability, of any action or event. Only from a deep understanding, we can implement positive changes. The Center for Sustainable Cities, as well as IE School of Architecture and Design, adopts the United Nations Sustainable Development Goals (SDGs) and seeks to promote their implementation, through research, education, and outreach.

The Center for Sustainable Cities highlights our commitment to good and responsible city-making. It will do so focusing on climate change and the role of cities, in order to assess current and future risks, make choices and propose new ideas that enhance resilience. The Center will also provide a space (physical and virtual) where different agents involved in the process: government, the private sector, non-governmental organizations, citizens, and academia can come together in the search for collaborative answers.

Climate change poses serious threats to urban infrastructure, quality of life, and other urban systems, in both developing and rich countries.

Recognizing the seriousness of the current situation, the Center for Sustainable Cities seeks to address how to insure sustainable, livable cities for the future. As an educational institution we have a responsibility to train future leaders who will have to shape a more humane world and to create and disseminate knowledge.

Authors:

Manuel Pérez Romero

Manuel Pérez Romero has an interdisciplinary background as an architect, urban designer, lecturer, and inventor. Pérez Romero is Chair of the Center for Sustainable Cities and Director of the Bachelor in Urban Studies at IE University. He is the founding partner of the nodo17 group, a Madrid based group of architects, urban designers and ecologists operating within the field of the city and the territory.
Pérez Romero holds a Ph.D. in Architecture from Madrid Polytechnic University and a Master of Architecture and Urban Planning degree from Las Palmas de G.C. University. He is continuously researching new techniques, for which he has patented and developed several structural and construction systems.

Ruxandra Iancu Bratosin

Ruxandra Iancu Bratosin is a spatial designer,computational researcher and lecturer exploring the fields of ecology, social impact and design processes and her work has been exhibited at worldwide forums such as the Venice Architecture Biennale of of 2016, the Rotterdam Design Biennale of 2017 and the London Design Biennale of 2021. Her research on the boundaries of digital ecology, the aesthetics of computation and the notion of human-machine collaboration has been widely published in books and publications.
She is currently teaching and researching across various programs at IE University in Madrid, and she is founding partner at 50(Super(Real)) a studio focused on multi-scalar spatial strategies, driven by the harmonious marriage of human values with technological innovation.

Rodrigo Rubio Cuadrado

Rodrigo Rubio is an architect, designer and researcher focused on the fields of ecology and computation. He has served for more than ten years lecturing, teaching, and researching at institutions such as IAAC (Barcelona) and TSA (New Orleans) and he has been directing research projects such as the Endesa Pavilion (Smart Cities World Congress, Barcelona, 2011) and the BCN Circular Economy (Ajuntament de Barcelona, 2016).
He holds and M.Arch. with Honors by the Madrid Polytechnic University and a Master of Architecture and Urban Planning at the Barcelona Institute of Advanced Architecture of Catalonia. He is currently teacher at the Bachelor in Design at the IE University, PhD candidate at the Madrid Polytechnic University, and founding partner of 50(Super(Real)).

Alessandro Mattoccia

Alessandro Mattoccia is an architect, building engineer and computational expert focused on the research on coding and its applications onto the automatization of design processes and techniques, advanced modelling, and data-informed geometries. He has lectured widely in institutions such as the Engineering Faculty of Pisa, and the Madrid Polytechnic University.
Currently he is focused in pushing the boundaries of the Building Information Modelling methodology. He is co-director at Structuralia in the Master “BIM and Smart Buildings” and teacher at the “Programming Applied to BIM” Master Program. He is Adjunct Teacher at the Bachelor in Architecture at the IE University in Madrid and founding partner of 50(Super(Real)).

Research Advisor:

Martha Thorne

Martha Thorne is Dean of IE School of Architecture and Design. Since 2005, she has served as the Executive Director of the Pritzker Architecture Prize, popularly known as the “Nobel Prize for Architecture”. Her interests have always focused on international contemporary architecture, cities in evolution and changes in the role of the architect.
Martha Thorne received a Master of City Planning degree from the University of Pennsylvania and a Bachelor of Arts degree in Urban Affairs from the State University of New York at Buffalo. She undertook additional studies at the London School of Economics. She currently serves on an international jury for the award, ArcVision: Women and Architecture, a prize honouring outstanding women architects. She also lectures and assists with international architectural competitions.

Research Assistants:

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Ana Domingo is a 5th year architecture student in IE University, Bachelor in Architecture program. She has been involved with many university initiatives and volunteering projects.

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Moira Burela is a recent graduate of IE School of Architecture. Her interest lie in the intersection of the natural and the built environment.

Asmaa Elbaz

Asmaa Elbaz is a recent graduate of IE School of Architecture.She is a Detail-oriented and hard-working Architect adept at designing projects, providing professional creative concept solutions, and conducting reports on the progress of the projects.

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12: Glossary

Glossary

Analytic hierarchy process (AHP)
The use of the combination of qualitative and quantitative information to define and organize complex and ambiguous problems.

Business As Usual (BAU)
Refers to a situation where everything is happening as normal or as traditionally done, especially after a period of disruption.

Capacitated Vehicle Routing Problem (CVRP)
The capacitated vehicle routing problem (CVRP) is a VRP in which vehicles with limited carrying capacity need to pick up or deliver items at various locations. The problem is to pick up or deliver the items for the least cost, while never exceeding the capacity of the vehicles.

City Logistics
"City logistics deals holistically and systemically with context, actors, norms and operations within the city jurisdiction as well as in its relationships with neighboring cities. It recognizes that 'geographic, economic, social, and cultural circumstances affect city logistics and people's perception of critical issues related to city logistics." (Cardenas, et al.,2017):

Cross-docking
A logistics strategy whereby the carrier immediately unloads cargo from an incoming container and then loads it directly to an outbound carrier, also known as dock to dock. It is a practice that keeps supply chains moving quickly in a productive, effective manner.

Discrete-Event Models (DEM)
Method used to model real world systems that can be broken down into a set of logically separate processes that autonomously progress through time. Each event occurs in a specific process and is assigned a timestamp.

DUM
Urban goods distribution, from the Spanish "Distribución Urbana de Mercancías".

EV
Electric Vehicle.

Fast Moving Consumer Goods (FMCG)
Fast-moving consumer goods are products that sell quickly at relatively low cost. Consumers buy and replace these goods frequently. They are also called consumer packaged goods.

Fuzzy sets
Fuzzy models or sets are mathematical means of representing vagueness and imprecise information (hence the term fuzzy). These models have the capability of recognizing, representing, manipulating, interpreting, and utilizing data and information that are vague and lack certainty.

Geographic Information Systems (GIS)
A Geographic Information System (GIS) is a computer system that analyzes and displays geographic information of many types and from many sources.

Green logistics
«Green logistics consists of all activities related to the eco-efficient management of the forward and reverse flows of products and information between the point of origin and the point of consumption whose purpose is to meet or exceed customer demand». (Thiell et al., 2011).

High-Frequency Storeowners (HFS)
These are locally owned shops, bodegas, stalls, and kiosks and are known "high-frequency stores," because of the multiple times shoppers visit them during a single day or week.

Horizontal Collaboration (HC)
Collaboration by companies across the supply chain. This approach is characterized by companies sharing supply chain assets for mutual benefit. Often, horizontal collaboration is between companies in the same industry that, while perhaps not competing directly, market and sell to similar customers and consumers.

Hubs
Larger sites within the urban area, which are used by operators that often have their own national supply chains and make use of electric vans for last mile deliveries.

ICE Vehicle
A conventional vehicle powered solely by an Internal Combustion Engine.

Information and Communications Technology (ICT)
ICT, or information and communications technology (or technologies), is the infrastructure and components that enable modern computing.

Kerb weight + driver weight
Kerb weight plus the average driver weight, considered 75 kg.

Large Municipal Organisms (LMOs)
such as local authorities, hospitals, universities.

Last Mile (LM)
The last leg in a supply chain to arrive to a customer's location in a city, or the first leg from a customer's location in a city back into the supply chain" (Den Boer et al., 2017).
Also, refers to the very last step of the delivery process when a parcel is moved from a transportation hub to its final destination.

Last-Mile Impact Index (LM-LII)
The Last-Mile Impact Index is a specific tool developed in the present research to evaluate the impact of the logistics network in the urban environment. This tool provides a quantitative measurement of the impact, based on environmental, functional, socioeconomic, urban and information factors.

Logistics Ecosystem
The logistics ecosystem is a complex network of flows (delivery) and nodes (logistic facilities) regulated by the stakeholders and especially by the planning policies set by the public administration. Usually, the system produces a high social and environmental impact.

LEZ
Low-carbon Emissions Zones.

Logistic Intensity Areas (LIA)
The Logistic Intensity Areas (LIA) is a planning policy developed specifically for the present research. Its goal is to find a balance between the efficiency of the logistics network and the impact on the city. These areas can reduce the impact of the logistic flow in the urban environment and also promote a positive impacts. The location of the logistic facilities according to Intensity Areas, taking into account the urban structure is a first step to reduce negative impacts., The adoption of strategies based on community involvement, natural environment improvement and collaborative resources is the second strategy to enhance a positive impact.

Logistic Intensity Blocks (LIB)
The Logistic Intensity Blocks (LIB) groups in one area several blocks or buildings that have the greatest restrictions in terms of logistic facility and delivery vehicle of the Logistic Intensity Areas (LIA),. The aim of the Logistic Intensity Blocks is to promote a healthier environment of the blocks in

terms of GHG pollution, noise, congestion, visual impact, and stress

Logistics Network Diagram (LND).
The Logistic Network Diagram is an effective tool to visualize and evaluate the logistics network, that gathers most of the key findings of present research. The logistics ecosystem is represented through the logistics network diagram, which reflects the complex relationship between stakeholders, logistics facilities, delivery vehicles, and Information and Communication Technology (ICT) within the urban structure.

Logistics Service Providers (LSP)
Logistics Service Providers, or 3PL (third-party logistics) providers, are outsource entities that shippers leverage to manage a company's warehousing, distribution and transportation of freight.

Logistics sprawl
High land prices and the tendency for centralization of supply chains caused the relocation of logistics systems from central urban city areas to suburban areas (Dablanc & Rakotonarivo, 2010). Also called logistics suburbanization (Allen et al., 2012).

Logistics and Supply Chain Management (LSCM)
"That part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements" (Grant et al., 2015).

Micro-Hubs
Smaller sites within the urban area, which are used by operators with a more localized supply chain. These hubs focus mostly on bicycles and pedestrian porters for last mile deliveries.

Multi-Actor Multi-Criteria Analysis (MAMCA)
The Multi-Actor Multi-Criteria Analysis (MAMCA©) is a decision-making method to enable the simultaneous evaluation of alternative policy measures, scenarios, technologies, etc. while explicitly including different stakeholders' opinions at an early stage of the decision-making process.

Modifiable Areal Unit Problem (MAUP)
The MAUP is a potential source of error that can affect spatial studies using aggregated data. This problem was first addressed by Openshaw in 1984 "the areal units (zonal objects) used in many geographical studies are arbitrary, modifiable, and subject to the whims and fancies of whoever is doing, or did, the aggregating." When spatially varied data, such as population or disease cases, are aggregated into spatial units such as census tracts or geopolitical districts, the resulting summarized values, for example totals or rates, may be influenced and the original underlying spatial patterns may be distorted by the choice of district boundaries.

Multi-Depot Vehicle Routing Problem (MDVRP)
If the customers are clustered around depots, then the distribution should be modeled as a set of independent VRPs. However, if the customers and the depots are intermingled then a Multi-Depot Vehicle Routing Problem should be solved.
A MDVRP requires the assignment of customers to depots. A fleet of vehicles is based at each depot. Each vehicle originates from one depot, service the customers assigned to that depot, and return to the same depot.

PUDO.
Pick-up and Drop-Off point.

Social sustainability
The fulfilment of the increasing demand for time-sensitive deliveries and the high service quality required by the final customers affects the working conditions of the drivers.

Stakeholder.
"Any group or individual who is affected by or can affect the achievement of an organization's objectives". (Freeman & McVea, 2001).

Stem Mileage
Stem distance which is the distance to and from a delivery zone (stem mile).

Superblock
The Superblock is an urban grouping and may be repeated throughout the city. In the case of Barcelona, the Superblock forms the basis of an urban regeneration project by favoring pedestrians within the superblock through several actions. Superblocks are a suitable solution for addressing

the main dysfunctions and challenges those urban systems face today (Rueda, 2019).

Supply Chain Management (SCM)
The planning, organization and management of all activities concerned with procurement and sourcing, conversion, and logistics management tasks. (Mariki, 2021)

Tara/ Kerb weight
Mass of the vehicle, with its equipment, fuel, water, oil, tools, etc. without any service personnel, passengers or cargo.

Travelling Salesman Problem (TSP)
The Travelling Salesman Problem (TSP) is the challenge of finding the shortest yet most efficient route for a person to take given a list of specific destinations. It is a well-known algorithmic problem in the fields of computer science and operations research.

Urban freight
Urban freight is defined as the transportation of goods by or for commercial entities (as opposed to households) taking place in an urban area. This definition includes the movement of all goods generated by the economic needs of local businesses. It includes warehousing and activities such as deliveries and pick up of supplies, materials, parts, consumables, mail and refuse. It also includes home deliveries to households, as these are generally done by means of a commercial transaction.

Urban Logistics (UL)
Part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and point of consumption, within the city, in order to meet customers' requirements.

Urban Consolidation Center. (UCC)
Urban Consolidation Center (UCC), also called "logistic hotel," is an urban logistics facility located in a multi-use and multi-story building, incorporating cross-docking and warehousing facilities, as well as serving as an interchange node. The objective of the UCCs is to avoid the delivery with partially loaded vehicle or non-appropriate vehicles, according to the restrictions or requirements of certain urban areas. Deliveries can be consolidated at the UCCs for their later delivery with the appropriate fully loaded vehicle.
Usually, UCCs are located in or close to high density areas within the city limits. UCCs can reduce the total urban freight transport by combining deliveries and filling up each truck to capacity (Dablanc and Rodrigue, 2014).

Vehicle Fill Rate (VRF)
On a pure logistics level, the Vehicle Fill Rate (VFR) can be defined as the ratio of the actual capacity used in a vehicle to the total capacity available in terms of weight and volume.

Vehicle Routing Problem (VRP)
Combinatorial optimization and integer programming problem seeking to service a number of customers with a fleet of vehicles. Proposed by Dantzig and Ramser in 1959, VRP is an important problem in the fields of transportation, distribution, and logistics.

Volatile Organic Compounds (VOC)
Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short- and/or long-term adverse health effects. Concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors. VOCs are emitted by a wide array of products.

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