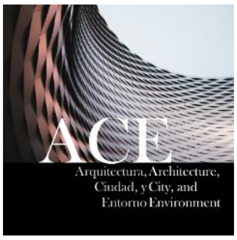

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A Methodological Proposal for the Integration of Robotic Services in the Urban Public Space of Cities

Propuesta metodológica para la integración de servicios robóticos en el espacio público urbano de las ciudades

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Abstract

The integration of urban services with robotic technology in the public space of cities requires an in-depth analysis of both the characteristics of the technological system and the existing urban structure. The proposal of this work, based on the methodology of the case study, proposes a process to develop the research, and selects the case study of last mile distribution services with the autonomous robotic platform ONA. Throughout the process, a theoretical analysis is proposed, to which data, empirical evidence and rounds of discussion between professionals in urban planning, robotics, architecture and engineering, as well as end users and citizens, are added, seeking to reach a consensus on the characteristics and requirements of the technology that must be integrated and the changes that must be made in the urban public space, both in its planning and design. The RUS (Robotic Urban Services) Template, incorporating the characteristics of a specific urban robotic service and the list of urban aspects to consider, is used as a guide of the opportunities and the constraints detected for the integration.

Keywords:
urban challenges; urban robotics; public space

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Resumen

La integración de servicios urbanos con tecnología robótica en el espacio público de las ciudades requiere de un análisis en profundidad tanto de las características del sistema tecnológico como de la estructura urbana existente. La propuesta de este trabajo, basada en la metodología del caso de estudio, propone un proceso para desarrollar la investigación, y selecciona el caso de estudio de servicios de distribución de última milla con la plataforma robótica autónoma ONA. A lo largo del proceso, se propone un análisis teórico al que se suman datos, evidencias empíricas y rondas de discusión entre profesionales del urbanismo, robótica, arquitectura e ingeniería, así como usuarios finales y ciudadanos, buscando llegar a un consenso sobre las características y requerimientos de la tecnología que se debe integrar y los cambios que deben realizarse en el espacio público urbano, tanto en el planeamiento como en el diseño del mismo. La Plantilla RUS (Servicios Robóticos Urbanos), que incorpora las características de un servicio robótico urbano específico y la lista de aspectos urbanos a considerar, se utiliza como guía de las oportunidades y las restricciones detectadas para la integración.

Palabras clave:
retos urbanos; robótica urbana; espacio público

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1. Introduction

A wide range of urban challenges were proposed by European Cities (EU, 2023) to be solved by new technologies - including autonomous transport, personalized mobility support in pedestrian areas, inspection and maintenance of urban infrastructures, waste management and street cleaning, environmental monitoring and goods distribution -, to improve the quality of life and wellbeing of citizens. The answer to these urban challenges is coming hand in hand with disruptive technologies as the robotic one, through the transformation of the public transport in autonomous and robotic buses and vehicles; the new micromobility robotic devices for intermodal robotic transport system; the individual and collective urban services, including robots for last mile delivery or personal robots for shopping tasks, or the specific aging robotics services, for solving the mobility challenge of elderly people in urban environments. Some of them are already implemented in cities such as Helsinki (Fabulous, 2020); others, as prototypes, are looking for tests, experimentation and commercialization - as ONA robot -, and a big group of them are still in the solution design phase.

There is not a universal design solution for all urban environments and scenarios, since the forms of appropriation of public space are particular to each society, according to its cultural values and availability of resources (ONU, 2020). Urban planning is an approach to the design of buildings and the spaces between them considering a wide range of subjects from physical geography to social science (Geddes, 1915; Ravella, 2010) and an appreciation for disciplines, such as real estate development, urban economics, political economy, and social theory (Perroux, 1964; Lösch, 1967), to better organize physical space and community environments. Urban design refers to the formalization of the public space and the characterization of it in relation to citizens' scale and social needs (Cullen, 1961; Rowe & Koetter, 1993; Gehl & Gemzoe, 1996). The urbanism discipline defines the urban structure as the arrangement and relation of the city and people creating a sense of community (Talen, 1999) and describes the urban typology, the density and sustainability, the neighborhood structure and the quality of the architecture (Abercrombie, 1933). The urban dimension of public spaces is the sum of activities and services and includes walk-ability, connectivity, mixed-use and diversity, urban design, smart transportation, sustainability and quality of life (Jacobs, 1961). Other authors point out the idea of urban design as a continuous process of shaping places, fashioned in turn by shifting global, local and power contexts (Carmona, 2021).

There is a large group of studies about how the robotic technology should adapt to urban environments with wide research works on navigation, perception, data management or human robot interaction, (Sanfeliu et al. 2006; Sanfeliu et al., 2008; Kruse et al., 2011; Trautman et al., 2015; Garrell et al., 2017; Gooldhoorn, 2017; Repiso et al., 2020), but very few about how the urban planning and design discipline should consider the integration of robots and its operational procedures in the urban public space. The reason could be that the physical structure of cities evolves slowly because it is expensive, costly and not very flexible (Bibri et al., 2020), but it should be prepared to integrate these new technologies.

The irruption of robotic mobile platforms in urban services will require a mutual adaptation of the urban area, the citizens and the robotic platforms. The question about if we should build cities for robots or robots for cities has a clear answer in previous studies (Nagenborg, 2020), considering that we have to find a mixed approach where the built environment will be adopted to enable new robotic applications while safeguarding the quality of the city. It is in this context that we consider the objective of this research work: to propose a methodology for the analysis of the integration of urban robotic services in the public space of cities, a field that remains relatively unexplored scientifically. The work presented in this article is a continuation of the previous ones presented by the author on the analysis of human roles in human-robot interaction scenarios (Puig-Pey et al., 2022) and the human acceptance in a robotic last mile delivery scenario (Puig-Pey et al., 2023).

The unique nature of public spaces, characterized by the coexistence of diverse forms of mobility, interactions, actors, and other variables, makes it challenging to assess public acceptance when a new technology is integrated. This is the reason to select a research methodology that allows to address a complex topic and put order on it, as well as highlight the points where the constraints and relationships of the integration are significant. Yin (1994) defines the case study methodology as a research strategy that is characterized by studying phenomena in their own context, using multiple sources of evidence, in order to explain the observed phenomenon in a global way and considering all its complexity. Likewise, it is considered necessary to link a first theoretical analysis with a subsequent empirical analysis in such a way that both corpuses mutually enrich each other (Mintzberg, 1978).

According to the case study methodology, this research work proposes a process, structured in three steps, and validates it through a selected case study, the last mile delivery with ONA robot.

The three steps are: first, elaboration of the robotic urban service template; second, analysis of urban planning and design of the site; and third, the discussion and consensus of the feasibility of the integration of a robotic urban service in the public space of cities. Each one of the steps, requires having a theoretical analysis and the evidences and data obtained through other sources of empirical research and developed through rounds of discussion with all agents involved. In this work, it has been assumed that business and logistics models have been already analyzed, and the focus of the work is only on the integration of robotic technology in the urban public spaces.

This article is structured in 8 sections. Section 1 presents the introduction to the sustainability challenges posed by cities and how the incorporation of robotic urban services can respond to these challenges, being the objective of this article to propose the methodology for the analysis of the integration of urban robotic services in the public space of cities. Section 2 presents the related work and literature on urban studies that consider sustainability and technology issues, offering data that can shed light on the research. Section 3 introduces the research methodology, the process structure and the process development. Section 4 presents the case study and the application of the methodology and process to the case study: the robotic last mile delivery in urban public space with ONA robot. Section 5 presents the conclusions of the work carried out. Section 6 introduces the acknowledges and section 7, the authors' contribution. Finally, Section 8 lists the related bibliography.

2. Related work

The bibliography analyzed (Rueda et al., 2012; Cugurullo et al., 2020; Tiddi et al., 2020; Macrorie et al., 2021; Rosenthal-Von del Pütten et al., 2020) starts with the criteria for a sustainable city model, the requirements of the new urban mobility transport, the principles of the robot city discipline, that recognize the urban robots as part of a new digitized infrastructure that will manage city services, and the analysis carried out by the author (Puig-Pey et al., 2022-2023) on the human acceptance of human robot interaction scenarios in the urban public space.

Ecological urbanism (Rueda et al., 2012) proposes a set of indicators to check the sustainability of cities: the land occupation, the quantity and quality of the public space, the mobility, the diversity of urban uses and functions, the biodiversity, the metabolism, and the social cohesion of the city. Ecological urbanism values the particularities of the context as a basic premise for approaching the problem of sustainability to be dealt with. The set of indicators is applicable both in the planning of new urban developments, and in the transformation of the consolidated city. For the ecological urbanism, the public space is the structural element of a more sustainable city model. The quality of the public space is related to the concept of compactness defined as the axis that attends to the physical reality of the territory and, therefore, to the formal solutions adopted: the building density, the distribution of spatial uses and the percentage of green or road space determine the proximity between urban uses and functions (Rueda et al., 2012). This axis is accompanied by the mobility and public space model and the derived land use model.

Sustainable mobility must be part of an integrated approach, developed with a long-term perspective in which future needs and future urban, spatial and technological developments are considered. In the last years, some challenges of the introduction of new mobility devices in the cities, including micromobility solutions as bikes and electrical scooters, who now carry out last mile distribution, are similar to the ones that will be faced in the future robotic urban services. For example, the admissible limit of its incorporation into the city, the road capacities for segregated or shared lanes, the volume, gauge, and the speed of the new devices, match the development and the integration of the micromobility devices in cities and will be required also for the integration of the robotic technology in the urban public space. These types of micromobility transportation are characterized by having a low environmental impact (Rusul et al, 2021; Sun et al., 2023), most of them powered by human or electric traction, and a low spatial impact in urban environments because they are using existing urban infrastructure. On the other hand, these types of mobility tend to use shared mobility services on short and medium-distance routes – as last mile -mainly in high-density urban environments.

Also, the local regulations for current micromobility have to be considered. In the case of the city of Barcelona, the circulation spaces for the different typologies of micromobility devices are regulated. For example, the transit in sidewalks is only allowed for loading and unloading when the sidewalk is at least of 4.75m width and there is a 3m width free from obstacles; the speed is limited in the urban streets for a single platform; the maximum speed limit in a bicycle lane is 10 km/h; etc. From the parking point of view, micromobility devices can park only in authorized places, therefore it is forbidden to park next to trees, traffic lights, benches or other elements of urban furniture, or where functionality in the urban space may be hindered, for example as emergency exits of health centers, or on sidewalks, when it blocks pedestrian paths.

The article elaborated by Cugurullo et al. (2020) analyzes the urban futures focusing on the changes in urban design and sustainability characterized by shared and private "autonomous vehicles", human drivers and artificial intelligences overlapping and competing for urban spaces. Special mention is the research done by Kent Larson, director of the City Science (formerly Changing Places) group at the MIT Media Lab, and his team proposing R&D solutions for the next future (Noyman et al., 2017). Considering the city planners as the principal actors for the reformulation of the urban spaces, Kent Larson' studies include the development of new vehicles and devices at cities; the urban implementation of the new mobility solutions; the electric charging infrastructure; and the smart fleet management system.

From a transversal point of view, the article of Tiddi et al. (2020) explains the challenges of this new Robot City Interaction (RCI) discipline. It focuses on the review of a very extensive bibliography between 1996-2016, recognizing the urban robots as part of a new digitized infrastructure that will manage city services, as those mentioned before. At the same time, it gives the robot a role as producer and consumer of urban data, emphasizing the need for combining knowledge-based urban environments with modern data infrastructures technologies and robot-aware regulations. It is clear that we are in front of an interdisciplinary discipline, due to the number of different areas contributing to it that include Robotics, Information and Communication Technologies, Artificial Intelligence, Knowledge Representation, Ethics, Security and Privacy. These technologies are needed to design and implement systems in which autonomous agents are integrated in urban environments, however they do not include the disciplines of urban design and management. For the RCI discipline, the robot technology will be deployed by and for the city, to improve the existing urban services and six RCI areas have been identified: Citizen Assistance, Public Space Engagement, Mobility in Urban Dynamic Environments, Autonomous Urban Transportation, Urban Security and Urban Maintenance.

Macrorie et al. (2021) considers that cities are becoming experimental sites for new forms of robotics and automation technologies applied in a wide variety of sectors and in multiple areas of economic and social life. As these innovations emerge from the lab and the factories, this paper looks at how robotics and automation systems overlap existing urban digital networks, expanding human agency capabilities and infrastructure networks, and reshaping the city and communities with daily experiences of citizens. A research agenda was launched by the author, that goes beyond the analysis of discrete effects and applications, to investigate how robotics and automation connect in urban domains and the implications for differential urban geographies.

According to Rosenthal-Von del Pütten et al. (2020) the research on human-robot interaction has predominantly focused on laboratory studies, yielding a fundamental understanding of how humans interact with robots in controlled environments. As robots move from research and development labs to the real world, Human-Robot Interaction (HRI) research must adapt. The author argue that investigations should broaden their scope to explicitly include people who do not deliberately seek interaction with a robot (users) but instead spontaneously encounter robots in the middle of the city (bystander).

The work of Puig-Pey et al. (2023) about Human acceptance in the Human-Robot Interaction scenario for last-mile goods delivery, based in HRI scenarios (Scholtz et al., 2006; Zlotowski et al., 2011; Mintrom et al., 2022), introduces the Human Robot Interaction Template -HRI Template- (Puig-Pey et al., 2022) and analyses the robotic last mile delivery process using ONA robot. This work proposes a set of nine key indicators for human acceptance, and evaluates it through a set of interviews and surveys during the experimentation done in the site of Esplugues de Llobregat, Spain. This article also introduces a new HRI skill: The Robotic Set designer. This new skill, sketches and designs the new robotic scenario, and it is essential for the introduction of robotics in the day a day of human life, creating the scenography where humans and robots will coexist.

As mentioned before, due that multiple disciplines and actors have to be considered for analysing the integration of robotic services in the urban public space, the methodology chosen to carry out this research is the "case study methodology", that will be explained in the next section.

3. Methodology and process

As we have seen in the previous section, we are facing a complex problem with different disciplines that should take part in the analysis. The selected approach —case study methodology (Yin, 1994)—, allows a group of stakeholders to systematically approach a particular task or problem, using multiple sources of evidence and considering all its complexity. The collection and analysis of evidence and data, both qualitative and quantitative, should be done in a planned and systematic manner and a process should be designed. The methodology uses techniques such as observation, questionnaires, documents' analysis, surveys, interviews, and rounds of discussion to develop a consensus of opinion from the participants - a multidisciplinary team. A coordinator, with transversal skills, drives the discussion and formalizes the proposals.

To develop the research, first the structure and development of the process are proposed and second, a case study is selected. Throughout the process, the theoretical analysis of the case is developed, which is enriched by data and empirical evidence from the case study. In Fig. 1 the process structure is presented and in subsections 3.1-3.2-3.3 the process is developed.

Figure 1. Process structure for the analysis of the Integration of the Urban Robotics Services in the public space

	STEP 1	STEP 2	STEP 3
INPUT SOURCES	TECHNOLOGY characteristics and requirements - Urban DATA and EVIDENCES	RUS-Template OBSERVATION - EVIDENCES – USERS – CITIZENS FEEDBACK	RUS-Template URBAN Analysis Other EVIDENCES
TASKS	Elaboration of the ROBOTIC URBAN SERVICE TEMPLATE (RUS-T)	Analysis of the URBAN PLANNING AND DESIGN of the site	DISCUSSION and CONSENSUS
OUTPUT DOCUMENTS	RUS-Template	URBAN Analysis	ROBOTIC URBAN SERVICE TECHNOLOGY + PUBLIC SPACE DESIGN

Source: Own elaboration

Once the process is planned, the case study is selected on which a theoretical analysis will be carried out first and on which data and empirical evidence will be obtained through sources such as observation, surveys, interviews, and any other source that may contribute. Then, the process is developed through the case study:

Step 1 elaborates a Robotic Urban Service template (RUS-Template), a variation of the HRI template (Puig-Pey et al., 2022), that includes the description of the robotic urban service and the requirements of the robotic system - the robots, the operational procedure and the HRI Roles -. The inputs of Step 1 are the technology characteristics and requirements and the evidences and data obtained in the empirical research. The output is the RUS-Template.

Step 2 analyses the current Urban Planning and Design of the place, including the morphology, uses and activities, the citizens' social life, the urban systems and the accessibility. The inputs of Step 2 are the RUS-Template, the evidences and data obtained in the empirical research and other sources. The output is the Urban Analysis of opportunities, weaknesses, and conflicts.

Step 3 looks for a Discussion of relationships and constrains, seeking the feasibility of the proposal and reaching a Consensus on the integration of the new technology in the urban public space. The inputs are the RUS-template, the Urban Analysis and other Evidences. The results of this step will be, on the one hand, the characteristics, and requirements of the new robotic technology to be implemented and, on the other hand, the variations that must be made in public space to integrate it. In both cases, the proposed analysis can lead to the specifications of the respective public tenders.

For each step are proposed the group of stakeholders (Table 1) - of urban planners, robotic and technology engineers and architects-. Other stakeholders, as users, citizens and public entities should participate along the process. A coordinator with transversal skills, the Robotic Set Designer with methodological and participative competences, will drive the discussion and formalize the proposals.

Table 1. Stakeholders' participants along the process

	STEP 1	STEP 2	STEP 3
STAKEHOLDERS PARTICIPANTS	ROBOTIC SET DESIGNER		
	ROBOTICS AND ENGINEERS		ROBOTIC ENGINEERS AND SUPPLIERS
		URBAN PLANNERS - ARCHITECTS	
	USERS-CITIZENS-PUBLIC ENTITIES		

Source: Own elaboration.

Next, the three steps of the process for the analysis of the integration of urban robotic services in the public space of cities are developed, including the theorist analysis that will be improved with the data and evidences offered by the case study.

3.1. Step 1. Elaboration of the Robotic Urban Service Template (RUS-T)

To understand and describe the characteristics of the new robotic scenario where the robotic urban service will be implemented, the HRI (Human-Robot Interaction) Template (Puig-Pey, 2022) is used. The HRI template is updated in this work with the characteristics of the urban service and the logistic requirements, and is renamed as Robotic Urban Service Template (RUS-T). This template has to be completed by the robotic team. In the last phases of the innovative product (high TRL), where the product is close to commercialization, the suppliers can be included in the process. Through several rounds of discussion, including information from qualitative and quantitative data, the new robotic scenario is described: The robotic urban service, the logistics, the robot typology and characteristics, the robotic operational procedure, activities and the HRI tasks (Steinfeld et al., 2006) that has to be done in the urban public space and the HRI roles of the different agents that are participating in this robotic scenario.

The description of the robotic system includes: (1) navigation characteristics—such as autonomy level (autonomous, semi-autonomous, or teleoperated), speed, maneuverability, and access to energy charging infrastructure; (2) perception requirements—cameras, sensor networks, and communication facilities; (3) management and logistics protocols; (4) manipulation tasks in urban spaces, including hard and soft maintenance; (5) social HRI tasks—communication features and interfaces between humans, context, and robotic systems; and (6) data management—including databases, repositories, cloud service access, and legal protocols.

In addition, the human roles involved in this urban HRI scenario must be defined. These include:

1. The supervisor – responsible for overseeing the entire process, with or without direct involvement in logistics and technical supervision. This role requires a deep understanding of the robotic system's capabilities and plays a key part in continuous improvement processes.
2. The operator – in charge of teleoperating or piloting the robot(s), and capable of supporting human–robot interaction in complex urban situations.
3. The maintainer or mechanic – responsible for technical upkeep and repair.
4. The peer teammate – collaborates with the robot in public space tasks such as guiding or accompanying.
5. The peer end user – interacts directly with the robot as a beneficiary of its services.
6. The bystander – citizens, tourists, and urban workers who are indirectly involved through proximity or incidental interaction.

Some roles—such as the supervisor, operator, and off-line maintainer—may operate remotely. However, the off-line maintainer may also perform interventions in designated urban areas when necessary. Peer teammates, end users, and bystanders interact with the robot in situ, and their feedback should be collected, where possible, through surveys, interviews, or other qualitative and quantitative methods.

3.2. Step 2. Analysis of the Urban Planning and Design of the site

Once the new technological system is described, a group of urban planners, architects, and other urban stakeholders conduct an analysis of the urban site, identifying opportunities and constraints for integrating the new technology. This is done using information from the RUS-T, supported by a theoretical framework enriched with empirical data and evidence obtained from reliable sources such as observation, interviews, and surveys related to the case study.

The conditions of the urban site and its context—where the new technology is expected to be introduced—can be analyzed at two different scales: urban planning and urban design. Table 2 presents the structure of this urban analysis.

Urban planning focuses on aspects such as urban morphology, land uses and activities, citizens' lifestyles and sociability, accessibility, and urban systems. Urban design, on the other hand, examines the spatial and formal characteristics of public spaces, including platforms, elements, street furniture, and paving.

Let us now analyze the different aspects of urban planning:

- Urban morphology involves density, compactness, building typologies, spatial characteristics of streets and roads, and the quality of pedestrian areas. It includes the hierarchy of the street network and the characteristics of sidewalks and open spaces—such as pedestrian zones—with an emphasis on maintaining a minimum of 15 m² of public space per citizen to support urban sustainability. The typology of buildings, especially ground floors and their interaction with public space, is also critical. These factors influence the feasibility of operational tasks, such as the handover process.

- Public space must support a variety of uses and activities, balancing consistency with diversity in the urban environment. Urban services and their operational procedures are essential components of city life and are supported by public space. The complexity and intensity of use—residential, commercial, academic, or industrial—must be taken into account.

- Social life in the city must be considered, as the way people use public space (e.g., for walking or resting) directly affects the feasibility of introducing new agents, such as robots, due to safety and well-being concerns. An aging population and vulnerable groups (e.g., the elderly) will increasingly demand urban services (Jarzebski et al., 2021), such as delivery systems, which will require adaptations to public space.

- Accessibility includes physical infrastructure such as public transportation, micromobility services (e.g., bikes and scooters), and their role in enhancing logistics and intermodal connections. It also encompasses shared mobility systems and pedestrian accessibility. Additionally, management systems—such as information and communication infrastructure, networks for parking, charging, maintenance, and overall urban logistics—are key factors.

In summary, the conditions of the urban site and its context will determine whether the introduction of new technology—such as robotic systems—into public space is feasible without disrupting current social dynamics.

Once the urban planning aspects are analyzed, attention shifts to urban design. In this work, urban design is understood in a broad sense, encompassing both the existing physical configuration of the site and the elements that may be modified to accommodate the new technology. These include urban platforms, street layouts, furniture, and other spatial elements.

Table 2. Structure for the urban analysis

THE URBAN PLANNING				THE URBAN DESIGN
The urban morphology	The uses and activities	The citizen's social life	The accessibility system	Urban platforms
Density	Complexity & areas:	The citizens' activities	Physics infrastructures	The urban furniture
Compactness	Residential areas	Intensity of use	Management systems	The urban elements
Building typology	City centers	Population Ages	Urban Micro mobility	The green
Streets and roads	University campus	Vulnerable groups		The pavement
Sidewalks and pedestrian	Industrial areas	Individual to collective		
	The urban services	Citizen safety +privacy		
		Citizen well-being		

Source: Own elaboration.

3.3. *Step 3. Discussion and Consensus*

The third step of the process proposes a discussion to give viability to the integration of the chosen urban robotic service in the proposed public space. To achieve this, different discussion rounds between all the agents involved will seek to take advantage of the opportunities and resolve the constraints detected, suggesting adjustments to the new technology and necessary modifications in the public space. The result of this third step can give rise to a specification document for both the technology to be integrated and the urban project to adapt public space, thus allowing the bidding for both.

Let us analyse some implications of the integration of the Robotic Urban Service in an urban area from the point of view of Urban Planning and Urban Design.

- *The urban morphology*. The urban morphology affects directly to the characteristics of the urban service, making possible or not the new technological solution. The robotic urban service should be defined specifically for the different urban typologies of the city, neighborhood or quarter, depending on density, compactness and complexity, customers' segments and schedules.

- *Density and compactness*. The introduction of robotic urban services in low density areas will be easier than in dense urban areas, but less efficient for business analysis. Logistics could offer solutions through different robot typologies including personal robots. The site compactness influences some urban services as the delivery one, but it doesn't create a conflict.

- *Building typology*. Sustainable cities look to empty the public space of logistics places and move them to ground floors and underground locations. The ground floor network offers the necessary infrastructure for robotic urban services: logistic refuges, parking areas for maintenance or distribution hubs.

- *Streets and roads*. For logistic reasons, the characteristics of quarters' streets and roads could help to the introduction of new robotic urban services or could offer clear weaknesses. Plan and sections should be analyzed deeply, including the intersections and the continuity of the space. Some current streets and roads could not offer possibilities for the circulation of a robot. The collaborative robotic service, where humans and robots focus on the same goal, could be a possible solution. Once the diagnosis is positive, the new street design and the formalization through urban settings will ensure the integration.

- *The sidewalks and pedestrian areas*. Specific issues must be considered in these areas, including the robot design, dimensions, maneuverability and speed, making the safety of citizens prevail over the autonomy of the robot, which must need operator and peer teammate support more intensely. Specific ELES (Ethical, Legal, Economic, and Social) protocols and regulations of the urban robotic service should be proposed, looking for the citizens' privacy and safety.

- *The uses and activities*. The robotic urban services have to match with the final customer's purposes looking for an efficient solution: domestic, commercial or business. As we have seen before, once the business model is feasible and the different kinds of robotic solutions are analyzed, the solutions for the integration should be suggested, but not before. It is desirable that the necessary robotic infrastructures such as electrical charging systems, maintenance infrastructures, intermodal hubs, be shared between the different robots' floats. To elaborate a correct diagnosis of the introduction of robotic services in urban areas, we have analyzed four examples in the next section, to visualize the influences and relationships between them:

- *Residential areas*. The low density of residential areas is at the same time a strength and a weakness for the new solution. A strength because the new technology could be included in not crowded streets and roads, and a weakness, because the need of infrastructures and the logistics to reach the full area could lead to an inefficient solution.

- *City centers*. In these areas, robot navigation is the one of the main threats for a successful robotic service. The HRI roles, as the operator and the peer teammate, are essential. Diurnal and nocturne schedule could be a solution for crowded environments, but the robotic service could create a conflict with bystanders and citizens that should be considered by both, urban designers and robotic designers, to avoid human robot interaction threats in these dense and crowded areas. Despite the fact that robotics researchers suggest that current robots can circulate respecting the rules of urban coexistence without creating weaknesses with social life and the activities that take place, the integration of robotics for urban services will mean an in-depth redesign of the urban space in these areas.

- *University campus*. The introduction of robotic urban services in university campuses is very adequate because of the low density and characteristics of the customers and end users. As we have seen in previous studies (Puig-Pey et al., 2023) young people, under 40s, accept disruptive technologies better than elderly ones. On the other hand, low density could be a weakness for the business feasibility. The university campuses are a convenient area for new urban solutions and designs. As an example, the Barcelona Urban Robot Lab, at the Universitat Politècnica de Catalunya (UPC), with more than 10,000 square meters sensorized for robotic experiments, opens the door to test tactical urban design that could be petrified later on at the city.

- *Industrial areas*. As we have seen in the previous zone, the low-density areas are very convenient for the introduction of new technologies, and the integration will be easier. In industrial areas, the autonomy of the robot could be higher and the characteristics– dimensions, speed, gauge, etc., could be adequate to the current streets and roads. The urban services. The coexistence with other urban services could be problematic for logistic and schedule reasons. In some areas as the scholar one, it is important to consider the robotic urban technology with mixed uses, as for example the survey tasks.

- *The citizens' social life*. We are witnessing a paradigm shift regarding the use of public space by citizens. Increasingly, in our cities, public space becomes a place to socialize and do activities. The new technology must consider this point essential for its integration.

- *The citizens' activities*. There may be conflict between citizens' social activities and the integration of a new robotic technology, specifically in rest and promenade zones.

- *Intensity of use*. Detailed information of what is happening in the public space and new schedules proposals, including daily and night ones, could help in the solution.

- *Population Ages - Vulnerable groups - Individual to collective*. The public space should include clear and friendly information and protocols about the robotic scenario and, at the same time, areas where the citizen could be without interference to rest and be calm. On the other hand, the robotic experience is a good ally for kids and young groups, and their interaction could be part of or those areas with a big number of vulnerable groups and elderly using the public space, the activities developed by the robotic urban services will be more dependent on human roles as the operator and peer teammate ones.

- *Citizen safety +privacy*. A new urban protocol for citizens' safety and privacy should be considered when the robotic urban service is integrated in the public space. The characteristics of the robot should be adequate to the public space, the volume, and dimensions, the speed, the tour type and the displacement form avoiding noise and visual disturbing. The new public space has to offer a safe shared space for humans and robots, or segregated lines for robots and other micromobility devices. Urban furniture and elements that limit free circulation should be considered in the integration phase.

- *Citizen well-being*. Understanding the robotic urban services as a solution that will offer greater sustainability to cities and citizens, where the use of public space doesn't have to disturb human well-being. Linked to the previous section, the introduction of a new disruptive technology can start with solutions of human robot cooperative tasks, where the human roles as the peer teammate one will be mandatory for human acceptance.

- *The accessibility system*. The new technologies are the instruments to improve the current situation for mobility and accessibility in the urban physics infrastructures

- *Physics infrastructures*. New recharging infrastructures for energy, check points, as handover places, and parking areas are needed. The building ground floor could create a new physical infrastructure for urban services' logistics. The future "robotic vehicles" circulating in roads and streets, and the future "robots' devices", circulating in pedestrian areas and sidewalks is analyzed through the conflict between the current situation and the future one, apart from the one that can be generated by the autonomy of the vehicle. In the second case, there is a clear conflict that could generate the segregation of lines to circulate.

- *Management systems*. Information and communication plans and protocols will be developed to manage the data obtained by the new technology system. The public entities at the city will regulate the amount of data captured for logistic and manage reasons looking for citizen security and privacy.

- *Urban Micro mobility*. The current micromobility solutions are the opening act for the future robotic urban services. Logistics and schedules solutions could give feasibility to the introduction, proposing mixed uses and shared infrastructures. The robots could be included in the current intermodal urban hubs and nodes or in a new one. Other accessibility devices specific for pedestrian areas as the personal robot mobility will match the needs of a specific city population as the elderly one.

The specifications required of urban design and urban settings, look for the formalization of the streets with a deep description of the urban platforms, checkpoints, streets' plan and section and urban furniture. The current platforms could be adequate or not to robot operation with specific characteristics for pedestrian areas and sidewalks. The streets should change their plan, elevation, and section, providing a feasibility introduction of the new technology. The urban design and the urban settings as pavements, with color or texture differentiation, signals, barriers, bollards and other elements has to be projected. The current urban furniture could be used to include new technological infrastructures. The accessibility for citizens and pedestrians should be safe and comfortable, with segregated, integrated or shared lanes. The characteristics of the urban platforms, the urban elements, the urban furniture, the green, and the pavements should be considered with adaptations and transformations of the public space as lower as possible, but suitable of changes and not creating limitations to the technological proposal.

Next research works will develop deeper the urban design and settings of this new HRI urban scenario.

4. The robotic last mile delivery in urban public space with ONA robot

Once the methodology and the process development are introduced, the analysis starts through the case study selected: The Robotic last mile delivery in urban public space with ONA robot.

Last mile goods delivery refers to the trip between the last distribution centre run by the carrier and the final customer. It can be part of a business to business (B2B) or business to customer (B2C). The introduction of robotic technology for last mile distribution matches the challenge of the amount of goods to be delivered in metropolitan areas that will increase dramatically in the next few years (Bachofner et al., 2022) being at the service of the so-called new digital economy. Following the research process outlined above, we will begin with the description of the new technology to integrate, then the urban site and its characteristics and finally the cross analysis between them.

ONA robot (Fig. 2) is a ground robot with wheels that has a TRL 7. The volume is 1,2 m3 and has both autonomous and teleoperated navigation. It has the possibility to offer platoon navigation with more than one vehicle. The robot generates virtual models of their environment to avoid potential obstacles, and it is also connected to a general model of the mobility system of the urban centre. ONA robot transports goods to be delivered to customers.

Figure 2. ONA Robot for last mile goods delivery

Source: ONA Experiments in Barcelona Robotic Urban Lab. UPC. Campus Nord.

The reason to select this case of study is that several experiments had been done with Ona robot, some of them in Esplugues del Llobregat, located in the province of Barcelona (Spain), where autonomous robot platforms had to distribute goods. During the experiments, interviews, and surveys were recorded from users, citizens and other roles involved in the scenario with more than 100 of participants (Puig-Pey, 2023). In addition to the experiments, in 2022, a case study based on ONA robot for last mile goods delivery, was launched for the students of the last year in Architectural and Urban design degree (ETSAV) that offered good work for the analysis proposed. The information obtained in these activities will be used along the process as inputs of the research.

Experiments with ONA robot: Three surveys were done during real experimentation with ONA robot in urban environments, including an experiment in Can Vidalet site, that were introduced as a new input for the discussion. These empirical activities (Table 3), consisted first, in the preparation of a questionnaire in which a set of questions were posed to citizens, users and urban workers. The answers were prepared with a rating from 1 to 7, with 1 being the minimum level (of comfort, naturalness, ease, or agreement to the question) and 7 the highest level. Once the questionnaire was prepared, the surveys were made with the main objective to analyse the integration of robots in the last-mile goods distribution in the urban public space.

The first one was done during the experimentation at the UPC Barcelona Urban Robot Lab in March 2022, and 21 people participated. The second one was done during the experimentation in the urban pedestrian area of Esplugues del Llobregat, Barcelona in June 2022 and 24 people participated. Finally, the third one was an on-line survey with 60 participants. The questionnaire to peer end users and bystanders was structured by person ages. Besides the questionnaires, we interviewed the participants and researchers that assumed several HRI human roles during the experimentation. The analysis and the results of these experiments were published previously (Puig-Pey et al., 2023) in the article Human acceptance in the Human-Robot Interaction scenario for last-mile goods delivery, mentioned before.

Table 3. Experiments with ONA robot. Results of the survey to peer end users and bystanders

ROBOTIC LAST MILE DELIVERY IN URBAN PUBLIC SPACE	PEER END USER & BYSTANDER (ages)			
	<20	21-40	41-60	>60
THE URBAN MORPHOLOGY				
To what degree do you consider that the urban public space is prepared for a comfortable coexistence of citizens with distribution robots?	3,23	3,12	2,45	1,83
To what degree would you accept the presence of a home distribution robot in the public space?	5,86	5,45	5,10	3,00
In which of the following scenarios would the use of a delivery robot fit you best?				
University campus (public controlled space)	5,76	5,20	4,68	5,25
Industrial area (private controlled space)	6,55	5,26	5,03	6,17
City center (high population density)	3,52	3,37	2,71	2,50
Residential area (low population density)	4,95	4,83	3,71	3,58
THE CITIZENS' LIFE AND THE URBAN ACTIVITIES				
To what degree has sharing the public "sidewalk" space with a distribution robot generated insecurity?	6,17	4,59	3,00	2,63
To what degree has sharing the public space of the "square" space with a distribution robot generated insecurity to you?	1,50	2,78	3,38	5,00
To what degree have the activities of home distribution robots made it difficult to carry out other urban activities in this scenario?	3,50	3,81	4,33	4,08
To what extent do you think the level of noise generated by the robot's activity in public spaces could be annoying in the future?	3,17	2,48	1,75	2,67
To what degree do you think the activity of the distribution robot can be visually disturbing?	2,50	3,04	1,25	3,67
THE ACCESSIBILITY				
To what degree would you agree to segregate part of the urban public space to dedicate it exclusively to the traffic of distribution robots?	3,40	4,95	5,75	3,13
Would you accept the robot to navigate freely through public space (as opposed to segregating or signaling the area of its path?	5,50	5,48	5,88	2,78
To what degree would you prefer that the activities carried out by the distribution robot be limited to pre-programmed activities?	4,55	4,64	5,73	4,42
To what degree would you prefer that the activities carried out by the home distribution robot be limited to nocturnal?	3,47	4,00	4,97	2,58
THE ROBOTIC TECHNOLOGY				
To what degree do you consider that the design of the robot generate insecurity? Because:	4,82	4,70	4,71	2,50
Volume and dimensions	3,59	3,69	2,68	4,58
Speed	2,00	3,52	2,39	4,58
Tour type	2,41	3,34	2,86	4,64
Displacement form	2,29	3,33	2,41	4,33
To what degree would you prefer that the new support infrastructures (e.g. charging points and sensors) be integrated into the urban furniture?	5,24	5,88	5,97	4,00
To what degree would you see positive that an operator accompanied physically the robot?	2,95	3,88	4,27	4,83
How would you assess the robot collecting the waste (packaging, containers) generated by the distribution activity on its return trip?	6,60	6,39	6,88	6,00

Source: Puig-Pey et al. (2023).

The subject taught in ETSAV. In addition to the experiments, in 2022, a case study based on ONA robot for last mile goods delivery, was launched in the subject, Robotics in the city. An opportunity to redesign the urban public space. The subject was taught from September to December 2022 during 11 on site sessions, where the students of the last year in Architectural and Urban design degree (ETSAV), developed the diagnosis of 4 quarters of the site of Esplugues de Llobregat, Spain, analysing the feasibility of the introduction of ONA robot and proposing urban solutions and designs for the integration of the new technology. The case study that we present here is the work done in the Can Vidalet area by the group formed by the students Ines Miranda Lopes, Berta Muntean Albarran and Nerea Villaroya Pérez. At the beginning of the course, the students that made the study visited Can Vidalet quarter. Their analysis and proposals are included in the second and third steps of the process.

4.1. Step 1. Elaboration of the RUS Template for Last Mile delivery with ONA Robot

This subsection proposes the elaboration of the RUS Template for The Robotic Last Mile Delivery in Urban Public Space with ONA Robot.

The analysis consists of a theoretical framework enriched with empirical data, as outlined in subsection 3.1. This includes feedback obtained from surveys and interviews conducted with citizens, users, and urban workers during real-world experimentation. Key findings are summarized below:

- Participants emphasized that the robot's design and features should prioritize safety to mitigate potential risks.
- The robot's navigation system must be adapted to coexist safely with pedestrians, bicycles, pets, and other urban elements.
- Citizens responded positively to the robot's volume, dimensions, speed, and route type during testing.
- The robot's movement functioned well on roads and in wide, clearly marked pedestrian areas.
- Urban social conventions should be integrated into the robot's interaction protocol.
- The robot should operate autonomously and use visual (lights) and auditory (sounds) signals when in motion.
- The technological solution should incorporate sustainable practices, particularly in energy efficiency and waste management.

The template for Robotic Last Mile Delivery in Urban Public Space, with ONA Robot, was elaborated and discussed. The results can be seen in Table 4.

Table 4. Robotic Last Mile Delivery in Urban Public Space with ONA Robot

ROBOTIC LAST MILE DELIVERY SCENARIO WITH ONA ROBOT		
The infrastructures requirements for ONA deployment are an urban network of cameras to know the situation of the environment; a Wi-Fi network throughout the environment to work; parking areas for unload the goods to end users and a network of charging stations. The robot is also connected to a general model of the mobility system of the urban center so that their route can be optimized and the travel time reduced. Because of its autonomy, journeys can be programmed in advance and the delivery times can be made more flexible to reduce the congestion that currently occurs at rush hour.		
Type of Robot	Ground robot with wheels. 1,2 m3 / Platoons. TRL 7	
Navigation	Autonomous and Teleoperated. The robot generates virtual models of their environment to avoid potential obstacles and they are also connected to a general model of the mobility system of the urban center	
Transporting	Goods	
Communication	V2P – V2I – V2C – V2V	
Interfaces	Screen- Tablet	
Cloud Services	YES	
Robotic Operational Procedure, Activities and HRI Tasks		
The robotic operational procedure starts from a logistic operator to an urban HUB, a retail or a van, to the final customer. A central office program the robots' trial. An infrastructure of delivery hubs is created into existing parking zones or ground commercial premises; the merchandise arrives to the hub already structured. From the distribution hub, the goods are loaded directly in the robots by humans or automatically. Each individual robot makes the delivery to commerce or to customer. Moreover, the robot is able not only to deliver the goods, but also to pick up the package waste and bring to the trash. The robots navigate autonomously from the Hub to the customer through the public space. During the trial, a tele operator controls the mission and perform the activity.		

To be continued

Table 4. Robotic Last Mile Delivery in Urban Public Space with ONA Robot (continue)

ACTIVITIES AND HRI TASKS	LOGISTICS & TRIALS PROGRAM	LOADING THE VEHICLE	TELE-OPERATING	UNLOAD-HANDOVER	HARD & SOFT MAINTEIN.	SUPERVISION
NAVIGATION	Move the robot from A to B determining where the robot is, where it needs to be, how it should get there and how to deal with urban and environmental factors and contingences encountered on the way.					
PERCEPTION	Perceive and understand the environment for the specific activities to be done, stablishing a context through sensors and interpreting data within this context.					
MANAGEMENT	Coordinate and manage the actions of humans and robots, acting independently or in groups allocating and deploying resources to guarantee appropriate coverage. It also includes to assess availability, understanding capabilities, team coordination, monitoring, recognizing problems and intervention. The robot and the interface designs should facilitate the HRI.					
MANIPULATION	Integrate prehensile motions, as handover task, harmonizing software and hardware and describing what is has to be analyzed, how it has to be done and executed and verifies the outcome including informed requests for the human help.					
SOCIAL	Recognize and model users, understand social communication and norms models and acquire / exhibit social competences: Interaction characteristics - Persuasiveness - Trust – Engagement – Compliance. For human acceptation it is mandatory to stablish a friendly, functional and intuitive interface. The robot design is key for HRI success.					
DATA MANAG.	We assist to the globalization of the data. The cloud services will be necessary for almost all the activities performed by humans and for those performed by humans and robots. Services in the cloud will mandatory in robotized scenarios					
ROBOTIC LAST MILE DELIVERY SCENARIO WITH ONA ROBOT (continued)						
Human Robot Interaction ROLES in Robotized Scenario						
THE EXPERT AND TECHNICAL SUPERVISOR	This human role is located in a logistic center, out of the urban space environment, but he has an overview of all the processes that will be developed, the characteristics of the urban morphology, streets and roads and pedestrian areas. The supervisor has competences in robotic technology to optimize the urban service and logistic instruments to match the service proposal.					
OPERATOR	The operator should be a skilled agent that can teleoperate the robot from a remote site, in case it is needed. The accessibility system, the knowledge about the physics infrastructures and the management ones are necessary for a successful operation. Moreover, the operator manages the alarms and solves the navigation or delivery in difficult cases. In complex urban environments, the operator must be able to orient the robot within the urban environment in a semi-autonomous plan. The operator needs fully connectivity with the robot and with the environment sensors to manage the robot and can also interact with the bystanders and customers.					
MECHANIC	This human role always exists in all the robotic scenarios. The maintenance and repair tasks of software and hardware must be done in specific assigned areas, in a robotic workshop or in the manufacturer site. The mechanization of the mobility requires refuge zones for these new devices.					
PEER TEAMMATE	This role could do cooperative tasks as for example, loading the robot, guiding and accompanying the robot, doing handover tasks or recovering the robot in case of a problem. The peer teammate has to know the urban public space activities and uses and has to be situated near the delivery routes.					
PEER END USER	This is the customer that receives the goods. The accessibility system will allow the customer to receive the goods in delivery urban points, for example urban docks; directly from the robot in delivery and parking areas or in the customer location. We consider a specific design of the public space for a successful delivery, but other solutions should help the delivery to vulnerable groups as elderly.					
BYSTANDER	The bystander role is assumed by the citizens that co-exists in the same environment of the robot. The robot has to be aware of the type of citizens that could meet and its social life and activities developed in the public space. It could also interact with people following the social norms, be aware of them and use communication methods and signs that people can see, hear and understand.					

Source: Own elaboration.

4.2. Step 2. Analysis of the Urban Planning and Design of Can Vidalet for the integration of Robotic Last Mile Delivery Service

After Step 1, where information about the new technology was gathered and analyzed, Step 2 focuses on understanding the urban context of the Can Vidalet area.

The work done in the Can Vidalet area by the group of students includes the site analysis, the current urban morphology, the uses, and activities, the citizens' social life, the accessibility and the current formalization of the urban design, as it is explained in subsection 3.2., developing the theoretical analysis and including the empirical evidences from the interviews and surveys. The diagnosis of the urban structure includes the urban scenes and its characteristics, the analysis of the current urban platforms, borders, and exchange or guard points as bus stops to consider for the future integration. In Table 5 the characteristics of the site are analyzed and discussed looking for the opportunities and the constraints for the Robotic Last Mile Delivery Service integration in Can Vidalet.

The data obtained realize that the current public space is not prepared for a comfortable coexistence of citizens with distribution robots, but the presence of robots is welcome. The crowded zones as the city centre are conflictive for the integration, but the solution could arrive with day and night schedules.

The free navigation of robots is acceptable in the site where the experiment was launch. A new finding about the solution of "signaling the area of its path" with a laser light support this matter. The question about the segregation of exclusive lines doesn't give a clear answer about the preferences. It could be because the public space is scarce depending on which places, and citizens don't want to lose it compartmentalizing with lines.

Table 5. Urban analysis of Can Vidalet for the feasibility of Robotic Last Mile Delivery integration

<table>
<tr><th>URB-HRI SERVICES</th><th>THE ROBOTS</th><th>THE OPERATION PROCEDURE</th><th>THE HRI ROLES</th><th>OBSERVATIONS</th></tr>
<tr><td colspan="5">THE URBAN PLANNING AND DESIGN</td></tr>
<tr><td colspan="5">The urban morphology</td></tr>
<tr><td>Density</td><td colspan="3" rowspan="2">Opportunity</td><td rowspan="2">In the ONA Case Study, Can Vidalet offers an opportunity for the deployment of robotic goods delivery because its standard residential area with a population of 25,000 inhabitants and a density of 42,468 inhabitants/km²(approx.).</td></tr>
<tr><td>Compactness</td></tr>
<tr><td>Building typology</td><td>Neutral</td><td>Opportunity</td><td>Neutral</td><td>The collective housing with premises in the ground floor of buildings could be used for the operational procedure.</td></tr>
<tr><td>Streets and roads</td><td colspan="2">Constrain</td><td>Neutral</td><td>Can Vidalet is a neighborhood that has large differences in street typologies and public spaces. The streets inherently in Can Vidalet are asymmetrical, narrow streets in the inner area and a consolidated and dense neighborhood without flexibility. ONA is too big for some streets</td></tr>
<tr><td>Sidewalks and pedestrian</td><td colspan="3">Constrain</td><td>Lack of parking spaces, complex topography, and vandalism. ONA can navigate in roads but not in sidewalks</td></tr>
<tr><td colspan="5">The uses and activities</td></tr>
<tr><td>Residential areas</td><td colspan="2">Opportunity</td><td>Neutral</td><td>The robotic last-mile distribution is well accepted in urban public space, preferably in low-density areas. In Can Vidalet there are different urban scenes, residential with commercial premises in ground floor, multi-family housing blocks and single-family residential areas.</td></tr>
<tr><td>The urban services</td><td colspan="3">Opportunity</td><td>The tasks carried out by other agents in the public space have not been altered by the delivery robot.</td></tr>
<tr><td colspan="5">The citizens social life</td></tr>
<tr><td>The citizens' activities</td><td colspan="2">Constrain</td><td>Neutral</td><td>The delivery robot must not cause noise or visual pollution in its circulation through the public space.</td></tr>
<tr><td>Intensity of use</td><td colspan="3">Constrain</td><td>The robots are addressed to deliver for two types of customer profile: commercial users and domestic users.</td></tr>
<tr><td>Population Ages</td><td colspan="2" rowspan="2">Constrain</td><td rowspan="2">Opportunity</td><td rowspan="2">The great number of inhabitants that the service can supply, specifically a high quantity of elderly people. ONA and its delivery should be friendlier.</td></tr>
<tr><td>Vulnerable groups</td></tr>
<tr><td>Citizen safety + privacy+well-being</td><td>Constrain</td><td></td><td></td><td>The distribution robot has not generated insecurity for passers-by in free navigation. Elderly people may not agree due to their lack of mobility, so it is necessary to consider the distances and interaction with bystanders.</td></tr>
<tr><td colspan="5">The accessibility system</td></tr>
<tr><td>Physics infrastructures</td><td colspan="2">Constrain</td><td>Neutral</td><td>It doesn't' exist micromobility infrastructures in Can Vidalet. It is necessary an urban network of cameras to know the situation of the environment; a Wi-Fi network throughout the environment to work; parking areas for unloading the goods to end users and a network of charging stations.</td></tr>
<tr><td>Management systems</td><td>Neutral</td><td colspan="2">Opportunity</td><td>Logistics hubs in buildings' ground floor for Operational Procedure, management systems, charging premises, maintenance, etc.</td></tr>
<tr><td>Urban Micro mobility</td><td>Opportunity</td><td>Constrain</td><td>Neutral</td><td>Electrical bikes and scooters exist in Can Vidalet.</td></tr>
<tr><td>Urban platforms</td><td>Constrain</td><td>Neutral</td><td>Neutral</td><td>The current public space is not fully prepared to integrate this new technology and should be adapted. The new urban plan and section design to integrate the new technology should be asymmetrical, as the current streets are.</td></tr>
<tr><td>The urban furniture elements</td><td colspan="3">Opportunity</td><td>The existing urban furniture could be the base for the new robotic infrastructures.</td></tr>
<tr><td>The pavement</td><td>Constrain</td><td>Neutral</td><td>Neutral</td><td>New accessibility solutions.</td></tr>
</table>

Source: Own elaboration.

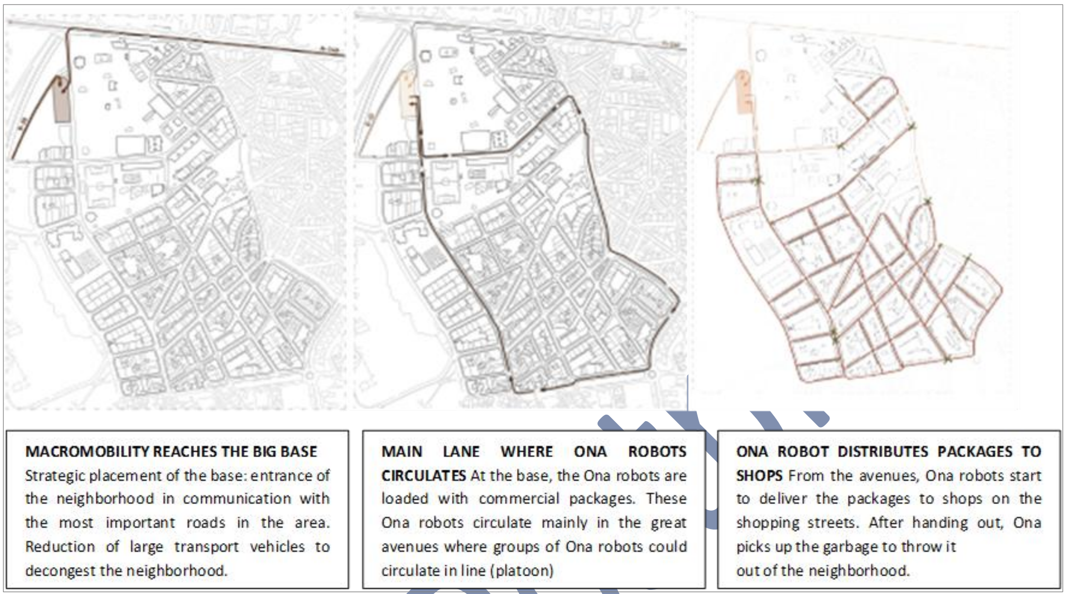
4.3. Step 3. Discussion about the relationships and constraints

Once the urban diagnosis has been done, the discussion step – introduced in subsection 3.3 – starts. In this last step, all the teams involved in the previous steps will participate.

The urban morphology.

- The proposal raises the introduction of a specific logistic and operational procedure through the combination of different types of robots. The reason is that the morphology of Can Vidalet (Fig. 3) doesn't' allow the delivery with ONA robot in all the streets and roads. The proposal includes day and night schedule.

Figure 3. Can Vidalet. Streets distribution proposal



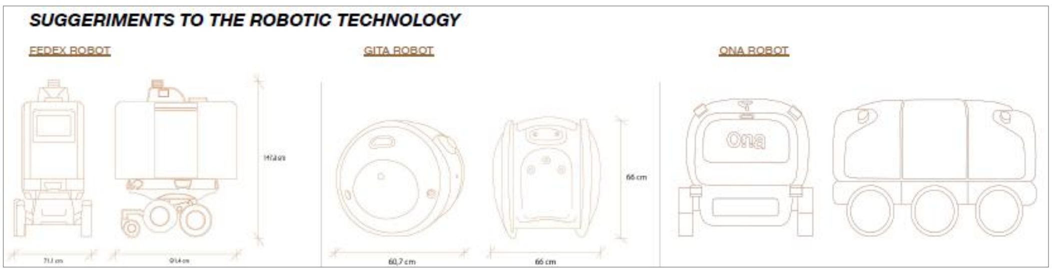
Source: Miranda, et al. (2022).

- The distribution to commercial users is made with the robot ONA. A van departs from their distribution center (near the highway) and carries ONA robots to the beginning of their route. This route is made in the early morning (Fig. 5).

- But the domestic distribution should be done with smaller robots as Fedex one (Fig. 5). The robots depart from their distribution center (in the center of Can Vidalet, in a ground floor premise) and each robot covers four blocks. These robots can deliver things from stores or pick-up points.

- On the other hand, it is optionally proposed to residents' users to opt for a smaller robot, the Gita robot (Fig. 4), that is entirely for private use and circulates on the sidewalks.

Figure 4. Three different types of autonomous robotic platforms for Can Vidalet Last Mile Distribution



Source: Miranda, et al. (2022).

Fedex Robot
Type of displacement: Terrestrial locomotion on any type of grounds. Displacement without direct human support. Can climb sidewalks and steps
Storage unit: The handling of the load is done by the order received. Transfer of goods, tools and objects from the loading locker is done laterally (lateral panel)

Circulation: Circulation on the lane created for this propose. Stop in the meeting points.
Technical specifications: The weight is 91 Kg and can carry a payload of 45 kg. The maximum speed is 16 Km/h.

Gita Robot
Type of displacement: Terrestrial locomotion on any pavement. Displacement with direct human support.
Storage unit: The handling of the load is done by the order received. Transfer of goods, tools and objects from the loading locker are from the top
Circulation: It follows the owner at the walking pace
Technical specifications: It can assume a volume of 33 liters and can carry 20 kg. Battery life: 8 hours of use. Top speed of 35 Km/h.

Ona Robot
Type of displacement: Terrestrial locomotion on paved road. Displacement without human support.
Storage unit: The handling of the load is done by the order received. Transfer of goods, tools and objects from the loading locker are done laterally
Circulation: Circulation on roads for vehicles. It stops in places used for motor vehicles.
Technical specifications: Ona's dimensions occupy a volume of 1,2 m3. The maximum movement speed is 20 Km/h. Maximum package: 30-40 kg.

Streets and roads.

- In order to reduce the mobility impact in the city due to the use of these delivery robots, the street parking for vehicles has to be removed during some hours, offering a line to the Fedex robot to circulate and deliver the packages to the neighbors without obstacles. Gita robot navigate on the sidewalks (Fig. 5)

The citizens' social life.

- The new HRI scenario should include the information and the presentation of it in an appropriate form – signposted ways, signals, physical posters.

Figure 5. Can Vidalet. Street sections proposal

Source: Miranda et al. (2022).

Intensity of use.

- We will need more dependence on the Operator and Teammate HRI roles, depending on the intensity of use.

Population Ages - Vulnerable groups - Individual to collective.

- It is optionally proposed to vulnerable groups of residents' users to opt for a smaller robot, the Gita robot. This is entirely for private use. It circulates on the sidewalks.

The accessibility system.

- Streets and urban zones must be analyzed and redesigned. Small robots could share pedestrian pavements with people, but it is preferable to avoid crowded zones. In open areas, it is not necessary to segregate a specific road, because the technology should be developed and natural to live together with humans. For the operator role, it is preferable to include the robot in the road, linked to autonomous vehicles than in the sidewalk, linked to bicycles and scooters.

Physics infrastructures.

- In order to apply our robots to reduce the impact of change in the city, we have to remove - for some hours - the street parking.
- Checkpoints: parking, refuge, bus stop for interchange. The loading and unloading zones and the points where robots deliver packages to customers should be an example of flexibility of use. The Bus stop could be a place for the meeting point where robots and customers meet. The robots can share parking areas with other vehicles to give more flexibility to the solution.

Management systems.

- The operational procedure of the last mile delivery in this area has the next approach: The ONA robot goes through the causeway. Its meeting points are in the loading and unloading zone of the street so the packages are delivered there (traders take the packages). When the robot has to return, it picks up the trash as well. It would be necessary for a person to help ONA putting the trash inside and changing the interior bag to a bag suitable to trash. The section design of the inner streets is asymmetrical using the lane of the car park to design a specific lane for the robots, solving the not continuity with the car park.

The urban design

- The existing urban furniture could be the base for the new robotic infrastructures: for parking, for delivery tasks. The urbanization should be a smooth, and rolling urbanization. Pavements (differencing platforms), boundaries and signage: Fedex and Gita (Fig.6) circulate in the sidewalk, whereas ONA Robot circulates in the road. To mark the limits of the lane of the robot, we should paint it and uses signs that communicates the neighbors that are not allowed to park. We will need new urban elements: Signaling: pavement, colors, texture, signs, bollards. Bollards to close and regulate the robot lane; a smaller obelisk to serve to signal the meeting point location.

With all these considerations, the consensus about the feasibility of the integration of the robotic last mile delivery in the public space of Can Vidalet, could be raised. The characteristics and requirements of the urban robotic service and the changes in the plan and design of the public space, should be recorded and a brief about both matters should be elaborated for future public procurement and tenders.

5. Conclusions

The research developed in this work aims to initiate a way of linking the incorporation of new technologies, specifically robotic technology, in the cities. The robotic technology should be adequate to the urban context where it has to be implemented. The urban context is complex and very varied. Robotic researchers should consider the characteristics of the urban context and the robotic scenario where the robotic urban service will be deployed.

The methodological proposal structures a new process and applied it to a case study, allowing a big group of stakeholders to approach a complex issue in different steps looking to reach conclusions and consensus.

Along the first step of the process, the HRI Template introduced in previous research works, has been improved to the RUS Template, incorporating the characteristics of a specific urban robotic service to the robotic scenario. The list of urban aspects considered in the second step of the process, the opportunities and the constraints detected for the integration is intended to be a guide not limited but exhaustive.

Throughout steps 1 and 2 of the process, discussions arise between the specific agents of each discipline, robotics and urban, it is in the third step, where consensus is sought between both about what technology is suitable to develop the urban robotic service and what changes must be made in the public space to be able to integrate it. To correctly address the problem and reach a true consensus, the preliminary steps are mandatory.

The HRI role of robotic set designer appears, being considered essential for a correct development of the analysis process. In the case presented in this work, this new role includes architectural and urban design competences and incorporates robotic technology knowledge and coordination tasks with soft skills.

The empirical data used in this work were previously recorded. If it is not the case, it is mandatory to obtain them through interviews, surveys, qualitative and quantitative. In our case study, the data recorder from the group of students, match some criteria proposed in the theorist analysis but ignore some others. The reason could be that urban planning studies are not including new competences in these disruptive technologies in their degree studies but in the postgraduate ones. Future research articles in education could help to update the academic curriculum to better answer these new challenges.

After the development of the last step, public entities can tender with an exhaustive document of characteristics and requirements and receive offers from both, the robotic urban service' companies, and the urban planning and design' projects, that must be implemented in the public space. This introduction must be accompanied by the necessary regulations and standards that allow the citizen to be safe, healthy and, comfortable.

As we have seen in the case study analyzed, the robotic urban service perfectly responds to the need for predictability and routine activities, creating order and discipline in the public space, in front of the sometimes chaotic and insecure accessibility and mobility for citizens and pedestrians in urban areas.

Next works, pointed out in this article, will focus on the formalization of the urban design proposals and urban settings with the objective of a successful integration and implementation of robotic urban services in the urban public space.

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7. Authors

Author 1, conceptualized and designed the research, analyse both de data from urban knowledge and robotic technology and wrote the paper; Author 2, designed the use case and coordinated the urban analysis; Author 3, contributed to the development of the case study; Author 4, conceptualized and coordinated the research.

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