Human acceptance in the Human-Robot Interaction scenario for last-mile goods delivery

A. Puig-Pey [1], J.Ll. Zamora [2], B. Amante [3], J. Moreno [4], A. Garrell [1], A. Grau [5], Y. Bolea [5], A. Santamaria [1], A. Sanfeliu [1]

***Abstract*— The introduction of robotic technology in an existing scenario must be analyzed from the point of view of all the human roles involved in that scenario. In the case of dealing with urban public space, the analysis must consider a large group of citizens who carry out different activities on it. The purpose of this article is to analyze the human roles and the human acceptance when the robotic technology is introduced in the last mile distribution of goods in urban areas. In this work, we start with the description of the Human-Robot Interaction (HRI) scenario for last mile goods delivery, we describe the human roles and we propose a set of relevant indicators to evaluate the human acceptance for this task. Finally, we evaluate the human acceptance through qualitative interviews and quantitative surveys. The study has been done for the peer end-users and bystanders human roles and around 100 people participated.**

I. Introduction

The new technologies are transforming the cities, and their impact in the citizens has to be evaluated. The reduction of pollution, the transformation of the city's mobility, the search for sustainable ecosystems or the aging of the population will encourage the use of collaborative robots in cities, and especially in proximity environments. The introduction of this disruptive technology will impact in the city and the citizens improving their efficiency, well-being, comfortability and sustainability.

In this article, we describe the scenario and the human roles involved on it, and we analyze the human acceptance of the robotic last mile goods delivery activity in the urban public space. To do this work, we have defined a new Human-Robot Interaction (HRI) scenario, denominated Last Mile Goods Delivery, and we have created a study case using the TERRINet HRI Template [1]. From this study, we have obtained the operational procedures required in this scenario and the human roles that are involved on it. Moreover, we propose to use nine topics to evaluate the human roles' acceptance for a collaborative robotic technology introduced in an urban space. The case study have been done with the ONA robot in two urban spaces, Fig.1, and we have evaluated the human's acceptance doing interviews and asking end-users and bystanders that were close to experimentation site.

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The affiliation of authors is: [1] IRI (CSIC-UPC) Barcelona, Spain, [2] with ETSAV, UPC, Barcelona, Spain, [3] with UPC EPC, Terrassa, Spain, [4] with ETSAB, UPC, Barcelona, Spain, [5] with ETSEIB, UPC, Barcelona, Spain

The contributions of this analysis are situated in the sphere of social acceptance and requires a multidisciplinary approach including a qualitative analysis with rounds of discussion and interviews with the different stakeholders involved. We consider that this kind of analysis should be done in the first phases of the research with low Technology Readiness Level (TRL), looking for the human needs and challenges that drive the technological innovation [2].

The work scheme of this article is the following. Section II presents a brief survey of the related works about the introduction of robotic technology in human based scenarios. Section III presents the new HRI scenario centered in the ONA study case, the new operational procedure for last mile delivery and the human roles that participate on it. Section IV proposes the list of indicators to analyze the human acceptance of the new technology and Section V explains the results of the questionnaires and interviews done in real experimentation. Finally, section VI describes the conclusions and contributions of the research.

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II. Related work

The amount of goods to be delivered in metropolitan areas will increase dramatically in the next few years. Many autonomous delivery robot technologies are emerging at the moment - NURO, Starship, UDelv, Alibaba, Clevon1 – and some of them will be commercially available soon. Robotic researchers have developed new methods where robots and humans collaborate for specific transportation and delivery tasks; in some cases, developing new robust and safe algorithms for perception and navigation; robot-human interaction techniques that are more intuitive, fast and robust; designing joint robot-human side-by-side transportation of a package or designing joint robot human goods handover delivery [3]. In addition to the motivation of the researchers and their ability to offer solutions, the market is asking for changes to improve the current situation, the public entities want to introduce more sustainability in urban public spaces and the citizens look to improve their well-being wondering about the implication of robotic solutions in their life.

Three articles have been the starting point for the elaboration of the human acceptance list of indicators. The first one, "Robots in public spaces: implications for policy design" [4], proposes a group of seven topics for policy designers to validate the new robotic solutions: safety, privacy and ethics, productivity, aesthetics, co-creation, equitable access and system innovation. The second article, ”Interaction scenarios for HRI in public space” [5], which presents some of the results of the IURO project, focus on the person based scenarios and what, where, how and when should be introduced the robotic technology. And finally, the article “Evaluation Methods for human-system performance of Intelligent Systems” [6], focused in the interaction and collaboration of a human robot team. All three were analyzed in several rounds by different actors, robotic teams, urban planners, logistic agents and end-users, using a research methodology characterized by the analysis of the problem in its own context [7], where the concepts are at the same time the inputs and outputs of the research. The conclusions of these rounds were a list of indicators for human acceptance analysis, structured by the categories of human roles that interact in a HRI scenario.

Other research works have been of interest of this article, as the new Robot City Interaction discipline [8], focused on the dimensions that characterize the interactions between autonomous agents (robots) and the land, the citizens, the government and the technologies; or the work ”Common metrics of human robot interaction” of Steinfeld et al. [9], that analyze metrics in social space, robot proximity and permitted actions. These works are more suitable for planning and design of the new urban public space in future analysis.

III. The HRI scenario for Last mile goods delivery in urban public space. The ONA study case

The methodology proposed for the analysis starts with the elaboration of the TERRINet HRI Template [1] for the Last mile delivery scenario in urban public spaces. It includes the analysis of the transformation of an operative scenario into a robotic one and the human roles involved on it.

The case study that served for the human acceptance study and the experimentation, were done using the ONA last mile delivery platform, a robot designed by CARNET (Fundacio Centre d’Innovacio i Tecnologia de la UPC), ID-MIND company and IRI (Institut de Robòtica i Informàtica Industrial (CSIC-UPC)). The experiments were done in the Campus Nord of the UPC and in the city Esplugues del Llobregat (Barcelona, Spain), under the research projects ROCOTRANPS and LogiSmile.

A. The HRI scenario: the ONA Robot and the new operational procedure

Last mile goods delivery refers to the trip to transport goods from the distribution center to the final customer. It can be part of a business to business (B2B) or business to customer (B2C), [10]. The HRI scenario template was prepared with the robotic platform ONA, which is a small platform that weights around 200kg and is roughly 1,8m x 1,1m x 1m with the outer shell. It can carry several parcels

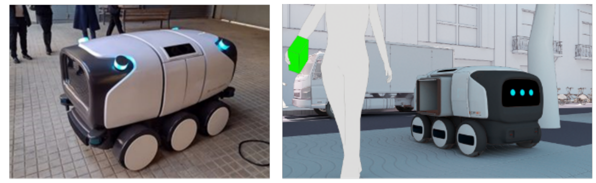
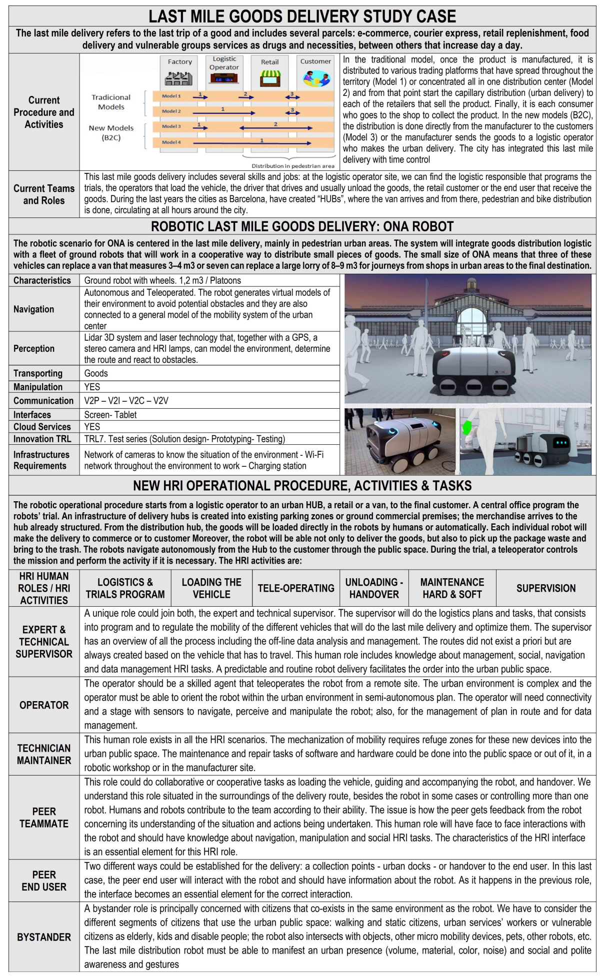


Fig. 1: ONA Robot



LAST MILE GOODS DELIVERY STUDY CASE	
The last mile delivery refers to the last trip of a good and includes several parcels: e-commerce, courier express, retail replenishment, food delivery and vulnerable groups services as drugs and necessities, between others that increase day a day.	
Current Procedure and Activities	Factory / Logistic Operator / Retail / Customer; Tradicional Models: Model 1, Model 2; New Models (B2C): Model 3, Model 4; Distribution in pedestrian area. In the traditional model, once the product is manufactured, it is distributed to various trading platforms that have spread throughout the territory (Model 1) or concentrated all in one distribution center (Model 2) and from that point start the capillary distribution (urban delivery) to each of the retailers that sell the product. Finally, it is each consumer who goes to the shop to collect the product. In the new models (B2C), the distribution is done directly from the manufacturer to the customers (Model 3) or the manufacturer sends the goods to a logistic operator who makes the urban delivery. The city has integrated this last mile delivery with time control
Current Teams and Roles	This last mile goods delivery includes several skills and jobs: at the logistic operator site, we can find the logistic responsible that programs the trials, the operators that load the vehicle, the driver that drives and usually unload the goods, the retail customer or the end user that receive the goods. During the last years the cities as Barcelona, have created “HUBs”, where the van arrives and from there, pedestrian and bike distribution is done, circulating at all hours around the city.

ROBOTIC LAST MILE GOODS DELIVERY: ONA ROBOT	
The robotic scenario for ONA is centered in the last mile delivery, mainly in pedestrian urban areas. The system will integrate goods distribution logistic with a fleet of ground robots that will work in a cooperative way to distribute small pieces of goods. The small size of ONA means that three of these vehicles can replace a van that measures 3–4 m3 or seven can replace a large lorry of 8–9 m3 for journeys from shops in urban areas to the final destination.	
Characteristics	Ground robot with wheels. 1,2 m3 / Platoons
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
Perception	Lidar 3D system and laser technology that, together with a GPS, a stereo camera and HRI lamps, can model the environment, determine the route and react to obstacles.
Transporting	Goods
Manipulation	YES
Communication	V2P – V2I – V2C – V2V
Interfaces	Screen- Tablet
Cloud Services	YES
Innovation TRL	TRL7. Test series (Solution design- Prototyping- Testing)
Infrastructures Requirements	Network of cameras to know the situation of the environment - Wi-Fi network throughout the environment to work – Charging station

NEW HRI OPERATIONAL PROCEDURE, ACTIVITIES & 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 will be loaded directly in the robots by humans or automatically. Each individual robot will make the delivery to commerce or to customer Moreover, the robot will be 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 teleoperator controls the mission and perform the activity if it is necessary. The HRI activities are:

HRI HUMAN ROLES / HRI ACTIVITIES	LOGISTICS & TRIALS PROGRAM	LOADING THE VEHICLE	TELE-OPERATING	UNLOADING - HANDOVER	MAINTENANCE HARD & SOFT	SUPERVISION
EXPERT & TECHNICAL SUPERVISOR	A unique role could join both, the expert and technical supervisor. The supervisor will do the logistics plans and tasks, that consists into program and to regulate the mobility of the different vehicles that will do the last mile delivery and optimize them. The supervisor has an overview of all the process including the off-line data analysis and management. The routes did not exist a priori but are always created based on the vehicle that has to travel. This human role includes knowledge about management, social, navigation and data management HRI tasks. A predictable and routine robot delivery facilitates the order into the urban public space.					
OPERATOR	The operator should be a skilled agent that teleoperates the robot from a remote site. The urban environment is complex and the operator must be able to orient the robot within the urban environment in semi-autonomous plan. The operator will need connectivity and a stage with sensors to navigate, perceive and manipulate the robot; also, for the management of plan in route and for data management.					
TECHNICIAN MAINTAINER	This human role exists in all the HRI scenarios. The mechanization of mobility requires refuge zones for these new devices into the urban public space. The maintenance and repair tasks of software and hardware could be done into the public space or out of it, in a robotic workshop or in the manufacturer site.					
PEER TEAMMATE	This role could do collaborative or cooperative tasks as loading the vehicle, guiding and accompanying the robot, and handover. We understand this role situated in the surroundings of the delivery route, besides the robot in some cases or controlling more than one robot. Humans and robots contribute to the team according to their ability. The issue is how the peer gets feedback from the robot concerning its understanding of the situation and actions being undertaken. This human role will have face to face interactions with the robot and should have knowledge about navigation, manipulation and social HRI tasks. The characteristics of the HRI interface is an essential element for this HRI role.					
PEER END USER	Two different ways could be established for the delivery: a collection points - urban docks - or handover to the end user. In this last case, the peer end user will interact with the robot and should have information about the robot. As it happens in the previous role, the interface becomes an essential element for the correct interaction.					
BYSTANDER	A bystander role is principally concerned with citizens that co-exists in the same environment as the robot. We have to consider the different segments of citizens that use the urban public space: walking and static citizens, urban services’ workers or vulnerable citizens as elderly, kids and disable people; the robot also intersects with objects, other micro mobility devices, pets, other robots, etc. The last mile distribution robot must be able to manifest an urban presence (volume, material, color, noise) and social and polite awareness and gestures					

Fig. 2: Template for Last Mile Delivery HRI scenario

which can be delivered to different customers. ONA is an electric vehicle with an autonomy of around 8 hours, Fig. 1.

The vehicle can navigate autonomously using different sensors: a 3D Lidar, GPS, stereo cameras and wheel odometry. It also includes HRI lamps to indicate to the bystanders, where the robot is going to move. ONA uses an autonomous navigation software developed by IRI, which can navigate in roads, pedestrian areas and sidewalks. The robot receives the optimal trajectory to reach the customers from a logistic platform developed by the company LMAD, and then plans its own trajectory to reach each of the customers. The summary of the operational procedures of this study case can be seen in Fig. 2.

The current operational procedure is done by humans and it requires the following job categories: the logistic responsible, that programs the trials to deliver the goods; an operator that load the vehicle; the driver that transport the goods and usually unload the goods; and the retail customer or the end user that receive the goods. The distribution in the pedestrian areas (including full pedestrian and sidewalks) is actually performed by humans using bikes, motorcycles, etc.

When it is used the new robotic technology, the robotic operational procedure is different. The system starts in the logistic operator, where the goods are loaded in the robot platforms and these robots are loaded in a van. Another possibility it is that the goods are directly load in the van. Then the van goes to an urban Hub for the distribution of the last mile. In the Hub, if the goods are in the van, then these are loaded in each of the distribution robots, or if the robots have already the payload, then the robots go down for immediate distribution. Finally, the robots get the delivery route from the logistic operator and navigate to the final costumers. When the robot has delivered all the goods, then it can load waste material to bring to the trashcans.

B. The human roles in the last mile delivery HRI scenario

Analyzing the different categories of human roles and HRI Tasks [1] that interact in a robotic scenario for last mile distribution, we find the following ones:

The Supervisors. A unique role could join both, the expert and technical supervisor. The supervisor organizes the logistics plans and tasks, optimizing the routes, the number of robots and the delivery of the goods. The supervisor has an overview of all the processes including the off line data analysis and management. The routes do not exist a priory, but they are automatically created to optimize the trajectories and the time to be delivered. This human role includes knowledge about management, social, navigation and data management HRI tasks. A predictable and routine delivery robot, facilitates the order in the urban public space.

The Operator. The operator should be a skilled agent that can teleoperate the robot from a remote site, in case it is needed. Moreover, the operator manage the alarms and solve 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 semi-autonomous plan. The operator needs fully connectivity with the robot and if possible with the environment sensors and it has an interface to receive the robot sensors information, robot navigation status and alarms. The operator has a full knowledge and expertise in HRI Tasks, can manage the robot and can also interact with the bystanders and costumers.

The Mechanic /Technician. This human role always exists in all the HRI 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 in the urban public space.

The 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 role has to be situated near the delivery routes, in order that it can actuate as soon as possible in the public space. In the special cases that human and robot has to cooperate in a specific task, for example, in the last phase of the delivery of goods where the robot can not reach the customer, then the peer teammate has to get feedback from the robot concerning its understanding of the situation and actions being undertaken. This human role should have knowledge about navigation, manipulation and social HRI tasks. The interaction between the robot and the Peer Teammate will be done through a communication interface, being this interface an essential element of a successful task.

Fig. 3: A new Human Robot Interaction Scenario

The Peer end-user. This is the costumer that receives the goods. The goods can be delivery in delivery urban points, for example urban docks, or delivery in customer location, where the customer pick up the parcel or the robot deliver the goods in a specific location. In the case that the customer pick up the parcel, the peer end-user will interact with the robot and should have information about the robot. As it happens in the previous role, the interface requires a specific study and design for the correct interaction.

The Bystanders. The bystander role is assumed by the citizens that co-exists in the same environment of the robot and they can fall in different categories: citizens in good health condition; vulnerable citizens as elderly, kids and disable people; urban services' workers; etc. The robot has to be aware of the type of citizens that could meet and also of pets, bikes, etc. It could also interact with people following the social norms, be aware of them and use communication methods and signs that people can understand, Fig. 3.

IV. The indicators to evaluate the human acceptance

The current stakeholders that use the urban public space must accept and tolerate the integration of a new agent – the robot - that occupies space, alters their routine and could generate visual, environmental or mental discomfort.

In order to integrate a robotic technology in the last mile delivery tasks, it has to be done a dissemination campaign and an explanation of the characteristics of the robots and its behavior and the human acceptance should be tested and checked. The social feedback could change the focus, design and development of the robotic solution or change the current taxonomy of the urban public space.

HRI ROLES / INDICATORS	SUPERVISOR	OPERATOR	MECHANIC	PEER TEAMMATE	PEER END USER	BYSTANDER
THE HRI SCENARIO						
EQITABLE ACCESS						
ESTHETICS						
CO-CREATION						
SUSTAINABILITY						
SAFETY						
PRIVACY AND ETHICS						
USER SATISFACTION						
WELL-BEING						

Fig. 4: The key indicators to evaluate human acceptance in HRI scenarios

Let us defined the key indicators for human acceptance in public spaces of the robotic last mile delivery of goods. In order to create this list, we have taken into account the works mentioned before, by Mintrom et al.[4], that propose seven inputs about the implications of robots in public spaces; Ferland et al.[5], prioritizing an analysis in the person based scenarios; and Shcoltz et al. [6], analyzing the aspects of the interaction and collaboration of a human robot team. Moreover, we analyzed these indicators with the different actors mentioned before, in a series of rounds and discussions. Finally, we selected the following key indicators, shown in Fig. 4, and presented below.

The HRI scenario. The information and the presentation of the new HRI scenario in an appropriate form should be done to the different human roles that will participate on it. Some urban areas will be better accepted than others due to their characteristics. The description of the new HRI activities should be done looking for a comprehensive knowledge and trustworthy of the human roles involved in [6]. The new robotic scenario should be designed giving rise to a new human role: *Robotic Set Designer*, which coordinates the multidisciplinary team that integrates the robotic technology in the current scenarios, creating the context where humans and robots will coexist.

Equitable Access. The transformation of the current scenario in a HRI one should give benefits to individuals and communities including vulnerable ones. The urban public space is now in the point of view of policy makers, looking to empower citizens in their use and governance. Positive discrimination for vulnerable groups in the development of the technology could be a good point for a successful introduction of a disruptive technology as the robotic one.

Esthetics. The current public space is not fully prepared to integrate this new technology and should be adapted. Streets and urban zones must be analyzed and redesigned. New infrastructures of sensors, cameras and energy charging system should be designed in the existing public space and integrated, or not, into the existing street furniture. The design should be safe, convenient and attractive for citizens and for all the human roles that interact on it.

Co-Creation. Robotic researchers and designers should understand and consider the human roles that interact with the robots considering that their presence and actions should be broadly acceptable to the communities where they will be deployed. With the previous analysis of the HRI scenario and the human roles, and rounds of discussion with different stakeholders involved in, the design and development of the technology can be made at responding to specific needs and challenges of our society.

Sustainability. The technological solution should include sustainable criteria in energy efficiency and waste management. The distribution robot must not cause noise or visual pollution in its circulation through the public space. The solution should be sustainable in short and long term.

Safety. The robot design and characteristics have to take into account safety design features in order to prevent potential risks and the robot navigation has to be adequate for pedestrians, bikes, pets, etc. The humans roles involved in should feel and be safe. The routine and predictable performance of robots in the public space can help to offer a greater order in the urban public space in the face of the current chaotic situation of micro-mobility devices.

Privacy and Ethics. The robots collect large amounts of information during their interactions with people and in the environment. A Data Management protocol about privacy and ethics should be included in any HRI scenario, considering the characteristics of human acceptance in urban public spaces.

User satisfaction. The interaction language and device should be friendly, understandable and efficient, both from the user and system perspective. The ”user experience” is driving the use of new technologies in existing tasks and activities. The new technology should be robust and meet human expectations.

Well-being. The robotic solution should be understood as positive, offering comfort, health and happiness to humans and not disturbing the current users of the scenario. The day or night performance could also help the integration. The technology should be aimed at providing support in those activities and tasks that involve the greatest effort, insecurity and unsafe, to the human. That is why it is important to carefully analyze the human roles that will interact in the new operational procedure and their specific needs for robotic assistance.

Finally, the concept of Evaluation methodologies for different roles proposed by Scholtz[6], has been used to structure the list of key indicators, including the HRI roles in columns [1] as it can be seen in Figure 4.

V. The experiments and the empiric validation

The empirical validation has consisted first, in the preparation of a questionnaire in which a set of questions were posed for each indicator, except for the indicators of equitable access, since we could not count on vulnerable participants, and Privacy and Ethics, since we did not have a Data Management protocol on which to base the questions. 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 (of comfort, naturalness, ease or agreement to the question).

Once the questionnaire was prepared, three surveys were made with the main objective to analyze 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, Fig. 5.

Besides the questionnaires, we interviewed the participants and researchers that assumed several HRI human roles during the experimentation.

Interview to a Technical Supervisor role. The interview was done with one robotic researcher in the role of technical supervisor with some knowledge about logistics. She agreed to the possibility to unify Expert (logistic) and Technical supervisor in the same role. From her point of view, the introduction of ONA robot could be easier in the public areas, controlled and with low population as the industrial, university campus and residential one. In city centers, ONA could be introduced in the road, but not in the pedestrian area. Small robots could shared pedestrian pavements with people, but is preferably to avoid crowded zones. In these areas, it is not necessary to segregate a specific road, because the technology should be enough developed and natural to live together with humans. From her point of view, the technology will need a full infrastructure integrated in the urban public space, but not necessarily in the current urban furniture. About the volume and dimensions, the speed and the tour type of ONA robot, her point of view was fully positive. Is not the same for the displacement form, that should be revised and improved as is the case for the necessary 360 degrees turns in navigation tasks or the urban social conventions to be included in the robot interaction protocol. The possibility to have the robot accompanied by an operator is dismissed. It could be necessary to have a peer team mate in the surroundings of the delivery area, giving support to various robots.

Interview to robotic operators. Three robotic operators have been interviewed. They consider that the robot is a prototype and it has to improve its technology in different aspects without requirement of human intervention looking for full autonomy. The motion of ONA is working well in roads or in wide and signposted pedestrian areas. The current public space is adequate for the robot navigation, but some obstacles as the beacons that separate road from sidewalk should be avoid. About where the robot should move, they prefer to include the robot in the road, linked to autonomous vehicles than in the sidewalk, linked to bicycles and scooters. The robot should be self-sufficient and it should sign with lights and sounds when it moves. They don't consider necessary urban infrastructures for re-charger or

HUMAN ROLES IN THE LAST MILE DELIVERY HRI SCENARIO IN URBAN PUBLIC SPACE	PEER END USER & BYSTANDER (ages)			
	<20	21-40	41-60	>60
THE HRC/HRI SCENARIO. INFORMATION PRESENCE AND PRESENTATION.				
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 an autonomous home 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
ESTHETICS				
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
To what degree would you prefer that the new support infrastructures (e.g. electrical charging points and sensors) be integrated into the public street furniture?	5,24	5,88	5,97	4,00
Would you accept the robot to navigate freely through public space (as opposed to segregating or signaling the area of its path? (In this case, the robot could signal the direction of its movement by an integrated laser)	5,50	5,48	5,88	2,78
CO-CREATION				
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 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
SUSTAINABILITY				
How would you assess (environmentally) the improvement of the robot collecting the waste (packaging, containers, remains) generated by the distribution activity on its return trip?	6,60	6,39	6,88	6,00
SAFETY				
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 has sharing the public sidewalk space with a home distribution robot generated insecurity to you?	6,17	4,59	3,00	2,63
To what degree has sharing the public space of the square with a home distribution robot generated insecurity to you?	1,50	2,78	3,38	5,00
USER SATISFACTION				
What degree of confidence would the delivery of your package generate with a delivery robot?	5,14	5,39	5,43	2,83
WELL-BEING				
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
To what degree would you see positive that an operator accompanied physically the robot?	2,95	3,88	4,27	4,83
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

Fig. 5: Human Acceptance for Robotic Last Mile Delivery: Survey to Peer End User and Bystander Roles

Fig. 6: Survey Images

shelter. The design of ONA is correct in volume, dimensions and speed. They know that the interface between operator and robot is the same as if someone drives a vehicle, with steering wheel, sensors and cameras. As operators, they prefer road limitations and routine activities to tele-operate the robots. For the operator, it is not necessary to have a peer team mate side-by-side to the robot, but the tele-operation could be done from a closer place where the human could perform both roles in one skill, peer team mate and operator. Some surveys images could be seen in Fig. 6.

A. *Human acceptance analysis in three aspects of the survey*

A study involving users was carried out to ascertain whether there are variations in the perception of robot acceptance based on the age of the user. Each scale response was computed by averaging the results of the survey questions comprising the scale. ANOVAs were run on each scale to highlight differences between the age, the dependent variable was normally distributed as it has been verified using the Shapiro Wilk test. Below, we provide the results of three main aspects.

First, we would like to analyse to what degree would users accept the presence of a home distribution robot in the public space. Here, we seek to gauge the respondent's opinion on whether they believe that the use of robots in public spaces for home deliveries is acceptable or not. The question implies that the introduction of home distribution robots in public spaces is not yet widely accepted, and the degree to which people would be willing to accept such technology is uncertain.

The responses to this question provide insights into the level of societal readiness for such technology and could be used to inform future policies and decision-making regarding the use of robots in public spaces. The *p* value obtained from ANOVA analysis is significant ($p < 0.05$), and therefore, we conclude that there are significant differences among ages, people under 60 years old would accept this kind of robots, while people over 60 do not accept it, Fig. 7.

Second, we would like to analyze the degree users consider that the urban public space is prepared for a comfortable coexistence of citizens with distribution robots. This question implies that the introduction of home distribution robots in

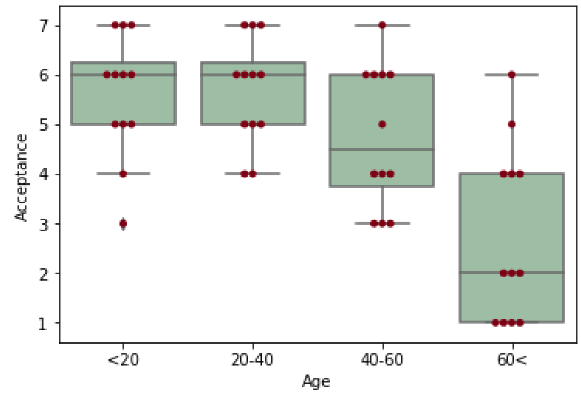


Fig. 7: Human acceptance of a presence of a distribution robot in the urban public space

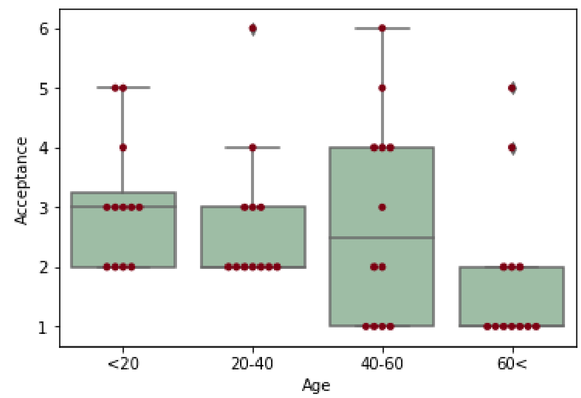


Fig. 8: Urban public space prepared for a comfortable coexistence of citizens with distribution robots

public spaces is not yet widely accepted, and the degree to which people would be willing to accept such technology is uncertain. The responses to this question provide insights into the level of societal readiness for such technology and could be used to inform future policies and decision-making regarding the use of robots in public spaces. Here, the p value obtained from ANOVA analysis is not significant ($p=0.14169545$), and therefore, we cannot conclude that there are significant differences among ages, it seems most users believe the public space is not prepared for this kind of task (Fig. 8).

Finally, we would like to analyze the degree of confidence would the delivery of packages generate with a delivery robot. The question implies that the use of delivery robots is a relatively new concept, and people may not yet be fully confident in this mode of delivery. The answer to this question would provide insights into the respondent's level of comfort with robots handling their deliveries and could be used to inform future decisions about the use of robots for package delivery (Fig. 9).

Factors that could influence a person's level of confidence in delivery robots may include the reliability of the robot, the accuracy of delivery, and the level of security measures in place to protect the package. The responses to this question

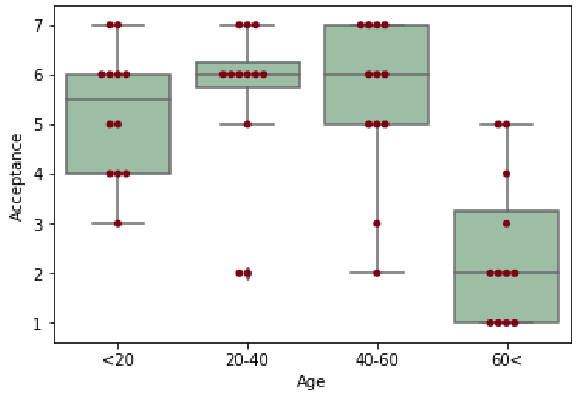


Fig. 9: Human confidence in robotic goods delivery

could help companies identify areas for improvement and establish a more widespread acceptance of delivery robots. The p value obtained from ANOVA analysis is significant ($p < 0.05$), and therefore, we conclude that there are significant differences among ages, and thus, people under 60 years old would accept this kind of robots, while people over 60 do not accept.

B. Discussion of the results

In conclusion, elderly people are reluctant in most cases to the introduction of a new technology in the urban public space. However, the rest of the interviewees have a positive view in general. The robotic last-mile distribution is well accepted in urban public space, preferably in low-density areas as the university campuses, the industrial and residential areas. In the city center, with high density, its introduction is not considered positive, although it could be carried out at night.

The current public space is not fully prepared to integrate this new technology and should be adapted. The survey offers a high acceptation of a free navigation of the robot instead of a segregated route. The supporting infrastructures, as charging points, cameras, sensors, could be integrated in the existing street furniture.

The distribution robot has not generated insecurity for passers-by in a wide space such as a public square, but it has generated greater insecurity in small spaces such as the sidewalk. The tasks carried out by other agents in the public space have not been altered by the distribution robots.

The robot's design is adequate for an urban scenario, but the big size of ONA difficult its motions in pedestrian areas, so it should be used in roads and open areas. The distribution robot has not caused noise or visual pollution in its circulation through the public space.

The peer teammate is recognized as a role not besides the robot, but in the surroundings of it, controlling several units and favor the integration. At the same time, routine and nocturnal itineraries should be considered.

VI. Conclusions

This work analyzes the HRI scenario for last mile delivery in urban public space, proposes a set of nine key indicators for human acceptance and evaluates it through a set of interviews and surveys.

The nine proposed indicators are: 1. The HRI scenario; 2. Equitable Access; 3. Aesthetics; 4. Co-Creation; 5. Sustainability; 6. Safety; 7. Privacy and Ethics; 8. User satisfaction; and 9. Well-being. The list is structured by the human roles categories involved in the HRI scenario.

The introduction of robotic technology in the urban public space creates a new ecosystem. Our approach analyze how this new ecosystem works with all the actors that take part on it, sketching and designing the new HRI scenario led by a new human role: Robotic Set Designer.

The formalization and the design of the new urban public space, roads and zones need a deep analysis in next studies. Robotics perfectly responds to the need for predictability and routine activities, creating order and discipline in the current chaotic scenario.

The research carried out and presented in this article can be extended to many other scenarios, offering a social point of view to robotics researchers and policy makers. As mentioned, the analysis of the HRI scenario and the human acceptance must be carried out in the initial phases of the innovative product or technology.

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