Public entities driven robotic innovation in urban areas

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Abstract

Cities present new challenges and needs to satisfy and improve lifestyle for their citizens under the concept “Smart City”. In order to achieve this goal in a global manner, new technologies are required as the robotic one. But Public entities unknown the possibilities offered by this technology to get solutions to their needs. In this paper the development of the Innovative Public Procurement instruments is explained, specifically the process PDTI (Public end Users Driven Technological Innovation) as a driving force of robotic research and development and offering a list of robotic urban challenges proposed by European cities that have participated in such a process. In the next phases of the procedure, this fact will provide novel robotic solutions addressed to public demand that are an example to be followed by other Smart Cities.

Keywords

Robotics; Urban challenges; Smart City; Innovative Public Procurement; Public End Users Driven Technological Innovation

1. Introduction

The Europe 2020 strategy includes innovative public procurement as one of the key market-based policy instrument for smart, sustainable and inclusive growth (European Commission 2010). Having reached the 19,4% of the gross domestic product, GDP, (European Commission, 2014), public procurement has an immense potential to fully exploit research and technology for innovation and also to deliver more cost effective and better quality of public services. The principal benefit of the Innovative Public Procurement is that innovation is addressed to needs of end users with a sure success in the market. In some cases the technologies needed to make these breakthroughs exist or are closed to the market; in other situations, investment in R&D is needed to ensure the progress of technological solutions that meet the social needs detected. In this last case, the instrument used by public entities is the Pre-Commercial Procurement (PCP) (Aho et al., 2006).

Despite this policies' deployment, there is little empirical evidence on the implementation of such aspirations put in the innovative public procurement (Georghiou et al, 2013)(Kattel and Lember, 2010). During the last years very few PCP have been initiated in Europe and in some cases the calls have been declared void. The possible reasons of this lack of success are a range of deficiencies in the PCP process including a lack of interaction between buyers and potential suppliers as well as little knowledge of public entities about what technology is suitable to solve their social needs.

In this scenario, ECHORD++ (The European Coordination Hub for Open Robotics Development) project is funded by the Seventh Framework Programme for Research and Technological Development (7FP) of the European Union, developing a PCP in Urban scenarios, giving us the opportunity to check the PCP instrument, proposing a deeper development of the preliminary tasks, and getting optimal results in Urban Robotic Technology.

In section 2 the objectives and scope of the article will be presented. Then the state of the art in Urban Technology and Robotic Technology in Smart Cities is described in section 3. Section 4 brings the possibility to bill a general description of urban needs and expose the 14 specific robotic challenges presented by European cities in ECHORD++. The most relevant robotic technology brought to urban environments is sketched in section 5. The urban robotic technology associated to urban challenges is analyzed in section 6. An overview of the innovative public procurement instruments introducing the novel Public end Users Driven Technological Innovation (PDTI) process is exposed in section 6. Section 7 describes the Case Study of ECHORD++ PDTI Urban and finally section 8 concludes the paper.

2. Objectives and scope

The aim of this article is to contribute and to join efforts to improve urban services or create new ones to the boost of the innovative public procurement in robotic technologies. The lessons learned along the ECHORD++ project encourage us to propose three main objectives:

- Foster and facilitate that public entities, in particular local authorities, know what robotic technology is and can offer in response to their urban needs. Urban competitiveness would drive municipalities to engage in innovation, but the innovative solutions, specifically the robotic technology is unknown for most of cities' procurers. The development of technology is the key to mastering the urban challenges and transformations in the European Cities. The processes of innovative public procurement are the right tools to accelerate them.
- Increase the processes of innovative public procurement in urban areas that can be solved by robotic technology. The processes of this public procurement of innovation (hereafter PPI) instruments should be reconsidered checking each one of their phases and proposing improvements addressed to get a real success in the technological solutions achieved. The management of all the stakeholders involved under the coordination of a research team, made mostly by robotic researchers, could offer a successful solution to the actual lack of initiatives.

- The third objective of this article is to offer a list of specific urban challenges proposed by European cities in ECHORD++ project that can be the starter point of new innovative public procurements. Cities are prepared and the Research and Technological Development (RTD) consortia are waiting for real opportunities. The take-off of the robotic technology could be possible: from Lab to Market addressing real urban needs of citizens and cities. The proposals obtained in ECHORD++ could be followed by other cities.

Few examples of Public Procurement for Innovation have been developed in Europe during the last years. The last data presented by the European Commission Directorate General for Communications Networks, Content & Technology (DG CONNECT) in December 2015 exposed that the Information and Communications Technology (ICT) procurement supposes the 2.5% in Gross Revenue (GR) and the R&D procurement the 0.1% in GR (European Commission 2015)(European Union, 2014). The European Commission is involved in enhancing the PPI processes looking to reach the good results at the United States of America public sector, that spend in research, development and innovation 20 times more than Europe (European Commission, 2014), 50$Bn a year in PCPs in front of the 2,5€Bn invested in EU.

The outcomes of this study are being disseminated in several forums of Social Sciences and Innovative Public Procurement in Europe.

3. State of the art

The term Smart City refers to a city that applies Information and Communications Technology with the aim to provide an infrastructure that ensures: a sustainable development, an increase in the life quality for citizens, a higher efficiency in the available resources and an active social participation. Therefore, those cities are sustainable in an economic, social and environmental way. Smart cities are born out of the need to maintain a harmony among those aspects. The purpose of a Smart City is to reach an efficient management in the whole areas of the city (urbanism, infrastructures, transportation, services, education, health, public security, energy…) satisfying its needs and the needs of its citizens at the same time (Lovins and Cohen, 2011). Those needs have to be achieved accordingly to the principles of the Sustainable Development presented in the Agenda21 [25], promoted by United Nations, taking the technological innovation and cooperation among economic and social agents as the main engines for the change. For the next 15 years, a new program has been launched by UN in 2030 Agenda for Sustainable Development [26]. Those principles should be applied specially to aspects as: 1) technological infrastructure: information networks as a mechanism of communication, intelligent platforms, eco-efficient infrastructures…; 2) energetic strategy: use of renewable energies, storage systems and energy harvesting; 3) resource protection and management: land and resource planning based on sustainable criteria, cooperation among administrations…; 4) service provision: development of new collaborative models that allow integrate public and private interests, associate service models…; 5) the Government: data accessibility, transparency in the management, sustainable policies applications.

It is expected that in 2050 a 70% of world population lives in cities (population of London growing at the rate of one full tube train every three days (Byles, 2016). This expectation makes that in the next decades the urban centers have to face an increasing number of problems linked to this fact such as: energy supply, CO2 emissions, car traffic planning, goods and raw materials supply, health care and security provision to those all people living in these huge and crowded cities. The philosophy "Smart City" starts increasingly to be undertaken in projects that will imply the transformation of many cities into Smart Cities [27].

But the origin of Smart City is in Singapore. This Asiatic city was the first one to coin the term Smart City, and since that time Singapore has led this architectonical trend. This has been done through many innovative ideas as a pioneer underground, highway tolls that vary accordingly to the traffic flows, fingerprint computers for building access, water recycling to obtain drinking water, and with special emphasis in energy efficiency. After Singapore, other pioneer cities have been: Masdar (United Arab Emirates), the first ecological city which is self-sufficient using solar energy, with low consumption buildings; Hammarby Sjöstad, eco-friendly neighborhood of Stockholm municipality, integrates a sustainable management of energy, water and waste in an ecological district that was an old industrial site; BedZED [28] (pioneering eco-village in south London, United Kingdom), the sustainable community that boosted green spaces and transportation; Curitiba (in Latin America), the flourishing of green urbanism; and Songdo (South Korea), high technology integrated. Those last two cities have developed an intelligent transportation system with innovative technology, high speed Wi-Fi in the streets and recharge stations for electrical vehicles.

Following these examples, at present many cities have incorporated some of the main relevant mentioned aspects. In fact, increasingly more cities support this model that allows a lifestyle more comfortable for their neighbours. Some cities are more advanced than others in this sense, but it is possible to find smart projects practically over the world. As a summary of the most relevant examples, the following cities are summarized:

City of Tokyo: it has been considered par excellence the Smart City with projects to improve the energy management, smart urbanism, mobility… It sticks out the NFC (Near Field Communication) [29] technology deployment in public transportation such as the underground, or in specific malls where the payment can be done using the mobile phone.

City of Amsterdam: among many of the smart initiatives promoted in this European capital, the Smart Light project highlights [30]. The trial is focused on various aspects of smart lampposts in public spaces. The lighting can be adjusted for a range of situations via remote operation or sensors, helping to improve security and save energy.

City of Singapore: as it has been mentioned before, it was the first Smart City and it is still one of the main leaders in this field [31]. In the city, a huge network of sensors connected to Internet has been deployed that compiles data in real time for a best performance of the city. The goal is to use such information to undertake initiatives that improve the citizens' lifestyle. In practice, those sensors allow to detect the flooding risk of sewage, to avoid traffic jams, to yield information about the public transportation, to detect the air quality, to find a free parking place, and many more of interest.

City of Barcelona: the city municipality offers a free Wi-Fi connection system. With 461 connection points this network is one of the largest in Europe. Barcelona City Council presented an international call inviting global RTD consortia to propose their technological solutions to six different challenges for the city looking for solutions to transform and improve public services, create a more inclusive city, accelerate innovation and leverage public spending more effectively to deliver better services: reducing bicycle thefts in the city, automatic detection and alerts of damaged road surfaces, empowering local retail through technology, improving the quality of social care through technology, monitoring pedestrian flows in the city and tools for digitization of museum and archive collections.

City of London presented in 2013 the *Smart London Board*, *not a single or a definitive solution, but a series of evolving interventions in response to our changing needs.* In UK other cities engaged the idea of urban needs solved by innovative solutions: Leicester, Ipswich that established a target to reduce its CO2 emissions by 60% in 2025; Stoke-on-Trent, where the congestion significantly affects public transport reliability and journey speed; Bristol, Glasgow, Southend-on-Sea, rising energy costs leading to an increase in fuel poverty and Leeds-Bradford, looking for solutions for a key infrastructure and housing not vulnerable to flooding.

City of Santiago de Chile: the Chilean capital has initiated the first prototype of smart city in the Parque de Negocios Ciudad Empresarial [32]. The key points of this smart city are the intelligent management of electrical grid, increasing its efficiency and the care of the environment. But this initiative goes beyond and it allows integrating in the business park many technological innovations as information screens, electrical vehicles, public Wi-Fi, lighting control and domotic buildings.

It is worthwhile to highlight the government model of Scandinavian cities. In the ranking performed by the European Smart Cities [33] study, the first cities with a better government action are in Finland (Tampere, Oulu, and Turku), Denmark (Aalborg, Aarhus, and Odense) and Sweden (Jönköping). Despite they have different and specific cultural, political, geographical and climatic models it is convenient to know the reasons why their government is remarkable and appropriate in a Smart City framework. In general, these are cities that historically have a homogeneous and orderly society with a solid technological integration. Some of these strong points correspond with the weakness that presents our society. Therefore, to set realistic targets and progress in the concept of government represents a challenge and an opportunity to build a better society [34]. In (Lember et al., 2011) the case study of six Nordic-Baltic Sea cities that have developed Innovative Public procurement from 1998 to 2007 is presented. Tallinn faced the challenge of introducing a universal ticket system for public transport; Copenhagen’s case was initiated because of an emerging need in educational policy; Malmö’s photovoltaic energy-supply purchase was a direct result of its environmental policy; Stockholm public procurement for innovation is strongly driven by environmental goals and Helsinki case was launched to meet emerging problems in their public transport sector.

So far, Smart Cities postulate a great business opportunity for the technological and ICT progress but not much in robotic aspects. In this paper, by means of ECHORD++ research project, many innovative robotic solutions will be introduced in order to fulfill many citizens' needs for the XXIst century that would not be possible to achieve without a robotic technology.

4. From urban needs to urban robotic challenges. The outcomes of E++PDTI Urban.

Smart cities have become a suitable scenario where robotic technology could have an important impact in the areas of energy, environment or mobility (Lund Declaration, 2009). The wide scenario of a Smart City has been structured in different areas under the smart cities concept (SCEWC): Energy, Technology and Innovation, Smart Society and Collaborative City, Sustainable Built Environment and Mobility. The exploration of social needs and the gap between needs and current supply started with the identification of the Cities and Citizens' needs in the different urban areas in order to establish a draft list of technological urban challenges. The analysis of the Smart City World Congress' memories 2013-2015 and individual meetings with city councils' departments and living labs give the following information.

Energy

Cities are a major contributor to CO2 emissions in Europe. Forthcoming challenges include the improvement of efficiency in energy consumption and transport, increasing production from renewable sources, creating infrastructures that consume energy but can also produce it, developing new ways of grids energy management, boosting energy production on an urban scale or reducing energy needs and its environmental impact.

ICT Technology

Cities can be turned into sensory beings that communicate their needs and their responses to certain scenarios in real time. Tomorrow's cities must establish systems capable of handling the massive amount of data generated by their residents and infrastructure. ICTs are becoming a key partner to help manage, monitor and detect special situations. Some of the urban needs detected in this area are to provide real time communication between needs and responses, to develop capable systems of handling the massive amount of data, becoming the information another infrastructure of the city (Ashton, SCEWC) and the data the next natural resource (Spalmacin, SCEWC), including prevention, detection and action in a resilient scenario managing data as a key to manage risk (Smith, SCEWC).

Smart Society & Collaborative City

Cities are facing higher demands from their citizens. New urban services need to be developed in a new landscape to make interact the society and collaborate, to empower citizens to develop their initiatives, to foster creativity and to learn new ways to innovate. Some of the urban needs detected in this area go towards the innovation of new approaches, to an independent and assisted living in the cities, to adapt the city to the people (Quinn, SCEWC) and specifically to elderly (Utsumi, SCEWC), to achieve an interactive and collaborative city where government should empower citizens to develop initiatives, creativity and innovation.

Environment

The world is facing major environmental challenges and cities are major managers and consumers of natural resources. Cities must take care and protect the environment and integrate different kinds of green spaces, urban agriculture, urban services and urban utilities into a new urban model. Some of the urban needs detected in this area are devoted to the protection the environment: air, water and land resources. In (Ng Lye, SCEWC), a new urban model with the integration of green spaces, urban agriculture, urban services and utilities and the management of waste from source to homes and from homes to wasteland had been presented.

Mobility

The context that sets the development of the smart cities is specially challenging in the framework of the mobility grid lock. With world population growing and concentrating in cities, the capacity of our road and street network has reached in many cases its physical and environmental capacity. In this regard, there is a widespread development of new technologies for all means of transport, service integration, sharing schemes and mobility management. Some of the urban needs detected in this area are to improve pedestrian areas, bicycle and public transport, mobilizing people (Hidalgo, SCEWC) and innovating new infrastructures for urban goods distribution to improve urban retail.

In front of these few examples addressed mainly to urban technology, the outcomes of the ECHORD++ PDTI in Urban Robotics have brought 14 urban challenges proposed by ten different European cities (see Figure 1).

INFRASTRUCTURES	**HELSINKI Finland**	**Traffic infrastructure inspection and maintenance.** Decreasing the cost of maintenance and increasing the area livability through robotising of the city's maintenance traffic at the Smart Kalasatama designated smart city area, including both vehicles and installed infrastructure in the area.
INFRASTRUCTURES	**BARCELONA Spain**	**Automatic detection and road surface damage warnings.** To find a solution that can gather data and analyze the 11Mm2 of asphalt paving surfaces, road, cycle and pedestrian across the whole city.
INFRASTRUCTURES	**CORNELLA Spain**	**Improving waste management and street cleaning.** Perform tasks with less cost for the maintenance of parks and gardens.
INFRASTRUCTURES	**BARCELONA Spain**	**Utilities infrastructures condition monitoring.** To mechanize sewer inspections in order to reduce the labor risks, objectify sewer inspections and optimize sewer cleaning expenses of the city.
ICT AND ENVIRONMENT	**MALAGA Spain**	**Environmental monitoring and control.** This challenge aims at the deployment of a robotic collaborative network for monitoring and mitigating the presence of air pollutants (including pollen), as well as odors that may be unpleasant to citizens.
ICT AND TOURISM	**GREENWICH United Kingdom**	**Improving tourist services at the city.** To provide a cost effective way of interacting with visitors to provide accurate information based on real time management data as well as information on attractions and related services.
ICT AND PLANNING	**SEVILLA Spain**	**Improving the management, planning and urban city observations.** The use of aero robots in the management, planning and urban city knowledge
ICT AND MOBILITY	**SEVILLA Spain**	**Planning and information of urban accessible routes.** The robotic challenge we propose is the realization of a LAND ROBOT prototype, as the basis for a battery of them deployed around the city taking mobility accessibility data with references that are inherent in the development of the Planner.
ICT AND SURVEILLANCE	**PADOVA Italy**	**Providing safe and secure environments for citizens.** The new technology should improve the limits of traditional surveillance cameras and should have more features (i.e. proactive action, movement ...) compared with the actual passive video surveillance/acquisition.
ICT AND MOBILITY	**VALENCIA Spain**	**Improving the management, planning and urban city observations.** An innovative monitoring system applied to urban bus lines to monitor Origin and Destination and sustainable mobility modes.
PEDESTRIAN AREAS	**BARCELONA Spain**	**Personalized mobility support for pedestrian areas.** To create a system or service that will guide the transport or mobility impaired through the neighborhood. The system must be integrated into the pedestrian area of the new city model raised.
PEDESTRIAN AREAS	**SITGES Spain**	**Providing safe and secure environments for citizens. N**ew robotic infrastructure where now there is a human intensive service. Objectives: noise reduction, surveillance and management of public spaces, especially in crowded events and support to disabled people in pedestrian areas
PEDESTRIAN AREAS	**BARCELONA Spain**	**Goods distribution technology to improve local retail.** To create a sustainable system to make the distribution from the neighborhood Warehouse to each commerce. This robotic system must to be integrated in the pedestrian areas of new neighborhoods.
PEDESTRIAN AREAS	**COIMBRA Portugal**	**Personalized mobility support.** To contribute to the downtown urban life revitalization, improving the existing personalized transport as a key issue to connect activities and people. To select and apply the best mobility solution that can assure an effective transportation role in the downtown.

Figure 1. ECHORD++ Urban Robotic Challenges.

5. Urban robotic technology associated to urban challenges

In the previous section, the list of PDTI projects has been shown, many of the ideas are still on the shelf, and just a few of them are deployed in real cities, buildings and streets. In this section a list of projects will be described, demonstrating that the future of the Smart Cities includes robotic solutions together with ICT and other technologies that will bring real solutions to fancy ideas, making a huge change in persons' lifestyle. The projects can be divided into a series of fields although some ideas come across this division.

Robotic solutions in Construction:

Masons will have soon a new assistant in building construction, SAM, short for Semi-Automated Mason, is a brick laying robot designed and engineered by Construction Robotics [35]. SAM100 is the first commercially available bricklaying robot for onsite masonry construction. The company is focused on advancing construction through the use of robotics, automation and the same principles used in manufacturing. Fast-brick Robotics [36] has been working for about a decade to refine the bricklaying robot. As long as you keep feeding it bricks, it can work continuously, placing 1,000 bricks an hour based on a CAD drawing. This works out to the shell of a new house every two or three days.

The specific situation in Singapore and its construction industry seems particularly suited for the application of robotic solutions for construction work, and can act as a catalyst for future applications. While the targeted high population growth over the next decades demands a high degree of unbroken building activity, the country suffers from the lack of skilled workers. Additionally, the high-rise typology with repetitive floor plans makes automation feasible. Tiling work, in particular, is suited for robotic automation. It is a well-defined subdomain of construction with clear interfaces that can easily be singled out. Further, it is a repetitive task and features no complex joinery. Moreover, tiling is the predominant surface treatment in Singapore. Therefore, automating this process is expected to benefit the construction industry as a whole [37].

Robotic solutions in Transportation:

Robotics and driverless cars are part of the larger "Internet of Things" discussion that forecasts more advanced forms of connectivity between devices, systems and machines. A more pervasive development in robotic smart city solutions may be the arrival of driverless cars and delivery drones. According to a study commissioned by Intel Corporation, 44 percent of American respondents would like to live in a driverless city where cars, buses and trains operate intelligently and automatically without people driving them. Google is not the only company with driverless cars on the road. Indeed, just about every traditional automaker is developing its own self-driving model, peppering Silicon Valley with new R&D labs to work on the challenge. Last year, a BMW drove itself down the Autobahn, from Munich to Ingolstadt ("the home of Audi"). Audi sent an autonomous vehicle up Pikes Peak, while

VW, in conjunction with Stanford, is building a successor to Junior. At the Tokyo Auto Show in November 2015, Toyota unveiled its Prius AVOS (Automatic Vehicle Operation System) prototype, which can be summoned remotely. GM's officers predict that self-driving cars will be on the road by the decade's end. Groups like the Society of Automotive Engineers have formed special committees to draft autonomous-vehicle standards [38].

Robotic solutions in Services:

Smart city technologies often fall into the realm of things like integrated communications networks, cloud computing frameworks and advanced instrumentation. But, as New York City demonstrates, there is room for your old-fashioned robot, too. The New York World recently profiled three municipal "workers" that automate diverse and important city functions. What these employees lack in the flesh and blood department, they make up for with their touch screens, thermal cameras and sophisticated programming. Some prototype examples are i) SuperDroid LTF, this Fire Department gizmo costs $100,000 and takes photos in collapsed buildings to assist with searches. It also takes metered readings during hazmat operations; ii) Andros HD-1. Employed by the Police Department, this 245-pound, camera-toting machine handles suspected bombs. It climbs stairs at angles of 45 degrees or more and travels at a speed of 4.3 miles per hour; iii) Robot-Rx. This Municipal Hospital robot handles more than 90% of medications dispensed from central pharmacy; iv) Mailbot. This automated mail tracking system delivered letters and packages to its Department of Housing Preservation and Development employees.

There exist many prototypes of service robots for elderly people assistance at home, mainly developed in Japan where society is aging very fast-- the number of elderly people in Japan is growing faster than that of any other country -- and the falling birth rate, which is expected to create a shortage of working-age people. The population is expected to start shrinking after peaking at 127 million in 2006, prompting companies to look at ways robots can help [39].

Robotic solutions in Cleaning:

There exist some research projects that have as objective the design and implementation of cleaning robots for indoor as well as for outdoor environment in buildings and cities. It sounds like something from a science fiction film, but the concept of robots cleaning our streets is becoming a reality with what is believed to be a world first. DUSTBOT ('Networked and Cooperating Robots for Urban Hygiene') is an original idea, which operates robots in partially unstructured environments (such as squares, streets, parks) to sweep up rubbish and dirt. They can also collect small quantities of home rubbish on demand from citizens, at their doors, and it is still a prototype. With Europe producing over 250 million tons of waste every year, the concept of using robots to do the job is not such a crazy idea. It could help the EU in their quest for new waste prevention initiatives to reduce the overall environmental impact [40].

Another nice example is called the Scarab, and it is an automated robot that has been designed to efficiently and quickly clean much larger areas, like shopping centers and neighborhood streets. Could these little robots be the future of urban waste collection? The Robot Harvester is a self-driven robot concept that has been designed to gather rubbish from shopping centers and street territories, and put them to the right place for disposal. It features two web cameras and sensors to detect length of an element which will help it to estimate the territory and locate the place where the rubbish is awaiting to be picked [41].

Robotic solutions in Surveillance:

Robots will be patrolling cities by 2040 according to (Sharkey, 2008), who predicts their tasks that will include asking for ID, tasering and arresting suspects as well as crowd control. In his work, Sharkey, a robotics professor at the University of Sheffield, forecasts a world in which the jobs of surveillance, security and law enforcement have largely been handed over to artificial intelligence. The robots might one day rise up and take over, but a Palo Alto startup called Knightscope [42] has developed a fleet of crime-fighting machinery it hopes to keep us safe. Knightscope’s K5 security bots resemble a mix between R2D2 and a Dalek from Doctor Who – and the system behind these bots is a bit Orwellian. The K5’s have broadcasting and sophisticated monitoring capabilities to keep public spaces in check as they drive through open areas, halls and corridors for suspicious activity; it is still a prototyping robot. Nowadays, there are many proposals of drones (UAV, unmanned aerial vehicles) whose main task is to monitor neighborhoods suburbs, borders and others areas of strategic interest [43]. Their deployment is not free of controversial between security and privacy.

Robotic solutions for welfare:

Larson and team at the MIT Media Lab are working on several innovations to make city dwelling far more livable, and some projects arose in their lab of ideas, such as i) a tiny car that can be parked anywhere, a two-person vehicle that not only spins and runs off a rapid-charging battery — it also physically folds in order to minimize its parking footprint, three of these small vehicles can fit into one traditional parking space; ii) headlights that communicate with pedestrians, in the city of the future will no doubt be filled with autonomous cars, so how will pedestrians know they’ve been seen without a driver that can make eye contact? AEVITA (Autonomous Electric Vehicle Interaction Testing Array) is designed to allow autonomous cars to interact with the world around them, giving pedestrians cues of recognition, and making driving intentions obvious to others; iii) bikes for elderly and disabled, Persuasive Electric Vehicle (PEV): bike lanes are generally the province of the young and fit, however, the MIT Media Lab is creating vehicles to allow the elderly and disabled to use them too, these three-wheeled electric vehicles are legal for bike lane use because they require pedaling, while giving the rider an electric boost of up to 20 mph; iv) an apartment that changes, thanks to robotic walls: CityHome and Robot Walls, 850 square feet is not a lot to work with, but an apartment can be made to feel twice that size through a transformable wall system that morphs with the push of a button, with robotic walls, a bedroom can transform into an office, or open up into a party space, a living room can morph separate offices or become a larger meeting space, each resident would work with a designer to figure out their needs, configuring the perfect system for their demands [44]. Most of those products are still in the prototyping stage.

The solution to urban social challenges as climate change, security and transport systems might be robotics. The European Commission is sure about that and is looking for Public Authorities willing to take part in the ECHORD++ Pre-commercial Procurement Pilot in Urban Robotics [45].

6. Overview of the innovative public procurement instruments and PDTI.

Policy may act where the demand for innovations is insufficient, or non-existent, but where a technological product has a high potential benefit (OECD, 2014). Innovation life cycles are concerned with the life cycles of generation of technology from the perspective of the economy and society as a whole as opposed to the life cycle of a specific product (Cohen and Amorós, 2014). Two main public procurement instruments have been developed into the product innovation life cycle: Pre Commercial Procurement (PCP) and Public Procurement for Innovation (PPI). Public Procurement for Innovation is procurement where contracting authorities act as a launch customer for innovative goods or services which are not yet available on a large-scale commercial basis, and may include conformance testing. Pre-commercial procurement means procurement of research and development services involving risk-benefit sharing under market conditions, and competitive development in phases, where there is a separation of the research and development phase from the deployment of commercial volumes of end-products (European Commission, 2014) (see Figure 2).

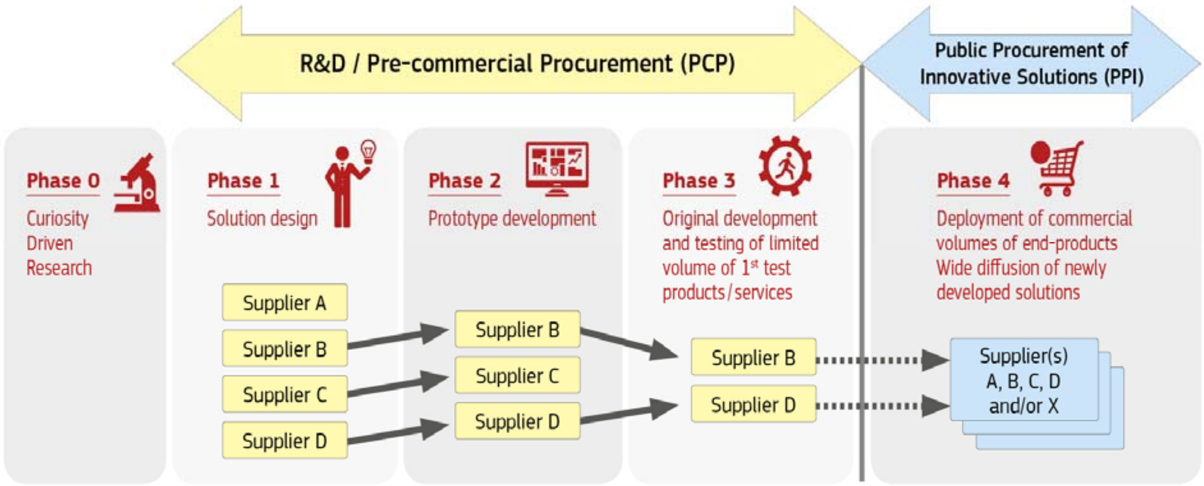

Figure 2. Innovative Public Procurement Instruments.

Despite the perception of innovative procurement as something of a policy panacea and repeated efforts to put procurement budgets to work to drive innovation, efforts have been met with limited success (NESTA, 2012). Numerous barriers have appeared from demand and supply side: there are market failures (information problems) and system failures (poor interaction); suppliers of potential new products and services often lack the knowledge on what customers demand; user-producer interaction and communication doesn't help to produce synergies results and innovative firms in the side of the suppliers perceived a lack of expertise on the side of the procurers and see it as a strong barrier to supplying innovative goods or services (Uyarra et al., 2014).

On the other hand, public call for RTD tenders or proposals, may not consider as a common call. Its complexity requires much more comprehensive development of the preliminary phases of public demand knowledge, as well as the specifications and features of the new technology. It is necessary to develop the initial phase, the phase 0 of the pre-commercial public procurement procedures, through activities aimed to know in depth the demand of both of the authorities and the users. Moreover, the innovative technology that can give a response to these needs has to be analyzed, while it allows to improve the quality of the public service or to reduce its economic cost. The aim is that the joint consortia of industry and academia could research and develop innovative pre-commercial products linked to real demand.

In this scenario, the lessons learned in the case study of ECHORD++ project bring us the possibility to introduce the novel innovative process PDTI - Public end users Driven Technological Innovation - and generalize the conclusions from robotic technology to other domains. Located into the product innovation life cycle, and based in pre-commercial procurements, the PDTI proposes a process that develops two main phases (see Figure 3):

- Activities for public demand knowledge and
- Activities for research and technical development of pre-commercial products.

PRODUCT INNOVATION LIFE CYCLE				
	PCP PHASE 0	PCP PHASE I-II-III	PPI PHASE IV
ACTIVITIES FOR PUBLIC DEMAND KNOWLEDGE		ACTIVITIES FOR RESEARCH AND TECHNICAL DEVELOPMENT OF PRE-COMMERCIAL PRODUCTS	PUBLIC PROCUREMENT FOR COMMERCIAL ROLL-OUT
PDTI			

Figure 3. Relation between PCP and PDTI processes.

The "Activities for public demand knowledge" increase and structure the tasks developed in the phase 0 of a common PCP. The "Activities for research and technical development of pre-commercial products" match the phase I, II and III of the PCP, ending in a pre-commercial product and making possible a Call for Commercial Tendering (PPI).

Policy instruments mainly address the act of procurement itself and do not engage with the whole cycle from identification of needs and forget to involve a wider set of actors and stakeholders (Edler and Georghiou, 2007)(Aschhoff and Sofka, 2009). From the importance of this identification of needs and looking to bring future needs and future supply together at an early stage, the first part of the PDTI process, Activities for public demand knowledge, develops four qualitative phases inspired in Delphi methodology (Dalkey and Hermes, 1963): Brainstorming, Narrowing Down, Ranking and Challenge Description (Delbecq et al., 1975). This group of activities ends in a Call for Proposals / Call for Tenders, initiating the Activities for research and technical development of pre-commercial products structured in three phases as it is proposed in a pre-commercial procurement: solution design, prototype development and small scale test series (see Figure 4).

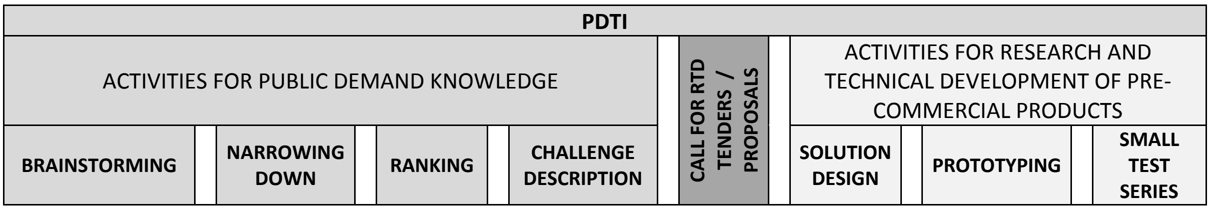

Figure 4. PDTI process and activities.

The novelty of the PDTI is to develop the phase 0 of a common PCP putting more emphasis in the preliminaries tasks and proposing a previous and indispensable phase of knowledge and interactivity between the stakeholders. The public entities, demand side, and the technological consortiums, suppliers, under the coordination of a research team and the supervision of the users constitute the stakeholders. Moreover, the innovation procurement requires a shared vision of the future needs between purchasers and suppliers and a systematic way of identifying and characterizing those possible needs (Georghiou et al, 2013).

This part of the PDTI process, namely “Activities for public demand knowledge”, is a qualitative procedure inspired in Delphi methodology and allows a group of stakeholders to systematically approach a particular task or problem (Paré et al, 2013). In our case the objective will be the reliable and creative exploration of social needs related to public services that could be solved through robotic technology and the production of sustainable information for decision making in the area of Innovative Public Procurement. The methodology will employ iterations of questionnaires and feedback through series of rounds to develop a consensus of opinion from the participants. The role of the coordinator is needed to drive and lead the complete process based on innovation giving the technological support to the public sector for developing and implementing the innovation-oriented procurement. Due to the complexity of this process, it is valuable that the coordinator has a team of researchers coming mainly from technological areas but also from economics, psychology or political science fields (Edquist and Zabala, 2012). In Figure 5, the “Activities for public demand knowledge” process can be seen in detail.

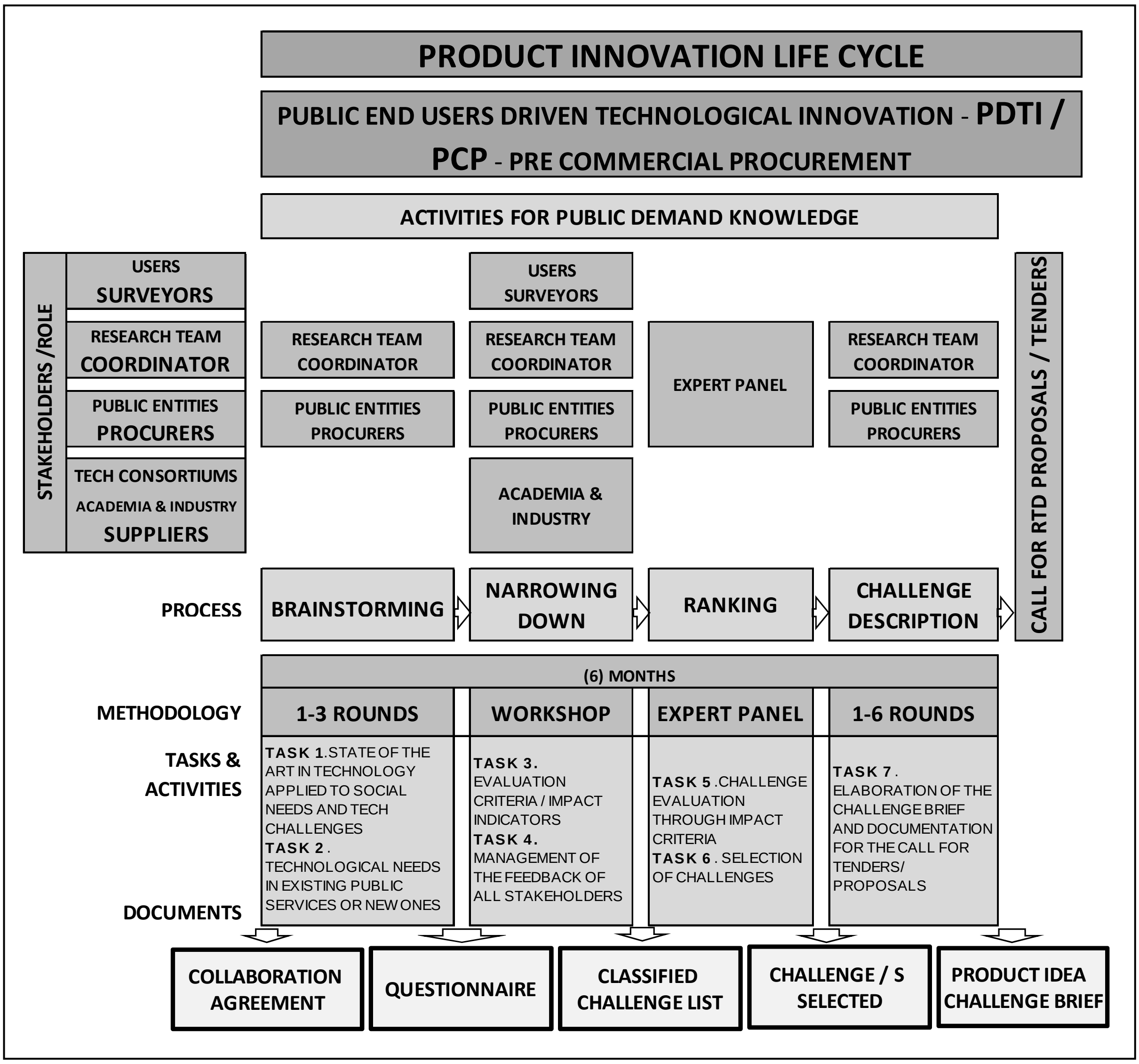

Figure 5. PDTI Activities for Public Demand Knowledge: process, methodology, tasks and activities.

The process starts with a Brainstorming looking to identify concrete needs in hands of the users and public entities. Two tasks are developed at least: to analyze the state of the art in technology applied to social needs and technological challenges; and to analyze the technological needs in existing or new public services. Sometimes the identification of needs is constrained by lack of knowledge of the innovation potential (Caldwell et al., 2005). The objective of this step is the elaboration of a Questionnaire of Public Needs and its associated innovative technology, based in the improvement of existing public services, their cost reduction or the creation of new ones. At the same time the knowledge about innovative technology can be introduced in public environments. Interactive collaboration between organizations is extremely important for innovations to emerge, in the demand/pull side as in the supply/push side (Edquist and Zabala, 2012). The success will come by interacting with the stakeholders in several rounds. A questionnaire of the public needs and the associated innovative technological solutions will be the tool used during the rounds. The information elaborated in each round will be collected, edited and returned to the coordinator. Finally an agreed "Final Questionnaire" will be elaborated.

Thus, a narrow down step has the objective to focus the needs proposed at the Questionnaire through specific criteria. It consists of two tasks. The first one is to obtain a group of impact indicators. These impact indicators sometimes exist in the public entities and in this case they can be used as starting point. In any case, a list of social, environmental, economic and innovative impact indicators must be created and they will be used in the evaluation and selection of the innovative Challenge List. The second task consists in the management of the stakeholders' feedback. One way to develop this phase is by organizing a workshop with the different stakeholders involved, discussing and receiving the feedback through the impact indicators and elaborating the Innovative Challenges List. Users, Industry and Academia Consortiums can be invited to participate in order to know their opinion. The produced document at the end of this phase is the List of Innovative Challenges and each one of these selected challenges should be described and evaluated through the proposed impact indicators (Dalpé, 1994).

The third step of the Activities for public demand knowledge, the Ranking one, will be done by a panel of experts composed by designed people from the public entity and the research team with two specific tasks. The first task consists in evaluating the list of innovative challenges and the other task is the selection of the Public Challenges. The experts' panel has to use the impact indicators; however other criteria can be used at the same time. In this process, the number of selected public challenges will depend on the budget of the public entity and at the same time of the potential market offered by the procurer weighting if it is relatively big or small to the cost involved in the development of the innovation.

Finally the last step of this first group of activities is the Challenge Brief. The main task consists in the production of the challenge description. The Challenge Brief is a document with a clear explanation of the public service and with enough information about the functions to be developed by the new technology. It is important to address that this Challenge Brief is not a common procurement document, but an innovation one, and has to be written taking in mind the functionalities (to do or required by the public service) instead of the specific requirements that could narrow the innovative field. It is necessary to be accurate with the inadequate identification and translation of needs into specifications that result frequently too narrowly defined and in terms of characteristics that can be easily measured and monitored and reduced to price rather than innovative features.

7. The case study of ECHORD++ in urban scenarios

Focus on application-oriented research and development, ECHORD++ has been funded by the 7FP for five years to improve and increase the innovation in robotic technology through small-scale projects and a "structured dialogue" incorporating public entities and citizens to the conventional platforms of industry and academia. Three instruments and processes are being developed under the ECHORD++ project: experiments (EXP), research innovation facilities (RIF) and public end-users driving technological innovation (PDTI). All of them improving and increasing the innovation in robotic technology of small and medium enterprises (SMEs) companies and addressing answers to social and industrial needs in different scenarios. Urban areas have been identified as one of the application scenario for the ECHORD++ PDTI and the Universitat Politecnica of Catalunya, UPC, (46) is leading its procedure under the coordination of the Technical University of Munich, TUM, (47) and with the support of all the ECHORD++ partners.

In October 2013 the Activities started for public demand knowledge considering the following stakeholders: city councils as smart procurers; technological industry and academia consortiums as futures suppliers, citizens as surveyors and the UPC research team as the coordinator (Unsworth et al., 2014). The objective was an open and coordinated dialogue between all the stakeholders involved following the four steps described previously (see Figure 5).

7.1 Brainstorming

We started with the Brainstorming phase, asking to the European city councils about their Urban Challenges. We used different means: personal interviews with different departments, emails and telephone calls. We also analyzed the documentation of the Smart City Expo World Congress 2012-2013 to know the cities' challenges and during all the process an essential task was to introduce the knowledge of robotic technology into the cities' managers, technicians, majors and other people related with the cities' councils.

A first group of urban needs were detected and we started to discuss how the robot technology could bring solution to these needs. First we did this discussion with the team of the UPC composed by robot researchers and people with economical and architectural background, and the outcome was a first document including cities needs and its associated robotic technology. Then we talked again with the city councils to see if those solutions fit their approach. We did these rounds four times and the outcome was an ECHORD++ Urban PDTI Questionnaire.

7.2. Narrowing Down

To prepare the Narrowing Down phase we reviewed the existing documentation about impact and evaluation criteria and we asked to the City Councils about their public procurement evaluation. We also analyzed the document in (48) developed for the Cities of United Kingdom. This document explores the expected benefits to citizens, to city economy and local authorities across the new solutions for public sector services. The first one is based on improvements in quality of life. The second one is based on the expected benefits from the future city economy characterized by the development of new products and services and catalyzing local start-ups. Finally, the third one is focused around improvements on decision-making, collaboration and transparency, along with more efficient delivery of services and reduced costs.

Using these documents, we elaborated a list of impact criteria which included the following elements: the Social and Cultural Impact, to improve citizen's participation, independence, accessibility and mobility, quality of life, better public services and replicability of the proposal in other districts and cities; the Environmental Impact, to improve resources efficiency, potential for sustainable growth and sustainable mobility; the Economic Impact, to increase the support to small and medium companies and leverage private funding, increase or improve employments opportunities and the evaluation of the cost/benefit of the new technology; and the Innovation Impact, based on the ability to execute, the evaluation of the risk/benefit of the proposal, the innovation in robotics and the capacity to integrate systems and synergies.

The ECHORD++ Urban PDTI Questionnaire, completed with the evaluation criteria, was sent to European City Councils, City Council Departments, Cities Associations, Smart City World Congress'13 Speakers, Robot Manufacturers and Research Institutions and Organizations. Two local living labs and the European Network of Living Labs (ENOLL) were also contacted. We did not get a good number of answers from these massive shipments and then we decided to contact again, personally by email or telephone and program individual meetings if it was possible. We also programmed a workshop in a propitious scenario, the Smart City Expo World Congress, inviting all the involved stakeholders. We discussed about the proposed urban challenges, its associated robotic technology and the proposed impact criteria. In order to introduce robotic technology into public entities, we invite a famous Japanese robotic researcher that presented the state of the art in urban robotics in Japan. This Narrowing Down phase brought us fourteen Urban Robotic Challenges from European cities addressing specific proposals with a detailed description of the public service to improve or to create by robotic technology.

7.3. Ranking

The third phase, the Ranking one, consisted in the evaluation and selection of the most promising Urban Robotic Challenge to be funded through the ECHORD++ project. A first evaluation round was done remotely by experts that weighted the proposals, and the outcome was a list of weighted challenges. The second evaluation was done by the same panel of experts during a physical meeting that selected the ECHORD++ PDTI Urban Robotic Challenge (the investment of the project should be applied only to one innovative urban challenge). The selected proposal was "To mechanize sewer inspections in order to reduce the labor risks, objectify sewer inspections and optimize sewer cleaning expenses of the city" presented by Barcelona City Council. The criteria used for evaluation was the same that was described in the narrowing down phase.

7.4. The Challenge

Finally, we prepared the main document for the Call for RTD Proposals: the Challenge Brief. As said before, the translation of the needs into functional requirements requires a team of people with highly developed competences. The team was formed by four UPC robotic researchers and four people of the city council directly involved in the performance of the public service. During eight rounds we discussed about the requirements of the new technology: present, possible and optimal public service functions. The discussion finalized in a document, the Challenge Brief, where the functions were described with the inputs of the robotic team, looking to facilitate the innovation on one hand and answering the real needs of the public service on the other that would give rise to a pre commercial product.

The second part of the ECHORD++ PDTI will include the activities for research and technical development of the pre-commercial products. This part will start in a Call for proposals and will be structured in the known three phases of a Pre Commercial Procurement: solution design, prototype development and small scale test series (see Figure 6).

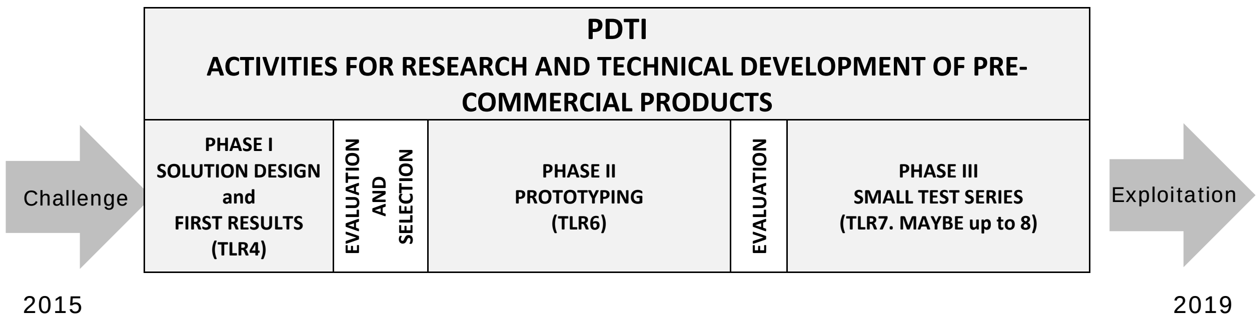

Figure 6. PDTI Activities for research and technical development of Pre Commercial Products.

8. Conclusions

There are cities and citizens' needs that have not an answer through existing products or services and requires innovative solutions: robotic technology could bring the answer to these needs The innovative public procurement' instruments, and specifically the Pre Commercial Procurement, are the solution to join public demand with innovative supply in urban scenarios. But the municipalities, the city councils, their officers and managers did not know the possibilities that robotic technology can offer to solve their urban challenges. The process developed through the novel PDTI - Public end-users Driven Technological Innovation - will set the link between cities, citizens, industry and researches, developing these initiatives. An urban scenario, proposed in the case study of ECHORD++, stands as one of the most promising because cities are prepared.

In a continuous learning by doing, the ECHORD++ PDTI in urban scenarios has given fourteen robotic urban challenges proposed by Cities' Councils of all Europe, all of them with innovative specifications about functionalities that will bring robotic solutions associated to be developed in the next phases. The role of the academia as coordinator was essential, not only in technological topics but also in the management of all the process. All of these proposals will be the starting point of a new robotic RTD solution.

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Glossary of terms

PPI	Public Procurement of Innovation
PCP	Pre-Commercial Procurement
PDTI	Public end Users Driven Technological Innovation
ECHORD++	The European Coordination Hub for Open Robotics Development Plus Plus
RTD	Research and Technological Development
GDP	Gross Domestic Product
UAV	Unmanned Aerial Vehicle
SME	Small and Medium Enterprises