ECHORD++

Public end-users Driven Technological Innovation – PDTI. Case Study: PDTI in Urban Scenarios

1st Annual white paper on the structured dialogue

Public end-users Driven Technological Innovation – PDTI. Case Study: PDTI in Urban Scenarios

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1 Summary

Focussed on application-oriented research and development, ECHORD++ (E++) is being funded by the European Comission in the 7PM for five years to improve and increase the innovation in robotic technology. Activities include small-scale projects and a “structured dialogue” incorporating public entities and citizens. Three instruments and processes are being developed under the ECHORD++ project: experiments (EXP), Research Innovation Facilities (RIF) and Public end-user Driven Technological Innovation (PDTI), all of them aimed at improving and increasing the innovation in robotic technology within SMEs companies and addressing answers to societal and industrial needs in different scenarios. E++ will elaborate four Annual White Papers describing the outcomes and results of the project, the tasks of communication and dissemination and the structured dialogue between all the involved stakeholders.

The first Annual White Paper is focused on the PDTI process and the lessons learned during the first 24 months of E++. The aim of this white paper is to introduce the novel PDTI process with the intention of boosting the innovative research in technologies and specifically in robotic technology and to contribute and join efforts to improve public services. After an overview of the innovative public procurement instruments, the PDTI process is described with emphasis in its relationships with one of these instruments, the Pre-Commercial Procurement (PCP) process, looking to investigate the 4 phases proposed in this instrument. The case study of the Echord++ PDTI in Urban scenarios brought us the opportunity to more deeply develop the phase 0 of a common PCP through a group of Activities for Understanding Public Demand with the active participation of the end users. Finally, this first Annual White Paper describes the outcomes and findings in robotic technology in urban scenarios and the future proposals for innovative public precommercial procurements.

2 Objectives and scope

Different policies from the European Commission have looked to take advantage of the very large volume of public procurement in helping to create an innovative Europe and solving the lack of an innovation-friendly market (1). The Europe 2020 strategy includes innovative public procurement as one of the key market-based policy instruments for smart, sustainable and inclusive growth. Currently being around 19.4% of the Gross Domestic Product in Europe, Public Procurement has an immense potential to fully exploit research and technology for innovation while also delivering more cost effective and better quality of public services. In some cases the technologies needed to make these breakthroughs exist or are close to the market; in other situations, investment in R&D is needed to assure the progress of technological solutions that meet the defined societal needs. In this last case, the instrument used by public entities is a Pre-Commercial Procurement (PCP), located into the procedures of Innovative Public Procurement. 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 could be a range of deficiencies in the PCP process including information asymmetries, lack of interaction between buyers and potential suppliers, perceived exclusion of small companies, risk aversion on both the public and private sides (2) and the lack of knowledge within public entities about what the technologies are and the problems they could solve.

However the good results of the Innovative Public Procurement in the United States of America public sector, where spend in research, development and innovation is 20 times that in Europe, give us a clear goal to reach. It is in this scenario where the ECHORD++ project proposes the process “Public end users Driven Technological Innovation” (PDTI) to increase and improve the innovation in robotic technology developing deeper the phase 0 of the commonly accepted PCP definition. Situated in the demand-side innovation policy, the PDTI develops a group of tasks and activities aimed at developing a deeper knowledge of public demand and which could be defined as a public measure to accelerate innovations and/or speed up diffusion of innovations through increasing the demand, by specifying and defining new functional requirements for public products and services that could be met through robotic interventions. An intensive dialogue between all the stakeholders involved has been essential to narrow the wide field for innovative public procurement: public entities as procurers; technological consortiums as suppliers; users as surveyors and the research team as coordinator of all the process.

3 Overview of the innovative Public Procurement Instruments

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 (3). Two main public procurement instruments’ have been developed for use in the product innovation life cycle: Pre Commercial Procurement (PCP) and Public Procurement for Innovation (PPI). Public Procurement for Innovation (PPI) 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 (PCP) means procurement of research and development services involving risk and benefit sharing under market conditions, as well as the 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 Comission, 2014) (Figure 1).

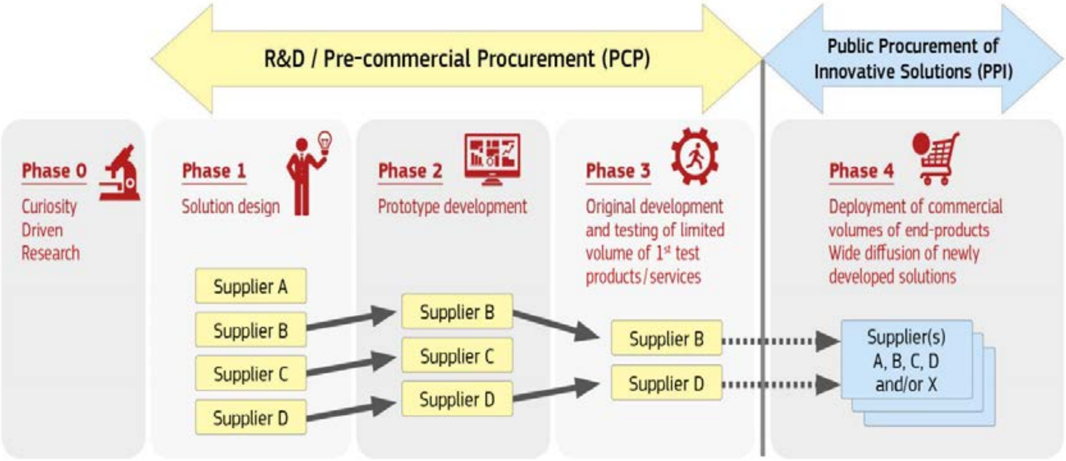


Figure 1. Innovation Procurement Instruments

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 exist from demand and supply side: there are market failures (information problems) and system failure (poor interaction); suppliers of potential new products and services often lack the knowledge on what customers might require in the future; user-producer interaction and communication rarely helps to produce synergetic results and innovative supplier firms perceive a lack of expertise within procurers and see it as a strong barrier to supplying innovative goods or services (4).

On the other hand, a public call for RTD tenders or proposals, may not be well understood by potential suppliers. Its complexity requires much more comprehensive development of the preliminary phases of public requirements, which takes account of 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 at understanding the requirements of both of the authorities and the users. Moreover, the innovative technology that can give a response to these needs has to be fully analysed to determine how it will improve the quality of the public service or to reduce its economic cost. The aim is that a joint consortia of industry and academia could offer innovative pre-commercial products linked to real demand.

The analysis presented in the document Quantifying Public Procurement of R&D of ICT solutions in Europe (Digital Agenda for Europe, SMART 2011/0036, European Union, 2014) highlights the poor initiatives developed by the 29 European Countries in regard to innovative public procurement. Only one country in Europe was working with policies aligned to innovative public procurement strategy in 2014: Spain. A series of policy measures supporting innovative public procurement in this country was the formal origin of the stimulus: the agreement of the Council of Ministers from 2/7/2010, where the State's Innovation Strategy was adopted; the Science, Technology and Innovation Act (Law 14/2011, June 1st) explicitly mentions innovative public procurement, while an agreement of the Council of Ministers from 8/7/2011 sets out the procedure for the implementation of innovative public procurement in all ministerial departments and public bodies. 13 innovative public procurement contracts were awarded in Spain between October 2012 and April 2013, with a combined total value of about EUR 18 million. In Urban policies, the article Urban Competiveness and Public Procurements for Innovation presents the case study of six Nordic-Baltic Sea cities that have developed six specific Innovative Public procurements from 1998 to 2007. The authors of the article propound the position that the main triggers for procurement for innovation is based in the necessity of the cities to answer social needs. The experience of the Nordic-Baltic Sea cities reveals that, in general terms, the fact that there are a small number of cases relates to the reality that public procurement for innovation at the urban level is not very common. Public procurement for innovation has not, ubtil recently, been seen as an inherent part of the cities' innovation policy and mostly the cities tend to implement supply-side policy measures.

4 The PDTI process

Given this background, the lessons learned in the case study of the ECHORD++ project could help in the introduction of novel PDTI processes and generalize the process to other domains. Routed in the product innovation life cycle, and based on Pre-Commercial Procurements, the PDTI proposes a process that comprises two main phases (Figure 2):

- Activities for understanding public demand
- Activities for research and technological development of pre-commercial products.

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

Figure 2. Relation between PCP and PDTI processes,

The "Activities for understanding public demand" increase and structure the tasks developed in the phase 0 of a traditional PCP. The "Activities for research and technological development of pre-commercial products", match the phases 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 does not engage with the whole cycle from identification of needs. They also tend to omit the wider set of actors and stakeholders (5). To the importance of this identification of needs, as well as looking to bring future needs and future supply together at an early stage, the first part of the PDTI process, the Activities for understanding public demand, develops four qualitative phases inspired by the Delphi methodology (6): Brainstorming, Narrowing Down, Ranking and Challenge Description. This group of activities ends in a Call for Proposals /Tenders, initiating the Activities for research and technical development of pre-commercial products structured as a Pre=Commercial Procurement: Solution Design, Prototype Development and Small Scale Test Series (Figure 3).

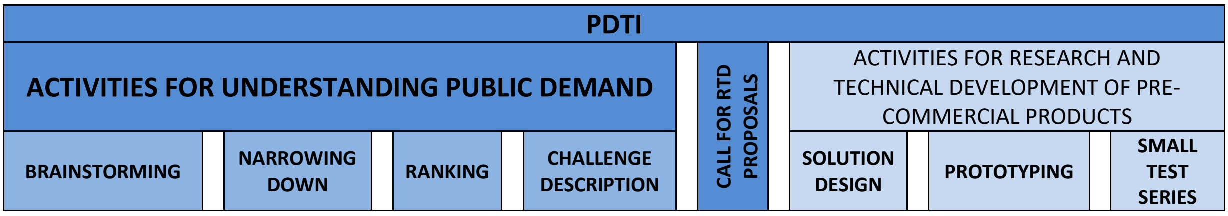


Figure 3. PDTI process and activities

An overview of the full PDTI process can be seen in Appendix 1.

5 The PDTI process: Activities for Understanding Public Demand

The novelty of the PDTI is to develop the phase 0 of a traditional PCP, putting more emphasis on the preliminary tasks and proposing a previous and critical 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 (2).

This part of the PDTI process, Activities for Understanding Public Demand, is a qualitative procedure inspired by Delphi methodology and allows a group of stakeholders to systematically approach a particular task or problem (7). In our case, the objective is the reliable and creative exploration of social needs related to public services that could be solved through technology and the production of sustainable information for decision making in the area of Innovative Public Procurement. The methodology employs iterations of questionnaires and feedback through series of rounds to develop a consensus of opinion from the participants. There is not a limit of time, but it is necessary to consider a minimum and a maximum number of rounds. After each step, specific documentation will be generated as the conclusion of the developed activities as well as the starting point of the next phase.

Figure 4 shows the methodology to develop the Activities for understanding public demand, the stakeholders involved, the tasks to develop and the documents elaborated in each one of the four phases. First of all, a Collaboration Agreement should be signed between all the stakeholders as an official requirement to start the process. This document will describe the roles of the different agents, the process and the proposed methodology.

	ACTIVITIES FOR UNDERSTANDING PUBLIC DEMAND				
USERS **SURVEYORS**		USERS **SURVEYORS**			CALL FOR RTD PROPOSALS /TENDERS
RESEARCH TEAM **COORDINATOR**	RESEARCH TEAM **COORDINATOR**	RESEARCH TEAM **COORDINATOR**	**EXPERT PANEL**	RESEARCH TEAM **COORDINATOR**	
PUBLIC ENTITIES **PROCURERS**	PUBLIC ENTITIES **PROCURERS**	PUBLIC ENTITIES **PROCURERS**		PUBLIC ENTITIES **PROCURERS**	
TECH CONSORTIA **SUPPLIERS**			TECH CONSORTIA **SUPPLIERS**		
PROCESS	**BRAINSTORMING**	**NARROWING DOWN**	**RANKING**	**CHALLENGE DESCRIPTION**	
	1-3 ROUNDS	**WORKSHOP**	**OPEN MARKET**	**1-6 ROUNDS**	
METHODOLOGY TASKS AND ACTIVITIES	**TASK 1.**STATE OF THE ART IN TECHNOLOGY APPLIED TO SOCIAL NEEDS AND CHALLENGES. **TASK 2.** TECHNOLOGICAL NEEDS IN EXISTING PUBLIC SERVICES	**TASK 3.** EVALUATION CRITERIA / IMPACT INDICATORS **TASK 4.** MANAGEMENT OF THE FEEDBACK OF ALL STAKEHOLDERS	**TASK 5.** CHALLENGE EVALUATION THROUGH IMPACT CRITERIA **TASK 6.** SELECTION OF CHALLENGES	**TASK 7.** ELABORATION OF THE CHALLENGE BRIEF AND PREPARATION OF THE DOCUMENTATION FOR THE CALL FOR TENDERS / PROPOSALS	
COLLABORATION AGREEMENT	**QUESTIONNAIRE**	**CLASSIFIED CHALLENGE LIST**	**CHALLENGE SELECTED**	**PRODUCT IDEA CHALLENGE BRIEF**	

Figure 4. PDTI Activities for Understanding Public Demand: process, methodology, tasks and activities.

The stakeholders will be the Public Entities and their specific departments, the Users, the Users' Associations, the Industry, the Technology Manufacturers, and the Research and Academy Institutions and Organizations. They have different roles to play in PDTI. The procurers are the Public Entities; the suppliers are the technological consortiums; the surveyors are the users; and finally, the coordinator is the research team, which will give the technological support to the public sector for developing and implementing the innovation-oriented procurement. The role of the coordinator is needed to drive and lead the complete process based on innovation. Due to the complexity of this process, it is valuable that the coordinator has a team of people coming mainly from technological areas but also from other areas such as economics, psychology or political science fields (8).

The participation of users will take place all along the development of the PDTI to survey the process and participate in it, through different activities. The contact and participation of users can be done through local associations such as Living Labs. These living labs offer us a real-life test and experimentation environment where users and producers co-create innovation in a trusted and open ecosystem.

- *Brainstorming*

The process starts with an identification of the real needs as perceived by the users and budget holders rather than procurement officials. At this stage two tasks are developed: Task 1. Analyze the state of the art in technology applied to social needs and technological challenges; Task 2. Analyze the technological needs in existing or new public services. Sometimes the identification of the needs is constrained by lack of knowledge of the innovation potential (2). The objective of this step is the elaboration of a Questionnaire of Public Needs and its associated Innovative Technology, based on an improvement of existing public services, the associated cost reduction or the creation of new services. At the same time the benefits of innovative technology can be introduced in public sector stakeholders. Interactive collaboration between organizations is extremely important for innovations to emerge, in the demand/pull side as in the supply/push side (8). The success arises through interactions between the stakeholders in several rounds. A questionnaire of the public needs and the associated innovative technological solutions is the tool used within each round. The information elaborated in each round will be collected, edited and returned by the coordinator to prepare the next round. Finally a consensus final Questionnaire is elaborated.

- *Narrowing Down*

This phase has the objective of focusing the needs proposed in the Questionnaire using specific criteria. It consists of two tasks. The objective of Task 3 is to obtain a group of impact indicators. Clear narrowing down instructions should be provided emphasizing the clarity and simplicity (9). 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 impacts indicators must be created and they will be used in the evaluation and selection of the Innovative Challenge List.

Task 4 consists in the management of the stakeholder 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 gain their opinion. Also, the use of social media allows a large number of people to be reached covering a wide spectrum of experience and expectations, however it is not always easy to obtain an actionable result. To gather users' opinion it is very useful to organize activities with them all along the process. As we have said, the elaborated 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.

- *Ranking*

The third phase of the Activities for understanding public demand is undertaken by an expert panel composed by designated people from the Public Entity and the

Research Team. Task 6 consists of evaluating the List of innovative challenges while task 7 is where the selection of the public challenges is undertaken. The expert panel has to use the impact indicators, however other criteria can also be used in conjunction. In this process, the number of selected Public Challenges will depend on the budget of the Public Entity and of the potential market offered by the procurer weighted according to the size relative to the costs involved in the development of the Innovation.

- ***Challenge Brief***

The aim of this phase is to create the Challenge Brief. This 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 ensure that this Challenge Brief is not a common procurement document, but an innovative one, and has to be written taking into account the required innovative functionalities benefitting the public service instead of the standard requirements that could narrow the innovation field.

Further rounds of discussion between the public entity and the research team are required to ascertain the functionalities that meet the high-ranking innovative challenges. The definition of the functionalities should involve the end user of the public entity rather than general service personnel who are not directly involved in their implementation, especially if they do not have direct access to the relevant information (10). At least, 2-6 meetings are necessary in order to get to the Challenge Brief. This document has to specify the functionalities of the new technology, which must be chosen from the current functions, those that can be developed but are not standard and the new ones that will optimize the benefit to the public service.

The translation of needs/problems/challenges into functionalities requires highly developed competences, or at least understanding, at the technological level on the part of the procuring organization (8) and the role of the researchers in the consortium is essential. The Challenge Brief will be the main document for the Call for Proposals/Tenders and the starting point of the second part of the PDTI process, the “Activities for research and technical development of pre-commercial products”.

6 The case study of E++ PDTI in urban scenarios

Urban areas have been identified as one of the application scenarios for the E++ PDTI. Cities cover 2% of the earth surface, and they represent more than 50% of the world’s population (11). Smart cities have become an important area where technology has an important impact in the areas of energy, environment or mobility (Lund Declaration, 2009). However, these smart cities present challenges that cannot be solved with the products and services that already exist, but they can be solved if research is undertaken to find the best solutions. More specifically, robotic technology will be one excellent capability that will able to solve problems that at present cannot be, or have not been, considered to answer urban challenges.

In this section we will explain, how the PDTI phase 0 described in the previous section has been applied to find robotic solutions to the urban challenges required by European cities. This work has been done by the Universitat Politècnica de Catalunya and the Technological University of Munich, inside of the E++ project.

The PDTI process is a tool for the municipalities to provide the enabling conditions for private sector exploring how local governments foster, support and aid in the creation and diffusion of innovation opportunities (12) answering societal urban needs. On the other hand, robotic technology could give real answers to cities and citizens' challenges, but is not well known by the public procurers. This lack of sufficient procurement expertise for complex purchases involving innovation (4) and the good preparation of the cities to receive new technological proposals have encouraged us to propose and develop the PDTI process in urban areas.

In October 2013 we started the Activities for understanding public demand, 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. The objective was an open and coordinated structured dialogue between all the stakeholders involved following the four steps described previously.

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

A first group of urban needs were developed, and we started to discuss how the robot technology could provide a solution for these needs. First, we discussed with the UPC team, which was composed of robot researchers, economists and architects, and the outcome was a first document specifying the city needs and the associated robot technology. Then we talked again with the city councils to see if those solutions were suitable. We undertook rounds of discussion and the outcome was the E++ Urban PDTI Questionnaire.

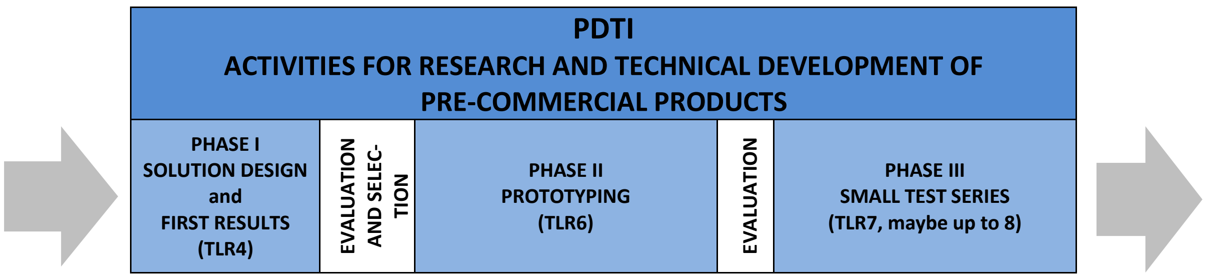
To prepare for the Narrowing Down phase we reviewed the existing documentation regarding impact and evaluation criteria and we asked to the City Councils about their public procurement evaluation. We also analyzed the document "Analysis of the feasibility studies from the Future Cities Demonstrator Program: Cities Solutions" (Arup, 2013), developed for the Cities of United Kingdom. This document analyzes the expected benefits to citizens, to city economy and local authorities. This identified three new solutions for the public sector services, the first one is based on improvements in the citizens' 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 costs' reduction. Using these documents, we elaborated a list of impact criteria, which included the following elements: i) **Social and Cultural Impact**, to improve citizen's participation, independence, accessibility and mobility, and to improve the quality of life, better public services and replicability of the proposal in other districts and cities; ii) **Environmental Impact**, to improve resource efficiency, to improve sustainable mobility and potential for sustainable growth; iii) **Economic Impact**, to increase the support to small and medium companies and leverage private funding, increase or improve employment opportunities and the evaluation of the cost/benefit of the new technology; and iv) **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. Finally, we also evaluated the **City Presentation** and its implication in a Pre-Commercial Procurement Pilot with the objective to increase and improve technological robotic innovation through public demand in urban environments.

The E++ Urban PDTI Questionnaire, completed with the impact criteria for evaluation (Appendix 2), 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 this massive effort and so we decide to make contact again, personally by email or telephone and program individual meetings when it was possible. We also programed a workshop in a propitious scenario, the Smart City 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 the robotic technology into public entities, we invited 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' proposals from European Cities addressing specific challenges with a detailed description of the public service to improve or create by robotic technology.

The third phase, the Ranking, consisted in the evaluation and selection of the most promising Urban Robotic Challenges to be funded through the E++ project. A first evaluation round was undertaken remotely by experts that evaluated and weighted the proposals, and the outcome was a list of weighted challenges (Appendix 3). The second evaluation was done by a panel of experts, during a physical meeting that selected the ECHORD++ PDTI Urban Robotic 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 others phases of the process. The final document included a prioritized challenges' list

Finally, we prepared the main document for the Call for RTD Proposals: the Challenge Brief. As we have 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 robotics researchers and four people of the city council directly involved in the performance of the public service. During eight rounds we discussed the requirements of the new technology: "present" (actual requirements), "possible" (desired requirements) and "optimal" (optimal requirements) of the 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 hand, that would give rise to a pre-commercial product (Appendix 4).

The second part of the E++ PDTI will include the activities for research and technical development of the pre-commercial products and they will be developed during the next 34 months. This part will start with 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 (Figure 5)



2015 Challenge Exploitation 2019

Figure 5. Activities for research and technical development of Pre-Commercial Products.

7 The outcomes of E++ Urban PDTI and the innovation in Urban Robotics

As we have said before, 14 urban robotic challenges were received from different European City Councils. The wide scenario of urban challenges was structured and analysed looking to stablish synergies between the urban needs proposed and under a new technological-urbanistic point of view. We structured them in three groups: city infrastructures, information and communication technologies related to different urban areas and technologic challenges for pedestrian areas at the city, (Figure 6).

INFRASTRUCTURES	**HELSINKI Finland**	**Traffic infrastructure inspection and maintenance.** Decreasing the cost of maintenance and increasing the area livability through robotisation 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 aerial robots in the management, planning and urban city knowledge.
ICT AND MOBILITY	**SEVILLA Spain**	**Planning and information of urban accessible routes.** The robotic challenge 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 6. E++ Urban Robotic Challenges.

We also organized two workshops with local living labs and we started the recruitment of E++ citizens' collaborators, looking to receive their feedback through the different phases of the project. We used the E++ web site to publish this activity. 103 citizens were involved to survey the activities programed in E++ Urban PDTI and their first task was to evaluate the Robotic Urban Challenge List (Figure 7) at the Science and Technical Party celebrated in June 2014 in Barcelona. We arranged the survey according to ludic criteria, in order to motivate their feedback as a qualitative procedure. We received comments and suggestions that we collected and joined to the challenges' evaluation.

URBAN AREAS	CITY CHALLENGES	CITIZEN S
INFRASTRUCTURE	Traffic infrastructure inspection and maintenance	6,44%
INFRASTRUCTURE	Automatic detection and road surface damage warnings	6,44%
INFRASTRUCTURE	Improving waste management and street cleaning	12,23%
INFRASTRUCTURE	Utilities infrastructure condition monitoring	6,44%
ICT & ENVIRONMENT	Environmental monitoring and control	11,30%
ICT &TOURISM	Improving tourist services at the city	3,92%
ICT & PLANNING	Improving the management, planning and urban city observations 1	5,98%
ICT & MOBILITY	Planning and information of urban accessible routes	5,98%
ICT & SURVEILLANCE	Providing safe and secure environment for citizens	3,64%
ICT & MOBILITY	Improving the management, planning and urban city observations 2	2,52%
PEDESTRIAN	Personalized mobility support for pedestrian areas	8,87%
PEDESTRIAN	Providing safe and secure environment for citizens	13,33%
PEDESTRIAN	Goods distribution technology to improve local retail	4,04%
PEDESTRIAN	Personalized mobility support	8,87%

Figure 7. Citizens' Evaluation.

8 Comparison and Conclusions

Urban competitiveness will drive municipalities to engage in the procurement for innovation, but the innovative public procurement is unknown for most of cities' procurers. Municipalities could boost procurement for innovation in the initiation phase of the technology life cycle, co-creating new solutions with the private sector to sustainability challenges and opportunities in the cities. The development of technology is the key to mastering these challenges and transformations in the European Cities and the PCPs and PDTIs are the right tools to accelerate them.

Few examples of Public Procurement for Innovation have been developed in Europe over the last few years. The last data presented by the European Commission DG CNECT Innovation Unit F2 in December 2015, showed that the ICT procurement amounts to 2,5% of GR (Gross Revenue) and the R&D procurement 0,1% of GR. As we have said at the beginning of this article, the United States of America public sector, invests $50Bn a year in PCPs as against €2,5Bn invested in the EU (European Commission 2015).

The case study of six Nordic-Baltic Sea cities (12) brings us six specific Innovative Public procurements from 1998 to 2007. 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. In Spain, 83 procedures of innovative public procurement have been developed from 2011 to 2016; 56 are pre-commercial procurements and 6 have been presented by local authorities related to Smart Cities. In general terms the fact that there are a small number of cases relates to the reality that public procurement for innovation at the urban level is not very common. Public procurement for innovation has not been seen until now as an inherent part of the cities' innovation policy and, mostly, the cities tend to implement supply-side policy measures.

In spite of this, the European cities are prepared. Their competitiveness makes them strong and at the same time, the innovative public procurement makes them more competitive. The lead-user role played by the cities can have spectacular results in innovative public procurement and the case study of Echord++ and the development of the first part of the PDTI bring us a structured and proactive process to achieve them: 14 urban robotic challenges posed and defended by 10 European City Councils, all of them with robotic technology associated one step below an innovative RTD public call.

Cities and citizens have specific needs, not solved by existing market products, which require innovative solutions. These innovative solutions are based in new technologies that are unknown for public managers. At the same time, the technological consortia of industry and academia do not understand the real cities' challenges. In this scenario, the PDTI process sets the link to public entities for the development of innovative public procurement. It is clear that the Innovative public procurement increases the support to companies and leverages private funding. thereby increasing and improving employments opportunities in the cities. The few cases of public procurement for innovation have had a positive impact, not only on the providers but also with regard to the positive influence that public sector can have on innovation-friendly markets. A positive impact on companies is evidenced by the increased exports and changes in companies' routines having an end user driving their RTD development. The social impact improves citizens' accessibility and mobility in most of the cases as well as resulting in better public services.

The results achieved in the Echord++ PDTI process, during the first months of work, in a continuous learning by doing, brought fourteen innovative urban challenges proposed by Cities' Councils across Europe. All of the challenges encompassed innovative technology, specifications about functionalities and were one step away from a call for RTD tenders. The role of the academia was essential, not only in technological topics but also in the management of the whole process.

All of these proposals could be the starting point of a new Innovative Public Pre-Commercial Procurement.

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Appendix 1. Overview of PDTI Process

INNOVATIVE PUBLIC PROCUREMENT INSTRUMENTS

	PUBLIC END USERS DRIVEN TECHNOLOGICAL INNOVATION - **PDTI / PCP** - PRE COMMERCIAL PROCUREMENT										**PPI**
STAKEHOLDERS ROLS	**ACTIVITIES FOR PUBLIC DEMAND KNOWLEDGE**					**ACTIVITIES FOR RESEARCH AND DEVELOPMENT OF PRE COMMERCIAL PRODUCTS**					**PUBLIC PROCUREMENT FOR COMMERCIAL ROLL-OUT**
USERS **SURVEYORS**		USERS **SURVEYORS**			**CALL FOR RTD PROPOSALS /TENDERS**		**EVALUATION & SELECTION**		**EVALUATION & SELECTION**		
RESEARCH TEAM **COORDINATOR**	RESEARCH TEAM **COORDINATOR**	RESEARCH TEAM **COORDINATOR**	**EXPERT PANEL**	RESEARCH TEAM **COORDINATOR**							
PUBLIC ENTITIES **PROCURERS**	PUBLIC ENTITIES **PROCURERS**	PUBLIC ENTITIES **PROCURERS**		PUBLIC ENTITIES **PROCURERS**							
TECH CONSORTIA **SUPPLIERS**			TECH CONSORTIA **SUPPLIERS**			CONSORTIUM A CONSORTIUM B CONSORTIUM C CONSORTIUM D		CONSORTIUM B CONSORTIUM C CONSORTIUM D		CONSORTIUM C AT LEAST 2	
PROCESS	**BRAINSTORMING**	**NARROWING DOWN**	**RANKING**	**CHALLENGE DESCRIPTION**		**SOLUTION DESIGN**		**PROTOTYPING**		**TESTS SERIES**	
METHODOLOGY TASKS AND ACTIVITIES	**1-3 ROUNDS**	**WORKSHOP**	**OPEN MARKET**	**1-6 ROUNDS**		**RTD MONITORING**		**RTD MONITORING**		**RTD MONITORING**	**COMMERCIAL PRODUCTS / SERVICES**
	TASK 1. STATE OF THE ART IN TECH APPLIED TO SOCIAL NEEDS AND CHALLENGES. **TASK 2.** TECHNOLOGICAL NEEDS IN EXISTING PUBLIC SERVICES	**TASK 3.** EVALUATION CRITERIA / IMPACT INDICATORS **TASK 4.** MANAGEMENT OF THE FEEDBACK OF ALL STAKEHOLDERS	**TASK 5.** CHALLENGE EVALUATION THROUGH IMPACT CRITERIA **TASK 6.** SELECTION OF CHALLENGES	**TASK 7.** ELABORATION OF THE CHALLENGE BRIEF AND PREPARATION OF THE DOCUMENTATION FOR THE CALL FOR TENDERS/PROPOSALS		• THE PROCESS IS MONITORIZED BY THE COORDINATOR AND THE PUBLIC ENTITY • CLEAR EVALUATION CRITERIA & TECHNIC AND IMPACT KEY PERFORMER INDICATORS (KPI) AT THE END OF EACH PHASE SHOULD BE PROVIDED. • ORIGINAL DEVELOPMENT OF A LIMITED VOLUME OF FIRST PRODUCTS					
MILESTONES											
COLLABORATION AGREEMENT	**QUESTIONNAIRE**	**CLASSIFIED CHALLENGE LIST**	**CHALLENGE SELECTED**	**PRODUCT IDEA CHALLENGE BRIEF**		**SOLUTION DESIGN** FIRST PROTOTYPE		**PROTOTYPE TESTED**		**PRE-COMMERCIAL PRODUCT**	

Appendix 2. E++ PDTI Questionnaire. Urban Robotic Challenges

ECHORD++ *PCP URBAN ROBOTS*: CHALLENGE EVALUATION PROCESS

Public authorities are faced with societal challenges in present cities. Technology is setting a new landscape of possible improvements in public services. ECHORD++ project in Urban Robotics looks for reliable robot systems in urban tasks.

Please, let us know your opinion about the proposed city challenges and its associated robot technology.

First column: Proposal: Challenges (in black) and its associated robot technology (in blue)

Second column: Write your comments and opinions. Try to address the challenge through impact indicators. (1)

Third column: Evaluate: Are you interested in participating in this challenge?
(5-Very interested, 4-Somewhat interested, 3- Neutral, 2-Not very interested, 1-Not at all)

Name and position *Insert your name* City *Insert your city* Contact *Insert info*

Cities and citizens challenge	*Comments*	*Interest* (1-2-3-4-5)
Energy. Increase the production from distributed and renewable energy sources and approach the uptake and storage of energy in the place of consumption, boosting energy production on an urban scale.	*Include your comments here*	--
Robotic infrastructure for cleaning and maintenance of solar panels.	*Include your comments here*	--
Robotic infrastructure for distribution of electric rechargeable batteries	*Include your comments here*	--
ICT Technology. Improve the quality of connectivity in cities.	*Include your comments here*	--
Mobile robotic repeaters to enlarge the connectivity in large agglomerations.	*Include your comments here*	--
Collaborative Society. ICTs are setting a new landscape for analyzing society, to make it interact and collaborate, developing citizens initiatives.	*Include your comments here*	--
Robot citizen information infrastructure.	*Include your comments here*	--
Robot urban citizen service.	*Include your comments here*	--
Robot technology to communicate with citizens.	*Include your comments here*	--
Collaborative Society. Empowering local retail through technology.	*Include your comments here*	--
Goods distribution robot technology	*Include your comments here*	--
Collaborative Society. Improve the quality of life ensuring citizens feel safe and secure.	*Include your comments here*	--

Robotic assistants in emergency situations.	*Include your comments here*	--
Robotic surveillance system	*Include your comments here*	--
Environment. To efficiently respond to the challenges in areas such as mobility, energy and environmental protection, resilient cities must establish systems capable of handling the massive amount of data.	*Include your comments here*	--
Robot technology to provide maps: acoustic, contamination and pest maps.	*Include your comments here*	--
Optimal path planning.	*Include your comments here*	--
Environment. Improve waste management and streets cleaning.	*Include your comments here*	--
Robotic street cleaning infrastructure	*Include your comments here*	--
Mobility. There is a new city planning, refocusing on how to make cities more pedestrian, bicycle and public transport friendly, while an expansion of new infrastructures to facilitate the mobility far of the car centered planning.	*Include your comments here*	--
Robotic wheelchair for elderly.	*Include your comments here*	--
Robots for dependable people in pedestrian areas.	*Include your comments here*	--
Mobility. 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. It's necessary the development of transport service integration, sharing schemes and mobility management.	*Include your comments here*	--
Robotic system for automatic detection of damaged road surfaces.	*Include your comments here*	--
Robots for sewage networks.	*Include your comments here*	--
Your Challenge *Include your challenge here*	*Include your comments here*	--
Robot Technology *Include your robot technology here*	*Include your comments here*	--
Your Challenge *Include your challenge here*	*Include your comments here*	--
Robot Technology *Include your robot technology here*	*Include your comments here*	--

Social & Cultural Impact: Does this challenge improve citizens' independence, accessibility and mobility? Does it improve quality of life and better public services?
Environmental Impact: Does this challenge address resource efficiency? Does it show potential for sustainable growth? Does it improve sustainable mobility?
Economic Impact: Does this challenge increase the support to *small and medium* enterprises? Does it increase or improve employment opportunities? Does it give a positive relation cost/benefit?
Innovation Impact: Does the proposal give a positive relation risk/benefit? Does it give a positive evaluation of the product life cycle? Does it present capacity to integrate systems and synergies?

Appendix 3. Evaluation Criteria and Impact Indicators

ECHORD++ PDTI PROCESS RANKING		SOCIA & CULTURAL IMPACT	ENVIRONMENTAL IMPACT	ECONOMIC IMPACT	INNOVATION IMPACT	CITY INVOLVEMENT
		25%	15%	15%	25%	20%
HELSINKI Finland	**Traffic infrastructure inspection and maintenance.** Decreasing the cost of maintenance and increasing the area livability through robotisation of the city's maintenance traffic at the Smart Kalasatama designated smart city area, including both vehicles and installed infrastructure in the area.					
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.					
CORNELLA Spain	**Improving waste management and street cleaning.** Perform tasks with less cost for the maintenance of parks and gardens.					
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.					
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.					
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.					
SEVILLA Spain	**Improving the management, planning and urban city observations.** The use of aero robots in the management, planning and urban city knowledge					
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.					
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.					
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.					
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.					
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					
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.					
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.					

SOCIAL & CULTURAL IMPACT: *Improve Citizens Participation, Independence, Accessibility and Mobility *Improve Quality of Life and Better Public Services *Replicability of the Proposal in other Districts or Cities. ENVIRONMENTAL IMPACT: *Improve Resources Efficiency *Potential for Sustainable Growth *Improve Sustainable Mobility. ECONOMIC IMPACT: *Increased support to SME and Leverage Privat Funding *Increase or Improve Employment Opportunities *New Tecnology Evaluation Cost/Benefit. INNOVATION IMPACT: Evaluation of the Risk/Benefit of the proposal *Evaluation of the product life cycle *Capacity to Integrate Systems and Synergies.

SEVENTH FRAMEWORK PROGRAMME

-

“UTILITIES INFRASTRUCTURES AND CONDITION MONITORING FOR SEWER NETWORK. ROBOTS FOR THE INSPECTION AND THE CLEARANCE OF THE SEWER NETWORK IN CITIES”

CHALLENGE BRIEF –CALL FOR PROPOSALS

Project acronym: **ECHORD ++**

Project full title:

European Clearing House for Open Robotics Development Plus Plus

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1. SUMMARY

THE CHALLENGE IN URBAN ROBOTICS: Robots for the inspection and the clearance of the sewer network in cities

Sewer inspections require many people to work in risky and unhealthy conditions.

Introducing a robotic solution in this process aims at reducing the labour risks, improving the precision of sewer inspections and optimizing sewer cleaning resources of the city.

This system should be able to determine the state of the sewer in order to identify sewer segments where its functionality has been reduced either by sediments or by structural defects. Other functionalities required are sewer monitoring and water, air and sediment sampling.

To well carry out these tasks, some general functions are desirable like remote operation, video and images capture, scanning and map building, among others.

2. DESCRIPTION OF THE CURRENT SITUATION

2.1. INTRODUCTION

The current need of the City of Barcelona is to mechanize sewer inspections in order to reduce the labour risks, objectify sewer inspections and optimize sewer cleaning expenses of the city.

The sewer network of Barcelona is 1532 km long, from which approximately 50% is accessible, which means that the pipe is at least 1.5 m high and workers are allowed to go inside it.

In order to determine the state of the network, visual inspections are done with different frequencies depending on the slope and other characteristics of the sewer. Workers walk all along the pipe, in some sections even four times a year, and decide where it is necessary to clean.

Moreover, sewers are classified as confined spaces which require special health and safety measures, in addition to other risks like slippery sections, obstacles or biological risks from the eventual contact with wastewater.

These features made the process of sewer inspection a risky and expensive process that requires improvements urgently.

Sanitation worker controlling a home drain

Sewer inspection is a service included in the public management of the sewers of Barcelona. Nowadays, sewer inspections are done by people performing visual inspections and collecting information about the state of the sewage like sediment level and type, pipe obstructions, etc.

Because of the sewer risks, the performance of the inspections is about 1.5 km of sewer every 6 hours.

This methodology requires approximately 1 million Euros per year in staffing expenses only, excluding equipment, machinery, health and safety measures, or other expenses.

The requirements for the new technology are given by the inherent sewer characteristics, namely:

- different ranges of pipe sizes
- possible high concentration of, not explosive, but toxic gases as hydrogen sulphide
- slippery areas
- obstacles
- atmosphere with 100 % humidity
- water temperature 16 °C
- no telecommunication coverage in the sewer

There is no regulation that applies to this public service except for the prevention of occupational hazards and, in particular, the regulation of access to confined spaces.

The city is willing to amend the legislation of its jurisdiction for introducing this new technology.

Barcelona sewage system network has a wide variety of sewers. As previously stated, the sewer network of Barcelona is 1532 km long, from which approximately 50% is accessible. This percentage is higher than other similar cities where it is normally less than 30%

This enables us to test the technology in various sewer sizes and facilitates the transfer of the technology to other cities.

This urban challenge is expected to:

- improve sewer workers health and safety measures
- improve the public service given since it optimizes the sewer cleaning resources
- improve the quality of life of citizens since it will improve the sewer performance

2.2. BARCELONA SEWAGE DATA

2.2.1. Characterization of sewers according to their visitability

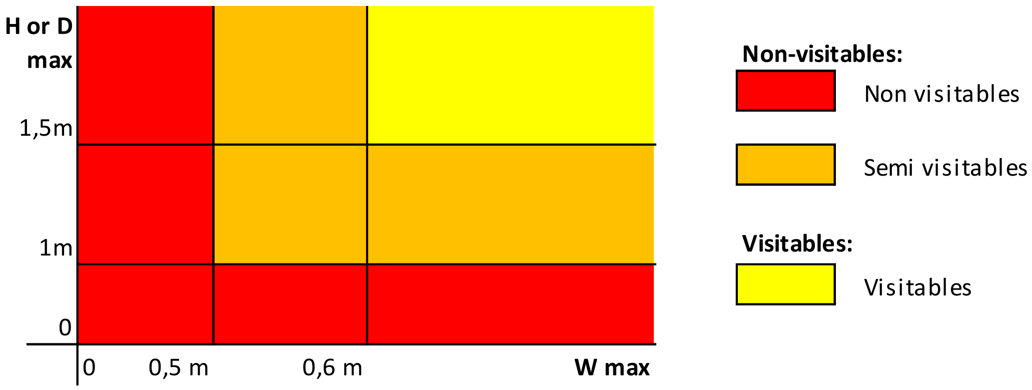
According to the characteristics of sewer sections, there are three possible situations according to their height (H) and width (W). In the case of tubular sewers, diameter (D) is equivalent to height (H).

a) If H or D ≥ 150 cm and W ≥ 60 cm: Visitable sewer, except sewers without curb (in this case it is considered as semi visitable sewer).
b) If H or D ≥ 100 cm and W ≥ 50 cm: semi visitable sewer.
c) If H or D < 100 cm or W < 50 cm: non visitable sewer.

Visitable sewers: these stretches are feasible due to their size and allow staff access to its interior.

Non visitable sewers: due to its dimension or morphology, these stretches do not allow staff access to its interior.

Semi visitable sewers: due to its characteristics, the access to these stretches is restricted to the application of additional measures, to be defined for each type of task.



Note: in tubular sections, visitability is conditioned by the size criteria (D) and the existence of curb. In case that the sewer fulfils size conditions but do not have curb, it will be considered as semi visitable.

2.2.2. Sewer network data

The following table states the length of the sewer network, in lineal meters, according to their visitability.

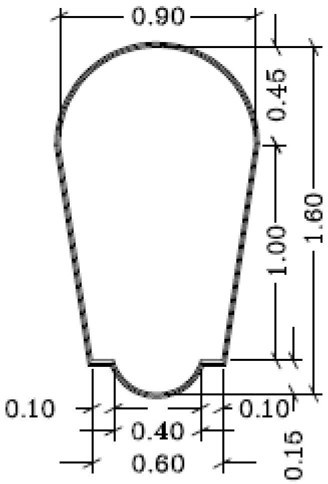
TYPE OF SEWER	LENGTH (m)	PERCENTAGE
Non visitable sewers	541.000	35%
Semi visitable sewers	148.000	10%
Visitable sewers	843.000	55%
TOTAL	**1.532.000**	**100%**

Total length of sewers is classified into the following ranges of heights. Notice that sewers heights below 1m are considered non visitable, and sewer heights between 1m and 1.5m are considered semi visitable.

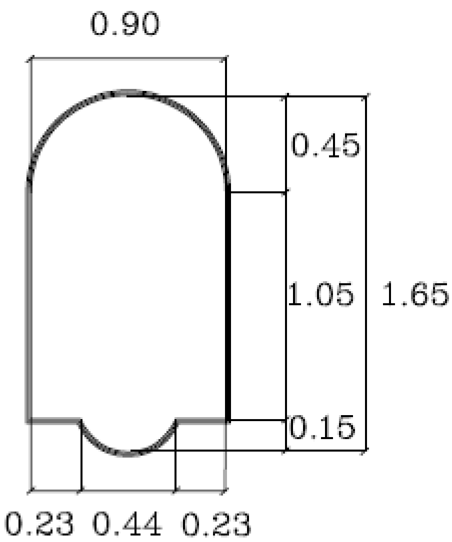
MAXIMUM HEIGHT	NO TUBULAR	TUBULAR
	LENGTH (Km)	LENGTH (Km)
< 1m	30	511
1m <= x < 1.5m	114	34
1.5m <= x < 2.0m	668	6
2.0m <= x < 2.5m	91	4
2.5m <= x < 3.0m	44	1
3.0m <= x	27	2
TOTAL	**974**	**558**
	1.532	

Sections that make up the Barcelona sewage network are widely varied. Nowadays, there are up to 2.076 types of sections from which the most common are the T111 and T130.

T111



T130



Finally, the following table states the number of existing inlets and manholes in the sewer network.

ELEMENT	NUMBER
Manholes	42.425
Inlets	62.397
Grates	3.564

3. CURRENT TECHNOLOGY FOR KNOWLEDGE AND MANAGEMENT OF SEWER SYSTEM

3.1. INSPECTION VEHICLES

Currently inspection tasks can be supplemented by inspection vehicles equipped with different types of sensors according to the level of detail and autonomy required.

The current market has been analyzed and here there is a list of solutions that currently exist to inspect the sewer.

More or less, there are common features in all devices that are:

- Rolling ground displacement devices.
- Ultrasonic sensors.
- Sonar sensor used usually for detection and inspection underwater not for navigation.
- Laser for 3D reports of de sewer.
- Pan-Tilt-Zoom cameras with several degrees of freedom.
- Own lighting, based on LEDs.
- Electromagnetic sensors to evaluate structural integrity.
- External control units equipped by a cable reel that supplies energy to the unit and transmit the control.
- Set of different bodies and wheels to adapt the inspection unit to the sewer that has to be inspected mainly with two criteria, the diameter and deterioration or condition of the sewer surface.

These inspection vehicles can do mainly the following functions:

- Follow the commands from the operator console.
- Move in one direction.
- Adapt the vehicle to the sewer dimensions before the access, in a range that goes from 100 mm to 2000 mm approximately.
- Move along the sewer as much distance as cable length is available in the cable reel.
- Illuminate the sewer by them-selves.
- Record video in several degrees of freedom and also with one articulated arm with a camera at the end of it, record some meters of bifurcation sewers that are smaller than the vehicle like for example inlet sewers.
- Generate 3D models of the sewer.
- Support for reports of the state of the sewer
- Support to evaluate the structural integrity of the sewer

3.2. INSPECTION ROBOTS

In addition to the inspection vehicles described, that are difficult to consider them as robots, there are other types of sewer inspection devices that are self-propelled. This kind of devices that could be considered as robots have the following features:

- They are able to move themselves in one direction by sewer and record video in 360º to register the state of the sewer.
- It is also possible to analyze the sewer by zooming and navigating in 360º by the video images.
- These robots are able to access into the sewer system at one point and being recuperated in other point in an autonomous way.
- They can be equipped with cameras, LASER, *Lidar* and INS** technology*, Sonar sensor (for underwater detection if there is some stream of water) and hydrogen sulphide sensor.
- With all data collected by the sensors, it is possible to generate a model of the interior of the sewer and identify the possible impairments.

The improvements in the existing technology that this project seeks for are

- To facilitate real-time decision making
- Innovation that make inspection devices more autonomous
- To have more degrees of freedom to move around the network
- The possibility to intensify the checking of a zone where impairment has been detected.

** The Lidar technology (acronym of Light Detection and Ranging) is used in robotics for the perception of the environment and classification of objects. With this technology is possible to make three-dimensional elevation maps of the terrain and take levels with high accuracy among other things.*

*** The INS technology (acronym of Inertial Navigation System) is used in robotics for navigation calculating via dead reckoning the position, orientation, and velocity (direction and speed of movement) of a moving object without the need for external references. This technology uses motion sensors (accelerometers) and rotation sensors (gyroscopes).*

4. FUNCTIONS AND CONDITIONS OF THE NEW TECHNOLOGY

The objective of developing this new technology is to mechanize sewer inspections in order to reduce the labour risks, objectify sewer inspections and optimize sewer cleaning expenses of the city.

Visitable sewers (under normal conditions, there is no light inside sewers)

4.1. ASSESSMENT CRITERIA AND WEIGHTING

The selection of the proposals will be based on the following four sections (in parenthesis the weighting relative to the total score):

1. Scientific and technological excellence (60%)
2. Quality and efficiency of the implementation and the management (10%)
3. Potential impact trough the development, dissemination and use of the project (10%) and economic impact (20%)

This brief challenge is expected to explain the **Scientific and technological excellence criteria** applied to the proposals' evaluation and the **Economic impact assessment**.

4.1.1. Scientific and technological excellence criteria

The **Scientific and technological excellence** part in turn is divided into the three following parts:

<u>How well the proposed technology addresses the challenge as detailed in the Challenge Brief document?</u>

The functions summarized in the following table are what the new device has to be able to do and are fully explained beneath. Within the weighting of this question, the weighting of each of these functions is the following:

<table>
<tr><th colspan="3">FUNCTIONS</th><th colspan="2">WEIGHT</th></tr>
<tr><td rowspan="5">Sewer serviceability inspection</td><td colspan="2">Sewer performance (at least 1000 lineal meter/labour day)</td><td>10%</td><td rowspan="5">80%</td></tr>
<tr><td colspan="2">Images (Video)</td><td>40%</td></tr>
<tr><td colspan="2">Geometric analysis (scanning)</td><td>20%</td></tr>
<tr><td rowspan="2">Monitoring</td><td>Air</td><td>9%</td></tr>
<tr><td>Water</td><td>1%</td></tr>
<tr><td colspan="3">Structural defect inspection</td><td colspan="2">15%</td></tr>
<tr><td colspan="3">Sampling</td><td colspan="2">5%</td></tr>
</table>

<u>How well does the proposed technology integrate the required functionalities?</u>

- *How intuitive is the technology for the end users?* This means for example the ease for operations and recharges achieved by the technology or the autonomy for self-resolving the operator orders.

- *How easy can the technology be integrated in the environment?* By this question it is expected to evaluate the minimum dependency from the environment conditions. For instance, the score for this question could be associated to:
  - Wireless technologies
  - Flying devices
  - A high operational speed in order to reduce the affectation to public roads by the opened manholes covers.
  - Maximum reliability with the minimum incidents (for recovering a robotic system, some staff has to be mobilised)

- *How robust is the technology?* Minimum maintenance expenditures and high components' reliability and simplicity will be assessed.

- *Does it solve specific technological challenges (Mobility, Communication, etc)?* In order to assess this question, the following abilities will be evaluated:
  - The level of motion capability
  - The level of communication achieved and the interaction capability
  - The expected autonomy (in terms of batteries or available energy)
  - The decisional autonomy
  - The degree of transferability
  - The scalability of the technology
  - The adaptability
  - The cognitive ability

- The configurability
- The dependability,
- The flexibility
- The manipulation ability
- The perception ability

And finally, to what extent shows the proposal a clear plan for the development of a working solution?

4.1.2. Economic impact assessment

The economic impact expected to be reached trough the implementation of this technology is fully explained in the subheadings 4.2.2.1. Economic performance and 5.1. Economic impact.
The price of the solution for total cost independent of the business model determines the points awarded. In between a linear scale will be used to one decimal point.

4.2. GENERAL FUNCTIONS AND CONDITIONS

4.2.1. Environment conditions

The general requirements for the new technology are given by the inherent sewer characteristics that restrict the staff access in plenty of cases:

- Possible high concentration of, not explosive, but toxic gases as hydrogen sulphide or carbon monoxide
- Slippery areas
- Obstacles
- Atmosphere with 100 % relative humidity
- Water temperature around 16 °C
- No telecommunication coverage in the sewer

In particular, for the robot size design, it is important to take into account the pipe size and the manhole diameter. In the case of sewers with diameter below 0.8 m the inspection problems are solved with the existent technology. Because of that, the future technology has to be focused in pipes with diameter over 0.8 m.

In addition, although the standard manhole diameter in the city of Barcelona is 0.70 m, it is suggested to consider a diameter ≤0.60 m since it could be reduced by the manhole stairs and other singularities.

4.2.2. General services

The following are the general services required for well developing the specific functions exposed beneath.

Economic performance

Developers should consider that the public administration is interested in obtaining the full service of inspection and not just the robot. That is why the cost of the complete inspection brigade for working in visitable sewers (with all its elements like inlets, manholes, siphons, slope changes, etc.) should be less than 0.50 € / lineal meter. This price includes the necessary and sufficient staff, the previous works required for the inspection, signage, elements of protection and security staff, ventilation, the equipment, tools, materials, assistance needed, reporting, editing, filming, etc. The current economic data for the sewer inspection service in Barcelona is fully developed in the subheading 5.1. Economic impact.

Robotic system performance

Since current inspection performance is about 1500 meters every 8 hours because of sewer conditions, the developed robot is expected to significantly enhance it. Thus the robotic system performance should be at least 1000 meters in 8 hours, and from this minimum inspection performance, the higher length inspection performance the higher score will be obtained by the bidders.

Remote operation

The robotic system must be able to receive instructions by an on-site operator located outside the sewer. The receiver has to be able to see images sent by the robot in real time.
In addition, the robotic system can navigate autonomously in order to move through the environment avoiding obstacles and sensing the sewer depending on the chosen functionality.

Digital images and video

The robotic system has to be able to send video images to the operator in real time at VGA standard at least. The images can be obtained with any kind of imagery sensor (CCD, IR, UV, X-ray….).

In addition to video sending, the robotic system has to have the ability of in-site recording snapshots at higher resolution and to make videos at WVGA-30fps system. Also, the robotic system has to be able to record video sequences at HD standard under demand.

Scanning

The robotic system has to be able to perform a 3D scan of the sewer under demand.

The planned uses for the scanning are:

- To compare the obtained data with the available information of the sewers (mainly type and section) and identify where the sewer serviceability has been reduced or where there is a structure defect.
- To precisely identify the sewer structure on the areas where reduction or widening of the sewer's section happens.

Sewer elements location and mapping

Sewer management, like any issue tightly linked to the territory, must be based on the reliable knowledge of the location and characteristics of the environment. This basic principle in network management services, traditionally solved using paper maps, now has dramatically improved with the use of geographic information systems (GIS).

Knowing the location of all sewerage lines and identifying its basic elements, such as connections, street inlets and home drains, enables a more effective sewerage management, as in most networks sewer operation is closely linked to terrain topography.

The service provider obtains significant benefits by adding geo-referenced information to their systems, for reasons not only technical but also strategic:

- It supplies precise knowledge about an important company's asset: the current infrastructure.
- This information is used to strengthen hydraulic models, which provide insight into the network hydraulic characteristics and thus allowing accurate strategic decision making and efficient operation, planning and development of new infrastructure.
- Provides greater flexibility in the distribution of information both inside the corporation and externally.
- Maintenance and rehabilitation of sewers require reliable knowledge about the network and the territory it drains.

Into the sewer there are a number of structures and connections that heavily modify network's behaviour and because of that it is needed to know their nature and location. Thus, this project should assist on the mapping of sewers and the localization of its elements:

<u>Sewer map building</u>

The mapping of sewers must be made taking as a starting point the location of the manhole covers. Each manhole cover should be referenced to the cartography base (sidewalks, buildings, road axis ...).
It is also necessary to map the typology of the path between the elements of the sewer (straight or curved), since these data are decisive for making the map and necessary in order to calculate the hydraulic parameters of the sewage system.

<u>Sewer elements location</u>

The distance between manholes and other elements inside the sewer should be measured as the robot moves forward through the sewer.

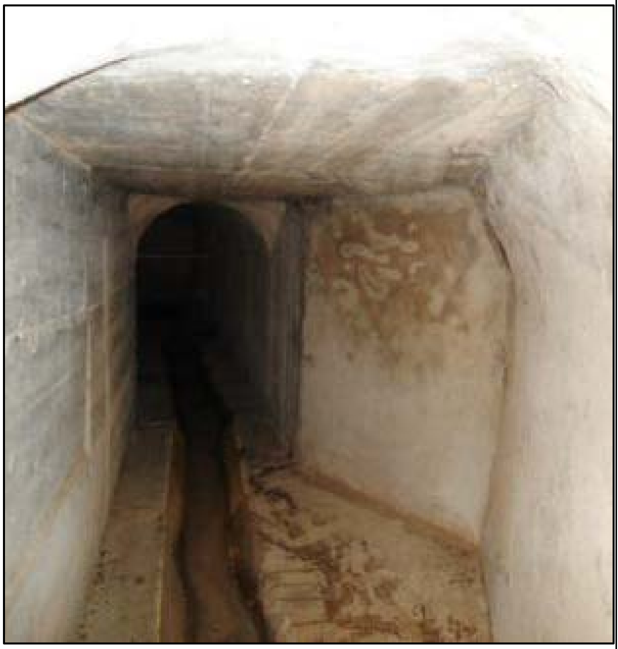
The angular position of each element from True North must be provided.

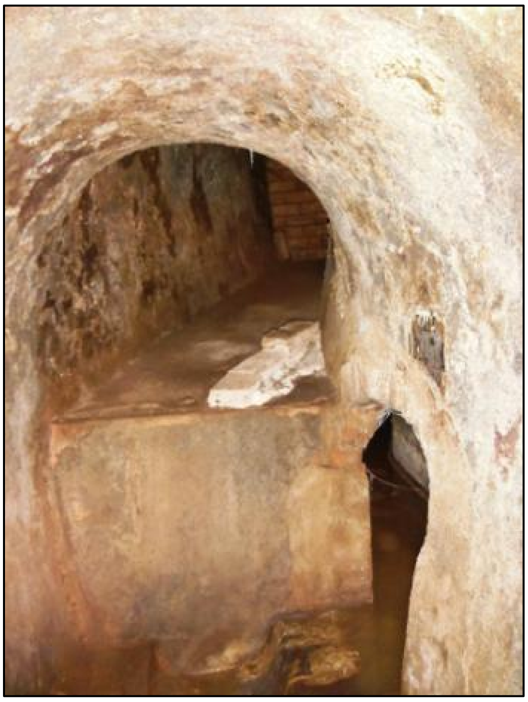
On the areas where reduction or widening of the sewer's section happens, a 3D scan must be done in order to precisely identify the structure.

The elements that have to be located at least:

- Manholes


- Home drains inlets	- Street drains inlets
	

- Points where two or more sewer lines cross at the same level and connect	- Points where a noticeable reduction or broadening occur
	

- Points with sudden slope changes	
	

4.3. SPECIFIC FUNCTIONALITIES

The specific functions that the new technology must address are the main challenges in the sewer inspection:

1) Determining the sewer serviceability
2) Identify critical structural defects
3) Sewer monitoring
4) Water, air and sediment sampling

4.3.1. Sewer serviceability inspection

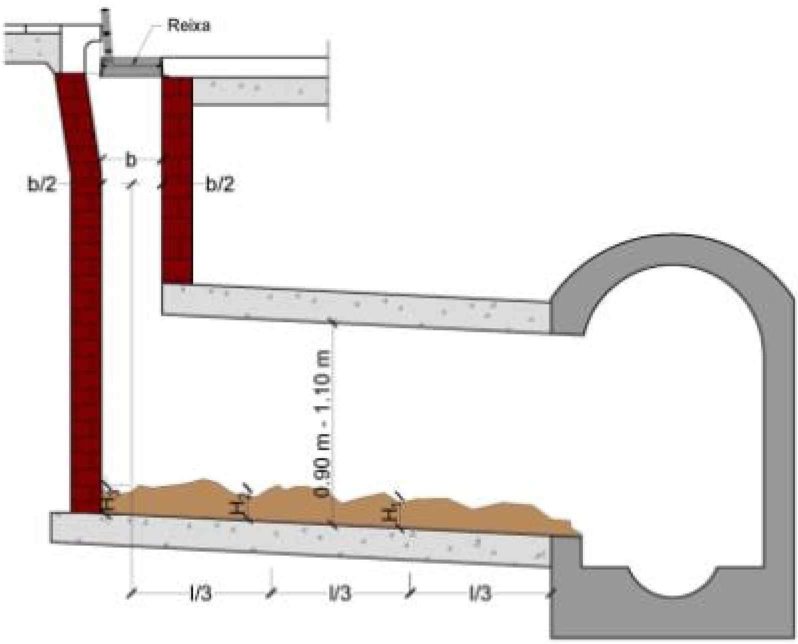
Serviceability reduction alarm

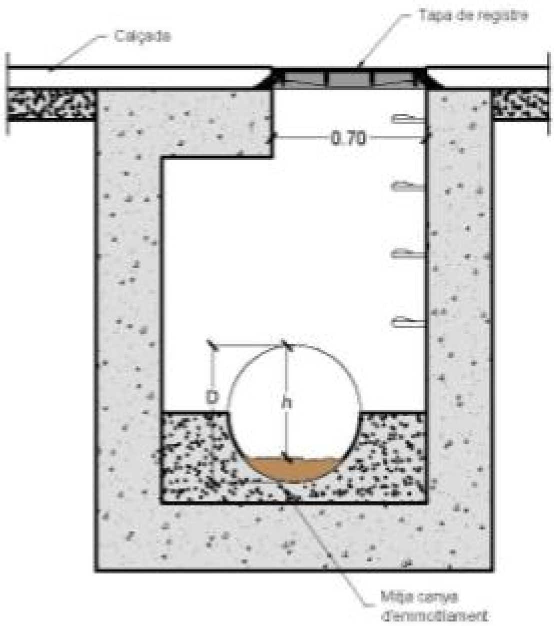
On the basis of the scanning or the video made, the robot has to compare the obtained data with the available information of the sewers (mainly type and section) and identify where the sewer serviceability has been reduced.

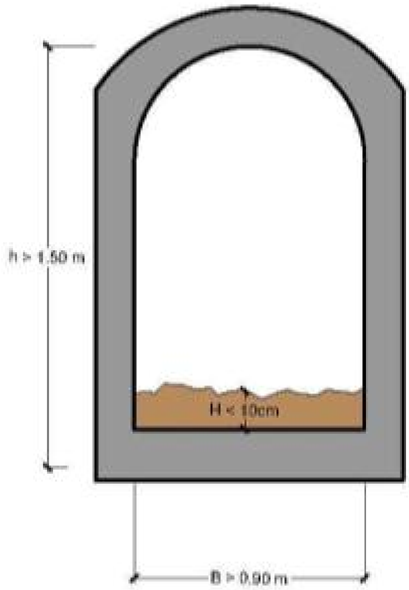
The operator should receive a “pop-up” alarm that indicates the location of the obstruction and helps to decide if the robot has to make an extra specific snapshot or video.

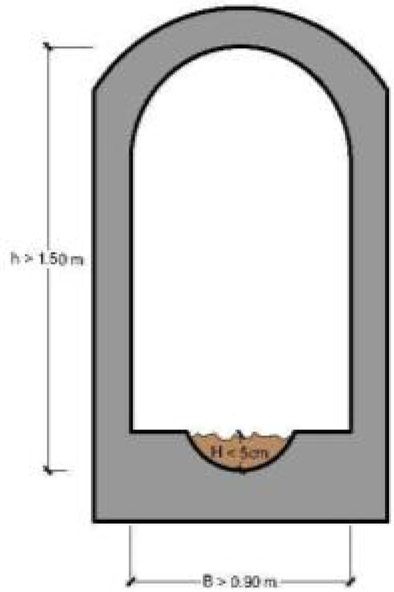
Criteria for serviceability reduction alarm

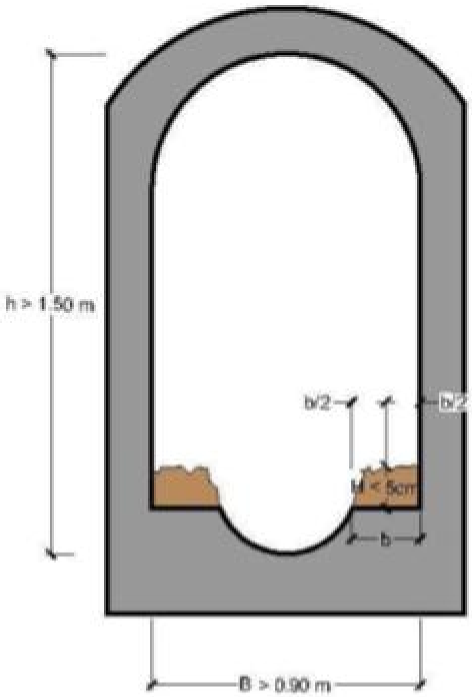
The following table shows the minimum standards of serviceability for the various items to be inspected by the prototype, which determine no need to be cleaned. Those elements that exceed the defined values will be collected on a proposal of sewer stretches that need to be cleaned in order to ensure the optimal operation of the sewer.

PARAMETER	VALUE
GUTTERS or INLETS	
Level of waste at Gutter Tunnel: Thickness of the waste accumulated in the tunnel gutter. The level of waste will be measured in three equidistant points distributed along the axis of the gutter tunnel considering the first measurement point located in the centre of the gutter manhole. The maximum height of the waste should not exceed 10 cm in two of the three measured points. The existence of bulky waste (stones greater than 10 cm in diameter, construction debris, wood or sticks, etc.) will imply cleaning the entire tunnel regardless of the measurement values obtained.  	< 10 cm

PARAMETER	VALUE
TUBULAR VISITABLE SEWER	
Free section: section of the tubular sewer free from waste. If the waste is deposited uniformly throughout the sewer, or part thereof, with circulation of wastewater without causing obstructions or odours, the height free of wastes will be measured at the manhole. If the waste is accumulated at one or more points distributed along the tubular sewer producing obstructions and odours, the sewer stretch will be proposed to be cleaned regardless of the measurement values obtained.  	> 90%

PARAMETER	VALUE
VISITABLE SEWER	
With flat sill: waste height deposited on the sill. If the waste is deposited uniformly throughout the section, or part thereof, with circulation of wastewater without causing obstructions or odours, the height of wastes will be measured at the point where the greatest volume of sediment is perceived. If the waste is deposited at one or more points distributed along the sewer producing obstructions and odours, the sewer stretch will be proposed to be cleaned regardless of the measurement values obtained.  	< 5 cm

PARAMETER	VALUE
VISITABLE SEWER	
With bucket: waste height deposited in the bucket The waste height will be measured in the centre of the basin at the manhole. If the waste is deposited at one or more points distributed along the sewer producing obstructions and odours, the sewer stretch will be proposed to be cleaned regardless of the measurement values obtained. 	< 5 cm

PARAMETER	**VALUE**
VISITABLE SEWER	
With Curb: waste height deposited at the curb. The waste height will be measured in the centre of the curb at the point where the greatest volume of sediment is perceived. If the waste is deposited at one or more points distributed along the sewer curb producing obstructions and odours, the sewer stretch will be proposed to be cleaned regardless of the measurement values obtained. 	< 5 cm

4.3.2. Structural defects inspection

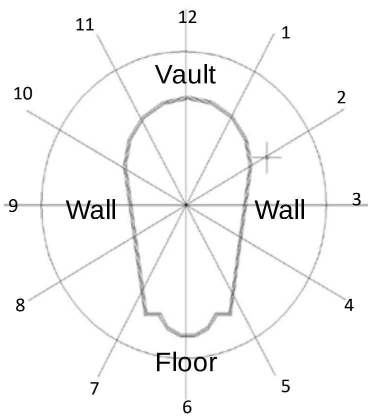
The prototype should locate and identify critical damage inside the sewers, whether it is located on floor (sewer's bottom), vault (sewer's roof) or walls.

Identification of critical defects should be done according to the table below:

NAME	UNE-EN13508-2 CODE	DESCRIPTION	EXAMPLES
Crack	BABB	Crack lines can be seen on the sewer's walls, floor or vault. Fragments are still in place.	
Fracture	BABC	Noticeably open cracks on the sewer's walls, floor or vault. Fragments are still in place.	
Break	BACA	Fragments of sewer wall, floor or vault visibly displaced, but not lost.	
Break with loss	BACB	Missing fragments on sewer walls, floor or vault.	

NAME	UNE-EN13508-2 CODE	DESCRIPTION	EXAMPLES
Collapse	BACC	Structural integrity completely lost.	

Defects location should be stated giving the following measurements:



Circular location following a clock-face pattern

- Distance from the nearest manhole to the defect: nodes (manholes and inlets) are codified in the GIS.
- Circular location following clock-face pattern (12-above, 3-right hand, 6-below, 9-left hand).

4.3.3. Sewer monitoring

The objective of sewer monitoring is to approximate the robot to the maximum level of sensitivity which will allow the sewer manager to make decisions without exposing to risky locations. Among other reasons, sewer monitoring is extremely useful:

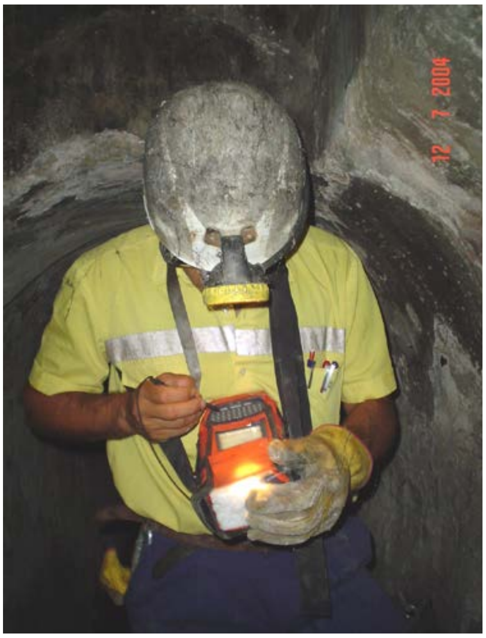
- To avoid access to sewers at risk situations
- To decide safety and health measures for staff
- To locate and follow spills or leaks, normally illegal, in order to protect sewer infrastructures from abrasion, rust and aggressive spills
- To determine tendencies in compounds (seasonal, daily, etc.)
- As a tool for environmental research in sewers

It would be highly recommendable to incorporate to the robot the following functions:

<u>Air Sensors</u>

Knowing the environmental quality of the sewers is very important to determine both safety parameters and odours occurrence. Improvements in the former could help to reduce risk situations and optimize human resources. Besides, the last is a very important issue for managers due to the increasing citizen's sensitiveness.

- Temperature (T)
- Relative Humidity (%RH)
- Carbon Monoxide (CO)
- Hydrogen sulphide (SH_2)
- Methane (CH_4)
- Oxygen (O_2)
- Lower explosive limit (LEL)
- Volatile organic carbons (VOCs)



Example of sewer monitoring

<u>Water sensors</u>

The knowledge of the water quality with real time monitoring is interesting for detecting tendencies in compounds (seasonal, daily, etc.) that flow along sewers. Complementing this functionality, punctual changes detected in water quality can alert about spills.

- Temperature (T)
- pH
- Conductivity
- Turbidity

4.3.4. Sampling system

Sampling objectives are the very same of monitoring systems. Furthermore, sampling systems in sewer networks, as a second step or as a complement after monitoring, is greatly important in order to obtain valid and traceable information which could be used afterwards to determine environmental legislation and policies.

Examples of spills

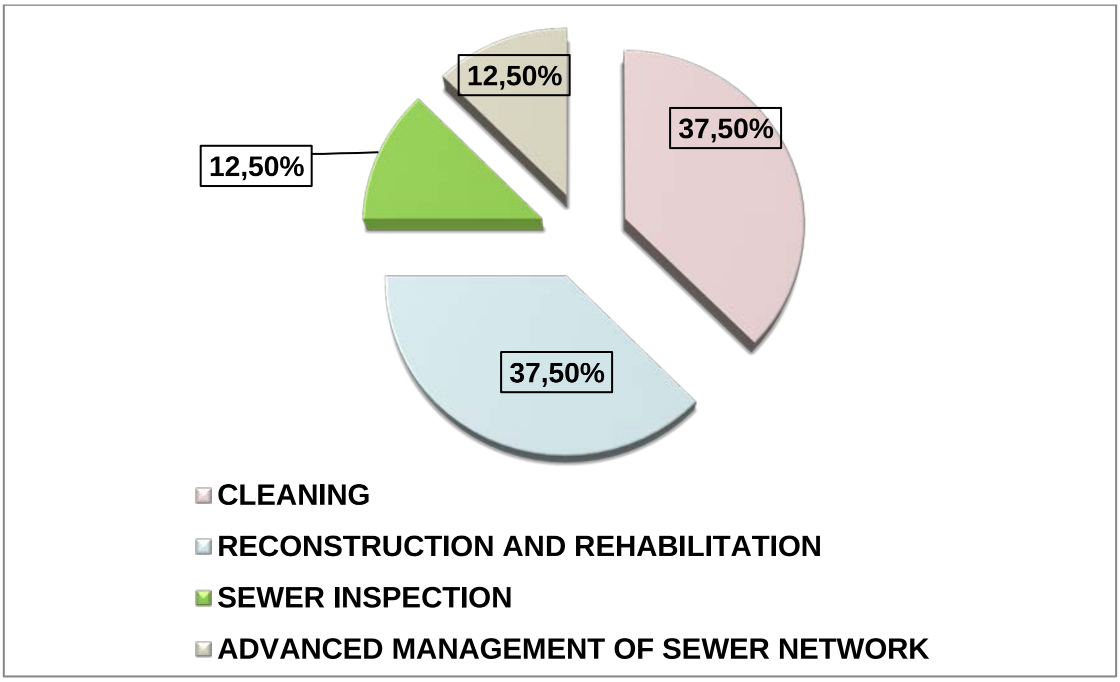
It is difficult to establish a minimum volume required per sample, as this depends on the parameters to be analyzed. However, at least the minimum following volumes would be necessary:

- Water sampling: 300 ml (higher volumes will have greater value)
- Air sampling:
  - Passive sampling system like active carbon filters (for instance, 530 mg of active carbon)
  - Active sampling system like air capsules
- Sediments sampling: 300 ml

5. EXPECTED IMPACTS

5.1. ECONOMIC IMPACT

The sewer inspection cost in Barcelona is about 1 million € per year what represents 12.5 % of the total cost of sewers management as it is shown in the following figure.



As shown in the following summary, the current cost associated to the inspection of visitable sewers with the objective of determining the serviceability level (not structural defects) is about **0.75 €/lineal meter**. This cost includes a complete inspection brigade for working in visitable sewers (inspecting all its elements like inlets, manholes, siphons, slope changes, etc.), the previous works required for the inspection, signage, elements of protection and security staff, ventilation, the equipment, tools, materials, assistance needed, reporting, editing, filming, etc.

<u>Summary of the principal cost data for the visitalbe sewer inspection service in Barcelona:</u>

- An inspection brigade is composed by 2 skilled officers, 1 pawn and a driver equipped with a van (leasing) and costs **110 €/h**.
- Nowadays there are 4 brigades available. That means: 4 brigades * 110€/h * 8 h * 214 labour days = **753.280 €/year** for the inspection service
- These 4 brigades inspect the 1.000.000 m of visitable sewers at least once a year. Thus, we obtain that 1.000.000 m / (214*4) = 1168 lineal m/(day*brigade) which means that a brigade can approximately inspect **1168 lineal meters per day**.
- Finally, as stated before, the unitary cost is 753.280 € /1.000.000 m = **0,75 €/ lineal meter**

Thereby, in case the new technology developed reduces the cost to 0.50€ /lineal meter, as it is required in the subheading 4.2.2.1. Economic performance, the saving would be about 30%.

Improving the efficiency of sewer inspections in general is expected to reduce not only the expenditure in sewer inspection tasks but the cleaning, reconstruction and rehabilitation expenditures as well. Savings done could revert in more investments for improving and innovating in sewage integral management.

5.2. ENVIRONMENTAL IMPACT

The impacts expected in environment are varied. For instance, by facilitating the inspection tasks, the new technology would help to enhance the sewer performance and in turn it would prevent overflows both to the city and to the environment.

Through early detection of defects in the sewer, it would be feasible to prevent waste water leaks to the underground that could finally get into underground water.

And, monitoring and sampling into the sewers would provide with deeper knowledge of the sewage tendencies. This would help to tackle and design measures to reduce odours from sewers and environmental policies would be directly addressed to the current specific circumstances of the city of Barcelona.

5.3. SOCIAL AND CULTURAL IMPACT

As stated before, the citizens' quality of life would improve since a better sewer performance would prevent overflows and odour problems.

Additionally, a sewer inspection made with a robot could minimize affectation to public roads as there would be no need to open all the manhole covers along the inspected segment for ventilating the confined space. In this way, roads that nowadays are inspected at night could probably be inspected in working hours thereby reducing its costs.

And last but not least, the new technology is expected to improve sewer workers health and safety since they will not have to enter into dangerous locations classified as confined spaces.

5.4. INNOVATION IMPACT

Access to confined spaces has always been a problem to deal with. Because of that, Barcelona city has developed a very specialized staff in entering into this kind of infrastructures, but the need of improving this method, making it more affordable and available, has been detected in other municipalities of the Barcelona Metropolitan Area and abroad in Spain. In these cases, where the public administration could not afford this service, visitable sewers were simply not inspected.

Thus, the new technology is expected to really improve the current inspection methodology by reducing the healthy risks for workers and making it affordable to public administrations.

5.5. ABILITY TO EXECUTE

Finally, the new technology is expected to be really feasible and affordable to implement and include in the current inspection services.

6. USES CASES

6.1. BARCELONA CITY

In order to better understand the current inspection difficulties, please visualize the presentation and the video presented during the Infoday Market Consultation that took place on the 20th November 2014 at Barcelona:

http://www.echord.eu/public-procurement/market-consultation-urban-robotics/

6.1.1. Affectation to public roads

The inspection methodology for confined spaces implies that all the manholes' covers along the sewer to be inspected have to be opened for previously ventilating the toxic gases. This means that the traffic has to be cut or reduced for doing the inspection. In the case of sewers under big and busy roads, inspections are done at night in order to reduce the affectation to the car traffic.

A sewer inspection made with a robot could minimize affectation to public roads as there would be no need to open all the manhole covers along the inspected segment for ventilating the confined space. In this way, roads that nowadays are inspected at night could probably be inspected in working hours thereby reducing its costs.

6.1.2. Toxic gases detection

In some points into the sewer network, high concentrations of hydrogen sulphide have been detected, probably due to an entry of waste water from a private pumping. In these cases, the access into the sewer is not possible or has to be done with extra safety measures as air masks. The application of the new technology could help to do a previous inspection in order to identify the source of the hydrogen sulphide.

7. OTHER EXAMPLES

7.1. BARCELONA METROPOLITAN AREA AND SPAIN

Although in lesser extent, other municipalities from Barcelona Metropolitan Area also have visitable sewers. As well as Barcelona City, they have to deal with the strict safety measures related to confined spaces and suffer from lack of specialised staff. Consequently, visitable sewers could sometimes not be inspected at all.

Some examples of cities with this kind of problem in Spain are Sevilla, Valladolid, San Sebastián, Saragossa or Palma de Mallorca, and cities where Barcelona sewage staff has done technical assessment are the following:

SITGES	LENGTH (Km.)	PERCENTAGE
Visitable	7.1	5.9%
No visitable	113.7	94.1%
TOTAL	**120.8**	**100%**

SANT ADRIÀ DE BESÒS	LENGTH (Km.)	PERCENTAGE
Visitable	9	13.6%
No visitable	57	86.4%
TOTAL	**66**	**100%**

SANTA COLOMA DE GRAMENET	LENGTH (Km.)	PERCENTAGE
Visitable	18.3	22.3%
Semivisitable	15.7	19.2%
No visitable	48.0	58.5%
TOTAL	**82.0**	**100%**

BADALONA	LENGTH (Km.)	PERCENTAGE
Visitable	50.3	15.8%
Semivisitable	33.3	10.5%
No visitable	234.8	73.7%
TOTAL	**318.4**	**100%**

7.2. CITY OF PARIS

The Paris sewage is more than 2.400 km length and has three basic characteristics: it is a combined sewer network, works by gravity and is almost completely visitable.
The network has the following types of sewers from the smaller to the highest:

TYPE OF SEWER	HEIGHT (m)	BUCKET (m)
Elemental sewers	1.3	-
Secondary collectors	3	1.2
Principal collectors	5 to 6	3.5
Emissaries (tubulars, no visitable)	2.5 to 6	-

The network is managed through an IT system named TIGRE (Traitement informatisé de la gestion du réseau des égouts) that stores the information about the sewers. This information is collected on site by the sewage staff that inspects the sewer network twice a year.