Ajuntament de Barcelona

Barcelona Cicle de l'Aigua SA

Medi Ambient i Serveis Urbans – Hàbitat Urbà
Barcelona Cicle de l'Aigua, SA

Acer, 16
08038 - Barcelona
Telèfon 932 896 800
www.bcasa.cat

Public end-user Driven Technological Innovation (PDTI)

"UTILITY INFRASTRUCTURES AND CONDITION MONITORING FOR SEWER NETWORK. ROBOTS FOR THE INSPECTION AND THE CLEARANCE OF THE SEWER NETWORK IN CITIES"

CHALLENGE BRIEF – RELATED TO THE ECHORD++ CALL FOR R&D PROPOSALS

Version 29.12.2014

INDEX

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.

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 potential 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

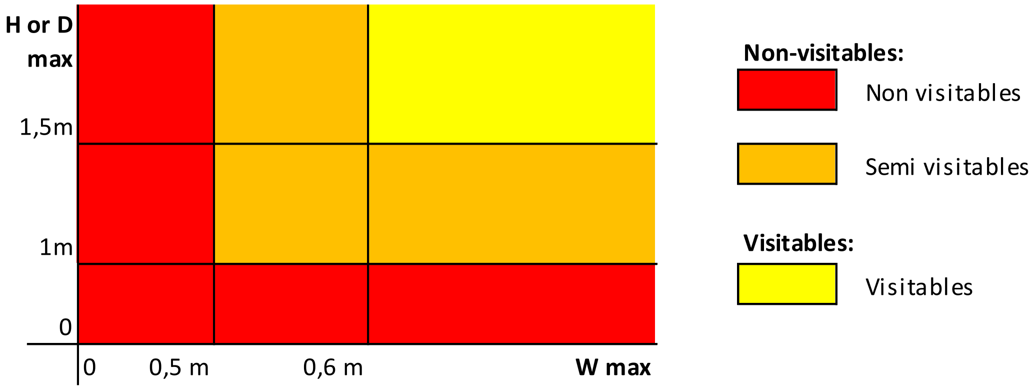
According to the characteristics of sewer sections, there are three possible situations according to their height (H) and width (W). In the case of tubular sewers, diameter (D) is equivalent to height (H).

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.

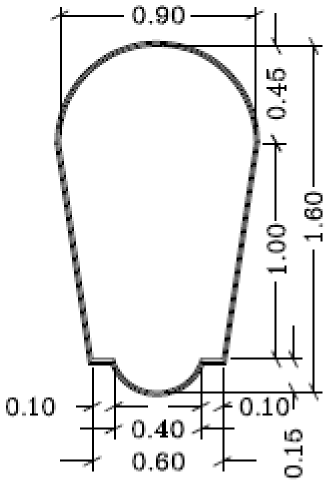
TYPE OF SEWER	LENGTH (m)	PERCENTAGE
Non visitable sewers	541.000	35%
Semi visitable sewers	148.000	10%
Visitable sewers	843.000	55%
TOTAL	**1.532.000**	**100%**

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.

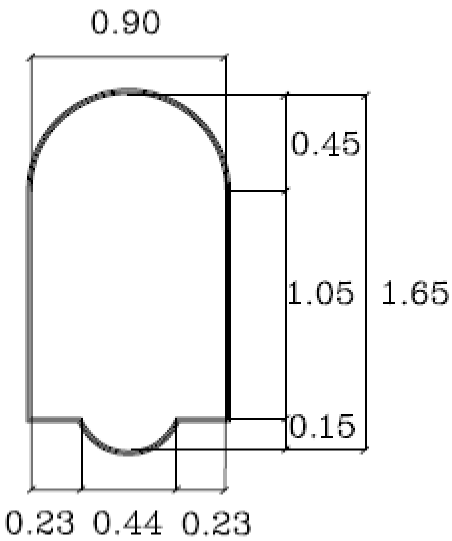
MAXIMUM HEIGHT	NO TUBULAR	TUBULAR
	LENGTH (Km)	LENGTH (Km)
< 1m	30	511
1m <= x < 1.5m	114	34
1.5m <= x < 2.0m	668	6
2.0m <= x < 2.5m	91	4
2.5m <= x < 3.0m	44	1
3.0m <= x	27	2
TOTAL	**974**	**558**
	1.532	

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 analysed 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 analyse 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. EVALUATION CRITERIA

The selection of the proposals will be based on the three criteria as outlined in the guide for applicants:

1. Scientific and technological excellence
2. Quality and efficiency of the implementation and the management
3. Potential impact trough the development, dissemination and use of the project and economic impact

4.2. RELEVANCE OF SPECIFIC FUNCTIONS AND THEIR INTEGRATION

<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. 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>

How well does the proposed technology integrate the required functionalities?

- *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

4.3. GENERAL FUNCTIONS AND CONDITIONS

4.3.1. 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.

4.3.2. General services

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

4.3.2.1. 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.

4.3.2.2. 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.

4.3.2.3. 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.

4.3.2.4. 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.

4.3.2.5. Scanning

The robotic system has to be able to perform a 3D scan of the sewer under demand, relaxing the robot performance in 4.2.2.2.

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.

4.3.2.6. 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.

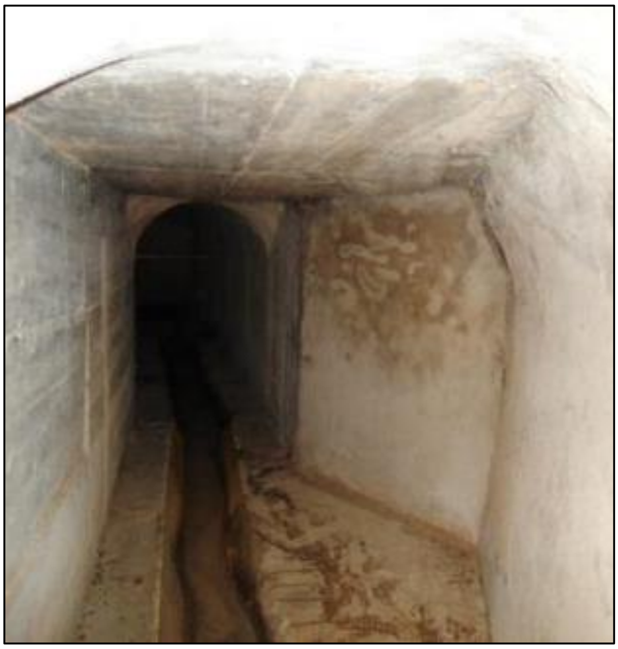
<u>Sewer elements location</u>

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:

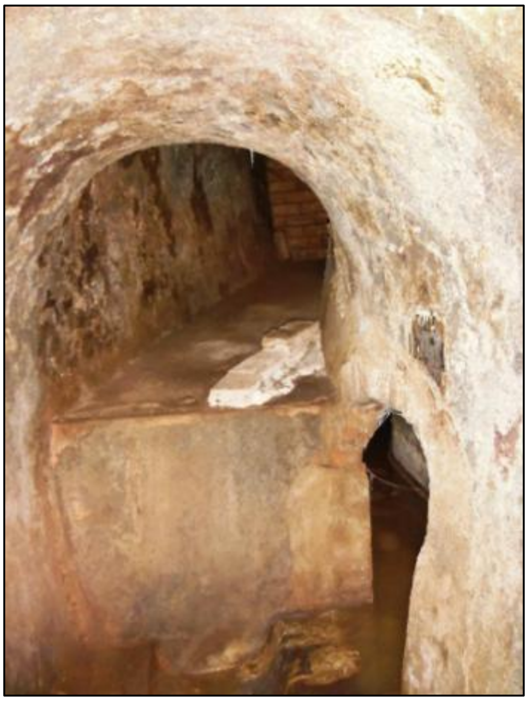
- Manholes


- 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

4.4. 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

4.4.1. Sewer serviceability inspection

4.4.1.1. 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.

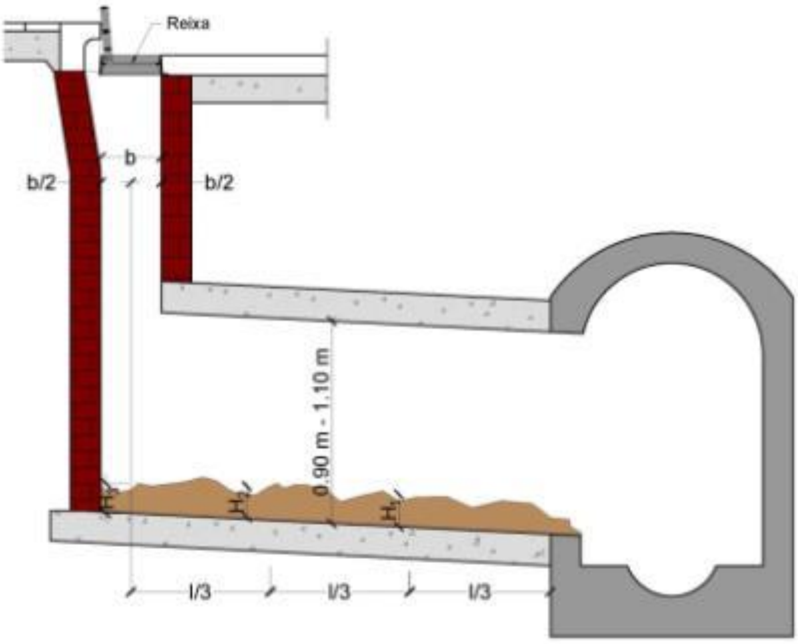
The operator should receive a "pop-up" alarm that indicates the location of the obstruction and helps to decide if the robot has to make an extra specific snapshot or video.

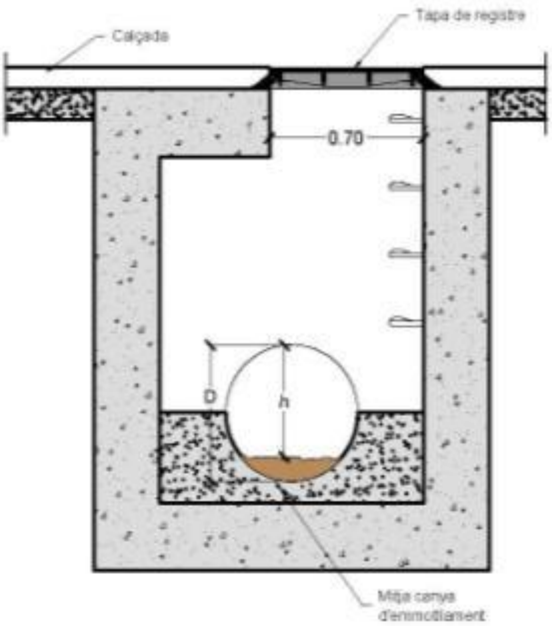
4.4.1.2. Criteria for serviceability reduction alarm

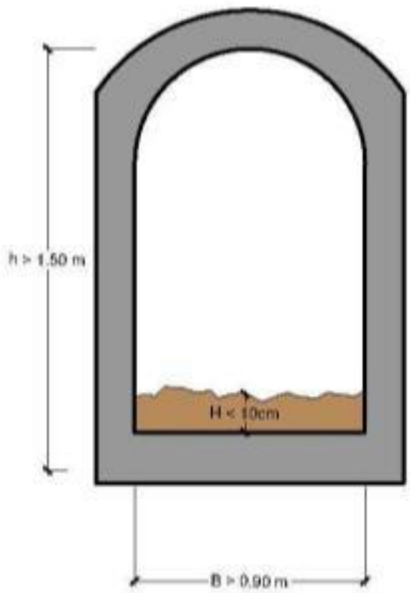
The following table shows the minimum standards of serviceability for the various items to be inspected by the prototype, which determine no need to be cleaned. Those elements that exceed the defined values will be collected on a proposal of sewer stretches that need to be cleaned in order to ensure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

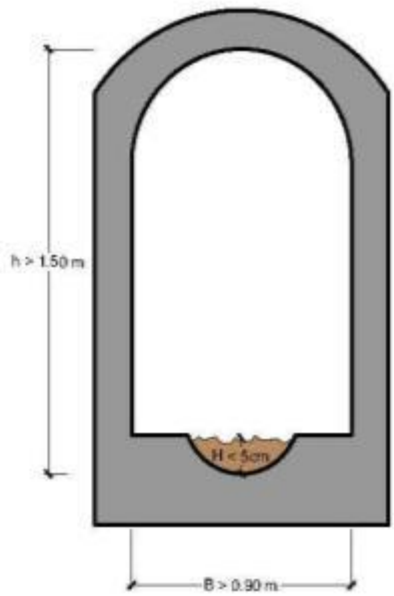
<table>
<tr><th>PARAMETER</th><th>VALUE</th></tr>
<tr><td>GUTTERS or INLETS</td><td></td></tr>
<tr><td>Level of waste at Gutter Tunnel: Thickness of the waste accumulated in the tunnel gutter.

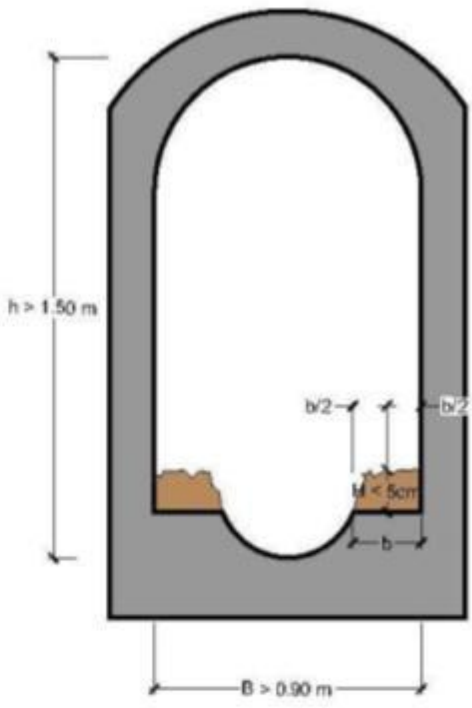
The level of waste will be measured in three equidistant points distributed along the axis of the gutter tunnel considering the first measurement point located in the centre of the gutter manhole. The maximum height of the waste should not exceed 10 cm in two of the three measured points. The existence 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.


</td><td>< 10 cm</td></tr>
</table>

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

4.4.2. Structural defects inspection

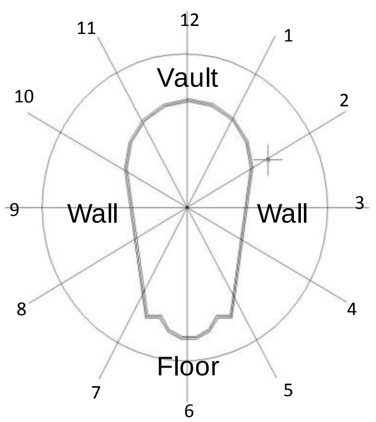
The prototype should locate and identify critical damage inside the sewers, whether it is located on floor (sewer's bottom), vault (sewer's roof) or walls.

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).

4.4.3. 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:

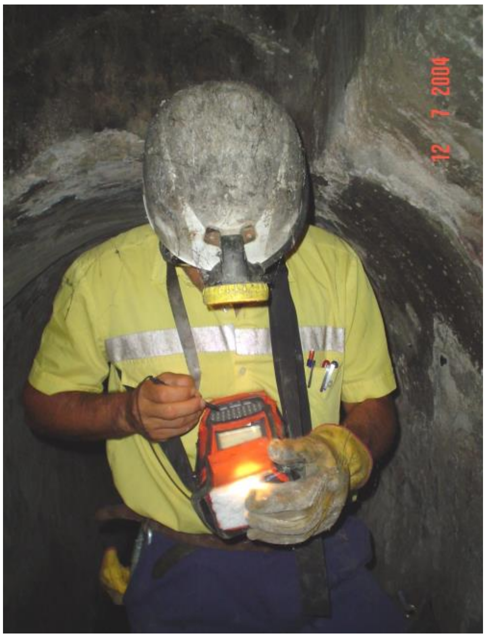
- To avoid access to sewers at risk situations
- To decide safety and health measures for staff
- To locate and follow spills or leaks, normally illegal, in order to protect sewer infrastructures from abrasion, rust and aggressive spills
- To determine tendencies in compounds (seasonal, daily, etc.)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

4.4.4. 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

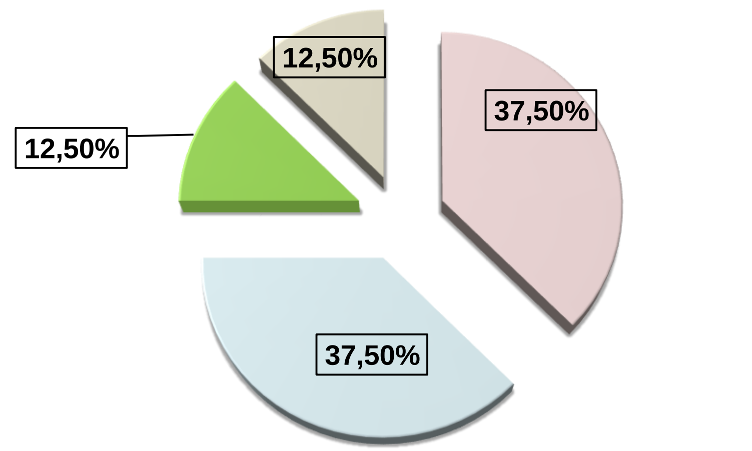
It is difficult to establish a minimum volume required per sample, as this depends on the parameters to be analyzed. However, at least the minimum following volumes would be necessary:

- 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 visitable 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.