PUNTOnet: Innovative Prototype of Urban Trash Containers Improving Waste Sorting and Widening the Services Offered to the City

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Abstract: In order to meet European objectives in the field of urban waste collection, dustbins need to achieve a greater intelligence to recognize users and measure their garbage. The ongoing changes in waste collection are transforming ordinary garbage bins into innovative urban interface with huge potential, especially due to the capillary diffusion of waste disposal in the built environment. This paper presents a research, commissioned by one of the leading Italian multi-utility operating in environmental service, with the aim to improve municipal management of separate waste collection through the design and test of an innovative multifunctional station, in line with the principles of circular economy. The pilot project combines existing technologies regarding urban waste collection and new smart services for the city (environmental quality, ICT, electrical charging for bikes, video-monitoring and others); PUNTOnet, the innovative urban waste collection point, improves user experience, provides further services for the city and ensures, at the same time, a better management. Results obtained after a 12-month test in a real-world environment show that a more intuitive and user friendly design of waste disposal, associated to rewarding schemes positively affect household behaviour and may generate virtuous attitude for correct waste sorting.

1   INTRODUCTION

A healthy and clean environment is essential for the wellbeing of a community, and an efficient waste management is a key aspect in achieving this.

Public waste management has always developed through history in relation to urban growth, and tightly connected to individual attitude and civil duty.

In the late medieval city there were no rubbish collection, and latrines and open refuse pits served as waste disposal facilities; individual behaviour was imperative for the intended work of these seemingly simple technologies, which could be badly affected by improper actions, for example by throwing waste in the streets gutters (Jørgensen, 2008).

Medieval towns had a lot of ordinances and laws to do with waste disposal, latrines, and toilets: in London, for example, people were responsible for the maintenance and cleanliness of the street outside their houses (O'Neill, 2013), as it was in ancient Rome, where rubbish thrown or dropped onto the streets may have been the responsibility of building owners if it was in front of their property (Taylor, 2005).

Before 1900 waste was generally stored in the houses and emptied out on the street at the arrival of waste collectors with their vehicles. In 1904, the Viennese government, for instance, had 104 horse-drawn collection carts, announced by ringing bells (Dostal & Zerz, 2004).

An important step in waste disposal took place last century, thanks to mechanical procedures that allowed a tangible waste management including separate refuse collection and conversion of waste materials into new objects.

In recent years, many inventions and methods have been developed using technology making the delivery of service more and more sophisticated. An increasing number of researchers and organisations are testing and using smart bins to maximise the efficiency of the collection and the data accuracy about the delivered waste.

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Ultrasonic sensors measuring the garbage level inside the container allow the local utility to plan the collecting routes accordingly, and in some cases inform the users about the fullness of the bin without the need for opening it (Mustafa & Ku Azir, 2017).

In 2014, Lazaro and Rubio worked on solar powered electronic trash can with a sensor able to scan the waste, open a particular lid depending on the type of waste and close it automatically after 10 seconds. However, the limitations in this prototype lay in its costs and in the automatic procedure, unable to record if a passing material is not intended as waste.

The US-based company EvoEco has developed EvoBin, a freestanding, modular, steel construction equipped with a video displaying items that are typically recycled, composted or landfilled, then showing feedback message depending on the types of thrown waste. Apart from the effective engagement of users, the small capacity (about 87 litres) compared to the overall height (170 cm), the absence of a profiling system and the uncovered lid make EvoBin more suitable as indoor solution rather than urban waste facility.

Not always technology advancements related to smart bin directly improve household every-day actions, and waste bins design is often the by-product of complex waste sorting regulations (OECD, 2017).

Therefore, this prototype research takes into account not only the former request of the local utility to improve municipal management system of separate waste collection, but also the pressing need to better the user experience at different levels.

This research has been carried out since 2016 by CFR Consorzio Futuro in Ricerca, specifically by Next City Lab, an interdisciplinary research group at Architecture Department University of Ferrara, headed by professor Gabriele Lelli, commissioned by the central innovation director of Hera Group, Salvatore Molé. The main authors are, from industry side, Eng. Enrico Piraccini, head of development & innovation of Hera Group and Eng. Simone Allegra, innovation central direction of Hera Group, and from University side MSc associate prof. Gabriele Lelli, MSc Walter Nicolino and MSc PhD Candidate Ilaria Fabbri.

2 CURRENT SITUATION IN ITALY

Waste is currently a central issue in the agendas of local and national governments.

The rapid growth of the population and the considerable changes in people lifestyle are outpacing the need of valuable solutions to improve the efficiency and the effectiveness of waste collection, urban disposals and recycling scores by taking into account the standard of health and environmental friendliness. In European countries, total and per capita waste production has been decreasing thanks to specific community policies which have been in place since the 1990s.

A briefing published on November 2018 by the European Environment Agency (EEA) highlighted that "pay-as-you-throw" (PAYT) schemes are effective instruments that drive recycling up. In PAYT programs waste management service is charged by unit or consumption, likewise other urban utilities such as electricity or water; specifically, the fees are based on the weight or volume of the generated waste. Besides, differentiated tariffs make residual waste more expensive than selectively collected waste streams, as an economic incentive for households to recycle their waste.

In line with the findings of EEA briefing, and with several lines of evidence supporting PAYT systems, many countries in Europe are adopting a waste rate proportional to the weight and/or the volume of the delivered garbage.

Italy abolished the flat-rate tax (TARSU) and it is gradually setting a target to complete the shift from tax to a user-specific rate.

Through its own plants and services, the Hera Group is Italy's first environmental operator which directly manages the entire integrated waste cycle in its own area, which consisted of 187 municipalities in 2017 with about 3.3 million inhabitants in total.

In 2015, before the research here presented started, Hera Group was testing urban waste containers with preliminary expedients measuring garbage volumes and recognizing users' identity. The most common model of urban garbage bin enabling users' profiling and waste measuring consists of a traditional 3200-liter container with a recycling cap on the top, with a capacity of 15 litres. In order to throw garbage bag, the user has to wake up the system pushing a button, log in with the personal RFID card on the sensor, pull the lever handle, fill the cap with garbage bag and close it up.

With such measuring caps, waste delivery is a complex and time-consuming process, rather than an automatic, effortless act. Moreover, the height of the cap penalizes the system in terms of accessibility to protected class of users.

The experimentation conducted by Hera Group in different area of Emilia Romagna Region also highlights that this model of dustbin badly affects user behaviour, with increased littering next to waste

containers: opening cap temporary out of order, impossibility to open the lid due to RFID card left at home, excessive hurry, difficulties in reaching the lever handle.

Littering or putting the wrong materials in the recycling bins lower the quality of separate collection and rises recycling costs.

Figure 1: The standard model of container lid, a recycling cap with several criticalities in terms of user experience.

The considered challenging situation leads Here Group to look for tangible alternatives to this type of waste container, to develop and test innovative solutions in line with European requirements and combining the ordinary garbage collection point with innovative urban services.

3 THE CONCEPT OF THE RESEARCH

The new urban point for waste collection capitalizes the outcomes of previous experimentation conducted by Hera Group following the introduction of specific tariffs.

The main objectives of the prototype research are described as follows.

3.1 Application of the PAYT European Law

This implies that the prototype should be able of recording collection frequency and user identity, and

measuring the amount of garbage and its type (if recyclable materials or refuse).

With the standard measuring cap, people may perceive that waste sorting is too demanding and time-consuming, while, on the contrary, the application of waste regulation (profiling and measuring) should not affect people during waste delivery and not cause them additional work.

3.2 User Experience Improvement

We identified 5 principles to get the most desirable experience for each user:

- Make the collection easier and quicker with only two operations: identification and disposal of waste;

- A clean experience that minimizes the physical contact with the bin, a hand less system with no contamination, no manual operations, no pedals, levers or other mechanisms. Users are identified through electronic systems (RFID and NFC) and they simply let the waste bag fall will into the containers without touching them;

- Introduction of a rewarding system, giving the users additional services according to his/her sustainable behaviour;

- Increase citizens' safety during waste delivery, according to car flow, sidewalks depth and other features of urban environment;

- Improvement in the station accessibility for a wide target of users, including children, elderly and frail people, since no levers or pedals are needed to open the containers, whose lids are comfortable and suitable for anyone, people on wheelchair included.

3.3 Urban Impact Improvement

Increase the appeal of household waste container and its surrounding area is another imperative of the research; there are plenty of interesting attempts to transform waste containers into clean and elegant urban objects, and in Italy there is big room for improvement on this side. The use of a multifunctional, modular, easy to use, technological, innovative and adjustable station can have a variety of application and can be used in different urban environments.

Moreover, positive changes in the physical environment can substantially affect individual decision-making, especially in contexts in which choices are made spontaneously, on the basis of

automated mechanisms and habits (OECD, 2017), as it happens for daily household waste delivery.

Improvement in the urban environment includes the adoption of smart solution for reducing and optimizing the itinerary of waste collection vehicles in accordance with real-time control of the dustbins' filling degree, with the expected consequence of fuel saving and atmospheric pollution reduction.

3.4 Innovative Combination of Urban Waste Collection with Other Services

The Italian multi-utility asked the research group to invent and present viable strategies and services to widen the Group's business offer to the city.

Thanks to its widespread diffusion in the urban environment, waste collection point has the potential to become a community interface, a reference site for data collection and urban services.

For instance, the UK Renew Startup installed before the 2012 Olympics about 100 recycling bins equipped with wi-fi and LCD screens around London.

The dustbin, able to track each phone that connects to them with wi-fi and to sell tailored advertising opportunities, were quickly labelled "spy-bins" (Harris, 2007).

The research here presented innovates urban waste collection points by the integration with a set of services as environmental sensors, wi-fi, electric bike charging, video surveillance, SOS emergency button. The research is still ongoing; other urban services are being studying and testing, and will further implement the innovative station, which is more than isolated dustbins.

As the system recognize users and measure their waste, which is the basis for the user-specific tariff, it is possible to record the collection trend of each station, which means the recycling habits of the neighbourhood itself. Showing off this last information has the potential subtle effect. Individuals are usually affected by the way people surrounding them behave (OECD, 2017:13) and comparing the recycling rate achieved by each urban district may trigger positive competitions among communities. For these reasons, we design for the implementation of a digital projector in the collection point, able to cast on the street recycling scores made by each community and real time feedbacks on waste collection. The outdoor digital projection makes effortful community sorting performance visible, and encourages positive competition between neighbourhoods.

The research group called the innovative urban waste station "PUNTOnet"; the name recalls the network of collection points in the city and it is to be also noticed that in the Italian language "net" hints to something clean.
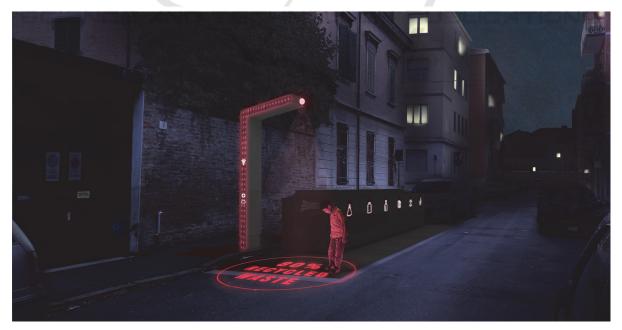

Figure 2: Urban placement study of the collection point with smart totem. The outdoor digital projection makes effortful community sorting performance visible, and encourages positive competition between neighbourhoods.

4 DESIGN PHASE 1 – INDOOR PROTOTYPES

Since 2016, 16 types of opening lid have been tested simulating the process of waste delivery through real mock-ups.

The research group, jointly with experts from Hera Group, compared the proposed opening systems with a specific evaluation matrix, including the following criteria:

1) USER EXPERIENCE

- Quickness of the delivery process
- Intuitive opening
- Accessible for people with disabilities
- Hands/fingers protection
- Protection from unpleasant sight
- Suitable both for bags and loose garbage
- handless system (the garbage weight is sufficient to open lid of the bin and closes by gravity)
- visual impact

2) INDIVIDUAL WASTE CHARGING

- User recognition system
- Volume control by the geometry of the lid
- Visibility of the waste from the smart totem (the lid does not hide the garbage)

3) WASTE OPERATOR

- Possibility to empty the bin from its top
- Possibility to empty the bin from its bottom
- Simple maintenance
- No hollows or notches simplifying cleanability
- Easiness in replacement of components

4) COMPATIBILITY WITH THE COLLECTION OF DIFFERENT MATERIALS

- Non-recyclable garbage (bags)
- Paper (paper bags)
- Paper (loose)
- Plastics (bag)
- Plastic (loose)
- Glass (loose)
- Organic (paper bags)
- Yard waste (loose)

A specific score has been given to each criterion, measuring the potential success or failure of each opening lid during each phase of waste collection.

At the beginning of 2017 Next City Lab Group presented a 1:1 scale prototype of the three most promising options of containers, suitable for indoor test, and a mock-up of a smart totem, an innovative element integral part of the waste collection station.

Figure 3: Indoor prototype of three opening lids.

Waste collection point consists of two elements: the dustbin, with a low level of electronic components, and a smart high-tech totem; each container has an interface strip on the front that recognizes users through NFC system.

Once the user logs in, the lid unlocks. The user doesn't have to touch anything, just throwing the rubbish away and the lid opens for gravity.

The identification with personal NFC card activates stereoscopic cameras on the smart totem for volume calculation. The cameras take stereographic images during waste delivery and a specific software processes them.

This sophisticated software, specifically created for this research, can determine the volume of a photographed amount of garbage.

For weight calculation, small but very accurate scales are set up at the base of each container.

Along with waste collection, the smart totem provides other services for the city such as:

- Environmental monitoring;
- Video surveillance;
- Information Communication Technology (wi-fi, 5G, data concentrators);
- Electric recharge (devices, electric bikes and Mobility Scooters for wheelchair users).

5 DESIGN PHASE 2 – OUTDOOR PROTOTYPES

The second phase of prototype developing has been achieved thanks to detail drawings of all the components of the innovative waste containers,

including the study of digital interface and the exterior shell.

In partnership with a mechanical workshop in Maranello in Italy, at the end of 2017 the research group completed the first prototype suitable for outdoor environment and fully functioning.

The first months of 2018 have been dedicated to testing, in a private context, how the prototype really worked. Moreover, it was connected to the internet to verify the functionality and stability of all components, also the ones being remotely installed.

In this phase the research had the valuable support of CERPA Italia Onlus (The European Centre for the promotion of Inclusion) about the system accessibility to different type of disabilities.

Different changes in order to improve the user interface, the inner volume of containers, the resistance to weather conditions, and other details were made during the private outdoor test.

Figure 4: Outdoor prototype for private test.

The second outdoor prototype was specifically meant for a public test in a real world urban context: 40 families of Castel Bolognese, an Italian town at roughly 10 000 residents, started testing PUNTOnet on October 2018. The testing stage ended on the 20th October 2019.

Figure 5: Outdoor prototype for public test.

6 FROM WASTE COLLECTION TO URBAN DASHBOARD FOR A SMALL TOWN

The huge amount of real time data produced everyday by our cities demands for an integrated system able to read through the information and interpret them.

Urban dashboards are becoming increasingly popular as an effective mean to assess and guide daily operational practices across public services and provide wider information to policy makers (Kitchin et al, 2016). However, the use of centralized operating systems of this kind is still infrequent in small villages.

The PUNTOnet experimentation in Castel Bolognese set the basis for a pilot project promoted by Hera Group of urban dashboard in a 10 000-inhabitant town.

Castel Bolognese dashboard displays five kinds of services:

- Environmental passport, addressing the eight topics of Bologna Environmental Chart and in line with ONU Agenda Sustainable Development Goals;

- Energetic Maps, a WebGis service that provides a composite visualization of gas, water, electricity consumptions in order to highlight specific needs of energy rehabilitation for public and private buildings;

- Satellite maps, both from Remotely-Piloted Aircraft Systems (RPAS) and aerial mapping;

- Environmental monitoring (e.g., weather, pollution level, noise).

- Technology infrastructures, concerning the delivery of services by Hera Group. In this section, graphs and maps show information about the trend of waste collection and the other services combined with PUNTOnet, including electric bike sharing points and smart bus shelter promoting sustainable mobility. The additional smart services connected to PUNTOnet are not completely disclosed and are currently under study and design process.

Figure 6: Pilot urban dashboard for a 10 000-inhabitant town, Castel Bolognese demo site.

7 PEOPLE ENGAGEMENT IN THE TESTING STAGE AND BEHAVIOURAL INSIGHT

The sample group of citizens who tested PUNTOnet for 12 months were chosen by Hera Group among the citizens. The proximity of their homes to the demo site has been the selection criterion.

Different strategies were studied to engage people in the experimentation in Castel Bolognese and improve the quality of waste collection; prototype waste containers were regularly monitored during the testing stage and two digital survey were submitted, the first one at the beginning of the experimentation and the second one at the end.

The main strategies were:

▪ Urban placement studies: evident changes in the physical appearance of urban waste containers might act as effective behavioural leverage for a more sustainable approach to sort and recycle. The exterior shell of the containers shows a re-elaboration of a work of art by Peter Kogler. Photoluminescent pigments produced by the Italian firm Reglow were used to pave the wooden platform next PUNTOnet, which made it clearly visible in the night. Individuals can be therefore incentivised to take care of a clean and appealing area.

▪ Rewarding approach, associating a tangible payoff to consumers' achievement. Citizens effortful change in their routine using the prototype are rewarded with discount vouchers for grocery and other shops in the centre of Castel Bolognese. There is mounting evidence that rewarding scheme may generate a positive norm in the long term (OECD, 2017).

▪ User-friendly feedbacks: at the experimentation kick off, the research team created a Community Broadcast chat with WhatsApp, opened to volunteers among the sample group of citizens testing PUNTOnet. The Broadcast Chat was meant to spread information from the research group about the prototype itself and the testing stage, and to give feedback about people waste sorting performance; through WhatsApp Service, people had the possibility to share questions and report litter problem with photographs and videos directly to the research group. This strategy appeared particularly successful in bringing a positive sense of recognition to those who participate in the experimentation, as resulted from the final survey.

▪ Descriptive commitment through graphics: the shell of the waste containers displays the text: "I'm just a prototype: help me to improve myself. Your suggestion will make the difference!". Users are invited to express their opinion during the experimentation period using the Smart Community Chat.

▪ Gamification: the prototype containers integrate informal audio communication; every time someone logs in, the container reacts with

greetings or other sounds that may be customized for specific audience. The Swedish agency DDB, with its "deepest bin in the world" as already proven how well this type of persuasion works (Alter, 2017).

■ Monitoring and penalties: PUNTOnet surrounding area was monitored by specific cameras on the smart totem, able to detect potentially negative actions as littering alongside the waste containers; alert notifications would be then visible on the general urban dashboard controlled by the multi-utility.

These strategies contribute to the positive outcomes of the testing stage. The sample group of testers showed a general satisfaction as assessed by the final survey.

Table 1: Final survey results.

QUESTION	YES	NO	NEUTRAL
Is PUNTOnet easy to open?	79,0%	10,5%	10,5%
Are you satisfied with the collection point neatness?	78,9%	0%	21,1%
Are you satisfied with the amenity and lighting of PUNTOnet surrounding area?	78,9%	5,3%	15,8%
Do you prefer traditional waste containers?	10,5%	68,4%	21,1%
Do you think that the diffusion of PUNTOnet model in the city would improve waste sorting and recycling?	84,2%	5,3%	10,5%

The results of the final satisfactory survey submitted to the sample group of citizens reveal a positive feedback and a general warm welcome to PUNTOnet innovative features.

The first part of the experimentation highlighted that the involvement of people in the prototype test has risen the awareness about separate waste collection. Furthermore, an easy-to-use, efficient and technological collection system has galvanised users to be more virtuous, for example they will separate waste better and they will deliver it correctly. This increased the quantity and the quality of separately collected urban waste and decreased unsorted urban waste.

8 FURTHER DEVELOPMENTS TOWARDS SERIES PRODUCTION

After the 12-month test, PUNTOnet refinements are ongoing, in view of further public experiments. On June 2019 the research team showed off the final prototype, at the conference "Re-inventing the city: smartness and resilience to face new challenges", organized by the Hera Group in Bologna, in the multi-utility headquarters.

The main difference between the second outdoor prototype and the third one is that the smart totem of the previous versions evolved into a different urban structure, a smart shelter for e-bike sharing; all the components previously stored in the vertical urban kiosk are located, in the last version, on the roof of the shelter, a painted steel structure with coloured photovoltaic glass panels.

In the third model of outdoor waste containers, the user interface is fully optimized: the interactive strip, including NFC sensor, RGB led and mini audio speakers, has been lowered and slightly slanted to enhance the visibility of the login target and light signals; furthermore, the interface bar is now fixed on the exterior shell of the container, that stands still during the emptying process. This solution provides for a greater protection from impacts and bumps, increases the life span of electronic equipment and dwindles the expected maintenance frequency.

Standard waste containers with metal structure and no smart components usually have an average life expectancy of 10 years; with the last implementation, PUNTOnet lifespan has increased, and it is expected to be about 7 years.

Regarding the end-of-life treatment, it has to be noticed that smart containers steel structure can be recycled and reused endlessly; in addition, for the exterior envelope of the third outdoor station the design team chose dark slats of Wood Plastic Composite (WPC). Not requiring special maintenance, at the end of their life cycle WPC panels can be extruded again and recycled up to 20 times, with no need of adding any other components and no physical or mechanical alterations. Next City Lab decided to shift from metal carter with adhesive graphic film of the first prototypes to WPC envelope because the latter is not only recyclable, but both components, wood and plastic, are sourced from recycling streams, too. Wood Plastic Composite slat has the warm touch of wood, but doesn't rot, and above all does not overheat as metal.

Looking towards series production, PUNTOnet containers offer an innovative solution for profiling and measuring, mandatory aspects for the application of upcoming user-specific rates imposed by European targets; they are also fully accessible to a wide range of people, even if accessibility is not yet compulsory in local bids for supplies of urban trash disposals.

9 CONCLUSIONS

The tested prototypes were designed with the imperative to achieve a greater user experience, to engage people in positive contribution to urban and environmental quality, as daily participation to community life is itself a component of individual wellbeing.

Current digital revolution and rising consciousness of environmental risks are shaping values and ethical framework: professionals involved in public space design should make an effort to increase organicity and coherence of urban objects and public services, through technology innovations, possibly driving shared values towards public health and happiness for all.

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