S[m2]art project: from digital island to vertical ring. Integration of environmental monitoring technology into street furniture

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PART II - Evaluation and Modelling Systems, and Tools

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S[m2]art Project: From Digital Island to Vertical Ring. Integration of Environmental Monitoring Technology into Street Furniture

Mónica Alexandra Muñoz Veloza, Lorenzo Savio and Stefano Bellintani

This chapter documents the research conducted as part of the S[m2]art (Smart Metro Quadro) project aimed at developing innovative street furniture that can deliver general and personalized services to the public administration (PA) and the citizens in an inclusive manner. Through an open design approach, S[m2]art seeks to provide urban solutions with recognizable aesthetics to monitor current urban phenomena and meet today's needs without banning the possibility of providing new services in the future. The primary outcome is a prototype installed on the campus of two of the main Universities in Italy: Politecnico di Milano and Politecnico di Torino. Due to its low maintenance and operating costs, the resulting prototype makes it possible to increase the number of aggregation and resting nodes in the city, expanding its physical and digital network. Moreover, the S[m2]art model can also provide the PA with tangible and intangible tools capable of collecting, monitoring, and analyzing data on environmental parameters through the various integrated sensors. To summarize, this landmark seeks to formally reference a design concept open to the ever-changing nature that characterizes smart cities.

Introduction. Thinking out of the telephone box

In recent years, digital reality has changed both the virtual space and our physical world. Urban areas, for instance, have had to adapt to the changes caused by virtualizing goods and services previously available only in person and through physical interaction. In addition, the use of stationary computers has been replaced by smart technology and mobile devices that facilitate portability and information transfer, making the ordinary citizen a key and constant participant in the global marketplace. On the other hand, the ease of accessing vast amounts of data in real time and its availability through the Web has revolutionized our perception of time. One main effect of the disappearance of the physical dimension's traditional limits is the need and desire for instantaneity and permanent connectivity. However, many cities' infrastructure continues to be inadequate for the needs that users on the move in it seek. The S[m2]art project aims to bridge this gap by equipping the city with physical and virtual tools that respond to the current citizens' needs, and that can be adapted, modified, or included to meet those future ones.

The 'S[m2]art (Smart Metro Quadro) Guardando la città metro per metro' research and development project was submitted on the 'Smart Cities and Communities and Social Innovation' call for proposals of the Ministry of Education, Universities and Research (MIUR) in 2012. The main intervention area in which the project sits is 'Welfare Technologies and Inclusion', but it also contributes to 'Territorial Security' as a secondary area. S[m2]art's main objective is to implement a new system of smart urban furniture that is scalable, adaptable, and <<connected as nodes of a network of data collection and processing, transmitted and processed by a digital platform, which aims to increase the urban well-being of citizens by implementing the efficiency, accessibility, and functionality of public services>> (S[m2]art team, Technical Specifications, 2021, p. 16).

S[m2]art reinterprets the traditional telephone booth: a small piece of street furniture that came into being in the late 1800s to help people communicate more quickly. This structure was part of the urban landscape worldwide during much of the last century. Although individually, it occupied one square meter of surface area, scattered throughout the city, it constituted a network. However, the arrival of private telephones and the latter wide spread of smartphones and wireless services led to the diminution of their usefulness and, consequently, their almost total disappearance. Based on an open design concept, S[m2]art seeks to revisit the telephone box's significance by integrating information technology and design features that allow the street furniture to adapt to current and future urban phenomena and new users' necessities. As a result, the research team built and installed two demonstrative prototypes called 'Vertical Ring' on the Politecnico di Torino and Politecnico di Milano campuses. This chapter presents an overview of the meta-project, the design and production stage, as well as the installation process and monitoring phase of the prototypes.

Type of actor	Partner	Activities and skills
Private: Companies	Telecom Italia	• Project coordination and organization. • Technology integration. • Communication of results.
	Santer Reply SpA	• Graphic design and layouts relating to the object and the tools for its visibility.
	Gruppo Thema Progetti	• Responsible for the aesthetic, functional, emotional, and communication design of the S[m2]art network. • Research and analysis of trends and benchmarks regarding furniture design and innovative tools. • Concept design and guidelines for developing urban spaces and furniture focus on well-being. • Concept design and guidelines for communication tools related to products and services.
	Metalco	• Prototyping, detailed design, testing, production, and installation of all finished product elements of the Vertical Ring.
	H&S Engineering	• Provision of innovative and high-quality technological services, products, and solutions. • Communication integration, software, and hardware research and implementation. • Interface software development. • Infrastructure installation and monitoring.
Public: Universities	Politecnico di Torino (Dipartimento di Automatica e Informatica - DAUIN)	• Data and systems analysis for database management, hardware and software design of networked embedded systems.
	Politecnico di Torino (Dipartimento di Architettura e Design - DAD)	• Technology meta-design, environmental sustainability assessment, and scenario definition. • Research and analysis of trends and benchmarks regarding furniture design and innovative tools. • Interactive mapping and sustainability analysis of street furniture in the Turin area. • User profile analysis for the S[m2]art furniture network. • Analysis of the needs, requirements, and performance for the S[m2]art furniture network.
	Politecnico di Milano (Dipartimento di Architettura, Ingegneria delle Costruzioni e Ambiente Costruito - DABC)	• Development of innovative business models for managing and installing new networks of S[m2]art furniture. • Research on the Milan area, development of product/service concept, monitoring of infrastructure. • Configuration of operational service management model with positive territorial spillover effects.

Table 1. Project partners' activities and expertise

An ensemble of energies for the city: private companies, entrepreneurs, universities, and Public Administrations:
To carry out the S[m2]art project, a consortium was formed with various public (universities) and private (companies) actors ensuring the development of strategies in the various fields of work. This teamwork based on the complementarity of knowledge enabled the project's successful outcome and contributed to the growth of each partner's skill domain by expanding their vision. In addition, the close relationship between the consortium and the public administration (PA) of the cities of Turin and Milan ensured that human capital was the first and most important resource for the project's development. Table 1 summarizes the activities and skills provided by the multidisciplinary nature of the final partners.

S[m2]art to bridge the digital divide
Not so long ago, we had to wait for a new edition of an encyclopedia to find up-to-date information on specific topics. Today, a connection to the World Wide Web is enough to find unlimited sources. This transformation has been made possible by the advent of the mobile Internet connection, which has promoted a fusion of the physical and digital worlds. It also has powerfully influenced our interaction with others and our surroundings, especially in cities, which are the daily reality for most of the world's population. Unfortunately, Information and Communication Technologies (ICTs) have not benefited everyone equally due to the social and economic gaps that separate the communities. In Italy, for instance, the public sector has been unable to keep up with the

digitalization and development of IT applications, negatively impacting people's lives as well as the relationship between them, the private sector, and PA. In the last two decades, the European and Italian normative frameworks have set some technological and informatics progress objectives[1]. However, one of the main reasons Italy is moving slowly on this path is the precarious state of its digital infrastructure.

Understanding the importance of bridging the digital divide and acknowledging the potential of public spaces and assets to drive technological innovation and digital transition, the collaborative efforts of the S[m2]art project partners have resulted in the proposal of the 'Vertical Ring' prototype, a smart urban furniture conceived not as a passive object but as a provider of physical and digital services. Vertical Ring aligns closely with the strategic framework and project guidelines of the National Technology Cluster 'Technologies for Smart Communities.' Furthermore, the proposal is entirely in line with the Cluster's primary focus on <<the development of the most advanced technology application solutions to enable innovative models of integrated solving for social problems of urban and metropolitan scale, (e.g., mobility, security, and land monitoring education, health, cultural heritage and tourism, green cloud computing, renewable energy, and energy efficiency, justice).>> (Ministero dell'Istruzione, dell'Università e della Ricerca, 2012, pp.5-6).

1 - The PNRR was approved in 2021 by the Italian government with two main goals: revitalizing the economy after the COVID-19 pandemic and enabling the so-called Twin Transitions, namely green and digital. It is part of the of the Next Generation EU program which intends to allocate 750 billion euros to help the economy of member countries.

Analysis activities and meta-design

Despite being a significant milestone within the S[m2art project, installing the Vertical Ring prototype is just one facet of its broader scope. This project encompasses diverse goals and outcomes, each coordinated by one of the partners involved. The primary role of the university partners (Politecnico di Torino and Politecnico di Milano) was to analyze the real possibilities of integrating S[m2]art infrastructures in the urban environment and to explore possible concepts of innovative services to be provided through the network of small infrastructures to stimulate the creative phase in alliance with the technological partners. The analysis activities have been partly developed by organizing workshops with architecture and engineering students in Italy and abroad, greatly expanding the foundation of creative thinking[2]. These collaborations have resulted in some cases also collecting the collection of potential future scenarios that may not be immediately applicable to the project's executive phase but are valuable as research outcomes in their own right (Figure 1).

Regarding the initial stage of the Vertical Ring development, the research group followed a simple and recognized methodology within the design and architectural technology disciplines to define service concepts: the user's needs/requirements/performance design approach. According to this approach, defining a precise 'picture' of the users and analyzing their needs is necessary before a design is developed. In this case, one of the most important activities

2- This partertships included the Alta Scuola Politecnica, a multidisciplinary training project active since 2004 in cooperation between Politecnico di Milano and Politecnico di Torino.

carried out was the analysis of the citizens' and PA's real needs and requirements to orient the design strategies toward the well-being of those who live or experience the city (Figure 2). Needs are the general or specific conditions necessary to carry out an activity or action (living, working, manufacturing, the fruition of urban services), and they can characterize management, safety, integration, well-being, accessibility, and environmental protection. The designer's task is to identify

Figure 1. Developed scenario for S[m2]art within the ASP project. Source: Politecnico di Milano and Politecnico di Torino students (Atanasovska Martina, Callegari Sandra, Chan Ho Yin William, Delvino Michele, Moreno Romero Juan Sebastian, Terraneo Emanuela).

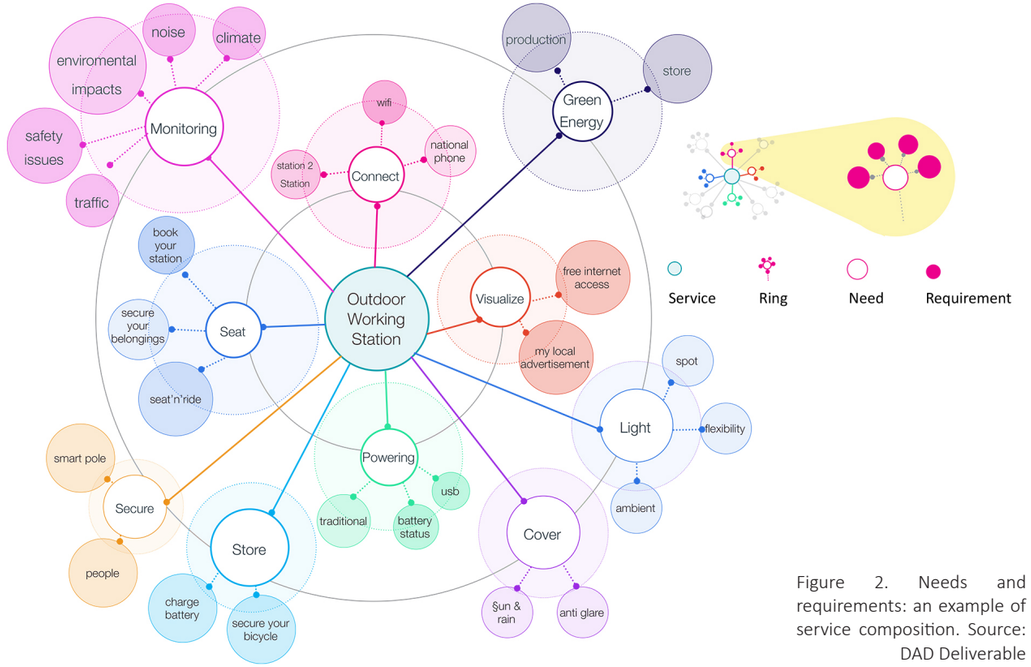


Figure 2. Needs and requirements: an example of service composition. Source: DAD Deliverable

the needs by engaging with the users. Subsequently, needs can be translated into design requirements, i.e., the expected behavior of the building or installation. These requirements can be met by various performances, such as specific design and technological solutions, which the designer will choose based on the opportunities available on the market, constraints related to the area of operation, and the overall economic sustainability of the project.

Learning from Others: best practices

Several pilot projects promoted by leading European and international cities have demonstrated the growing interest and emergence of potential new markets to increase widespread 'intelligence' in urban objects in recent years. In addition, they have highlighted how it is possible to envisage new ways of understanding the future smart city that can provide physical and digital services to the citizenry, such as Wi-Fi internet, the possibility of recharging mobile devices, defibrillators and first aid tools, information about services and the local area through augmented reality panels, state-of-the-art bike-parking stations, charging stations for electric and hybrid cars, among others.

During the meta-design phase (Savio, Cocina, Gariano, Giampetruzzi, Pagani, Pedrazzo & Pennacchio, 2017), the research team analyzed several best practices representing the sphere of innovative products and services offered to citizens from different geographical and cultural contexts. Some of these are collected in the following tables. The examples were selected from innovative projects in street furniture, experiments with the city as their field of application, and objects that make up the urban landscape and city infrastructure.

The selection was made considering 'smart', not any project that includes an ICT component with the service provided, as is usually the case. In fact, from the end user's point of view, it would be inappropriate to call smart an interface that is only able to provide content without ever receiving feedback, acquiring data, and reacting accordingly, working in a one-way perspective: it would be in the condition of establishing a dialogue with a deaf entity, incapable of listening. In contrast, the examples in these sheets always have a data-gathering component that places them in a two-way dialogue space, where listening is central, and the service offered is specific in response to the stimuli of the city and the citizen.

Each information sheet identified key project data such as location, client, and site where available. The project description and status followed the latter to define its degree of maturity (is the project at the concept stage, prototype, or already a commercial application). In addition, a spider chart highlighted the main themes addressed: welfare, safety, leisure, mobility, tourism, and infrastructure. This was followed by a description of the main areas the project impacts: management, well-being, environmental protection, safety, and usability. Table 2 is an example of the type of information sheet produced for each project analyzed.

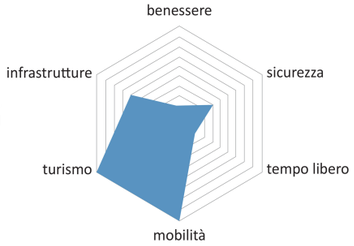
Link NYC			
Client	**Budget**	**Location**	**Designer**
NYC City Council	Unreported, self-funded through advertising	New York	Antenna, ABC Sidewalk Lab
Website	**Data production**	**Transmission**	**Implementation /feedback**
www.link.nyc	Map search data collection	Wi-Fi between users and bench, wired between artifact and central database	Return of context-aware publicity
Legacy	**Privacy**		**Third-party data use**
Generation of a search history concerning geographic location	The data is entirely anonymous. Wi-Fi registration allows for tracking of MAC addresses		For advertising purposes
Description			
Link NYC is the first phone booth 2.0 project to be fielded extensively. More than 7,500 New York phone booths have gradually been replaced by ABC's (Google) first actual project Sidewalk Lab. They contain superfast Wi-Fi routers for public Wi-Fi, phone lines, charging for cellular devices and tablets, and access to maps and tourist information. On the security side, it gives direct access to 911, the US emergency number. It is entirely self-funded through an ad hoc advertising system called "digital OOH advertising," which provides context-aware and functional directions to the user.			
Management		**Security**	
At the user experience level, it is the first example of a smartphone booth associated with a sustainable business model.		The phone booth allows rapid 911 calls.	
Usability		**Technology**	
The system is accessible to users with disabilities.		The system includes: - two 55' screens, one of which is equipped with a touchscreen interface; - electrical outlets for charging devices; - a telephone interface; - a high-speed Wi-Fi router.	
Project advancement			
The phase of progressive deployment throughout the Manhattan project began in 2015.			

Table 2. Sample information sheet for an ICT best practice.

For developing the Vertical Ring prototype, it was equally important to analyze other case studies that considered the innovation in design and ergonomics, the reduction of the environmental impact, and the ability to harness renewable energy resources. Through this analysis, the research team was able to understand the services, components, and tools that the smart furniture designed at the end of the meta-project had to offer to facilitate the most efficient use of smart furniture by the general public, as well as to make urban space more enjoyable and of higher quality. One of these best practices is summarized in Table 3.

Table 3. Sample information sheet for a design and ergonomics best practice.

Solar Lounge	
Client	**Location**
Research project	Chandigarh, India
Designer	**Website**
Chitkara University (Anu Singla)	www.chitkara.edu.in/news/chitkara-university-receives-first-patent-design-project-solar-lounge/
Description	
This exterior space is designed as an outdoor room. The seat and backrest provide a comfortable position while working, and on the roof, a series of solar panels power a battery that allows personal devices to be recharged. During the night, the stored energy is used to illuminate the space. Part of the system was granted a specific patent in 2016. Unfortunately, this street furniture project has remained at the prototype stage.	

Landing in the local context

The analyzed good practices showcased a diverse range of urban furniture and smart services, ranging from comprehensive digital islands composed of multiple urban furnishings to compact elements like poles, digital totems, and even smaller devices or inconspicuous sensors integrated into existing urban structures. Reflecting upon the international case studies, the S[m2]art research group pondered the ideal infrastructure to serve as a reference for integrating services and technologies.

Given the analysis of the urban contexts of reference and Italian cities in general (compact, dense, rich in small-sized green areas, and often urban voids created by the relocation of production activities), a workshop was organized between the partners to establish the essential characteristics of S[m2]art project. Through primary sources and fieldwork conducted in Turin and Milan, it was possible to verify that one of the main issues was the lack of devices providing digital services in the city's public areas. At the same time, the scarcity of advanced visual and sensory surveillance equipment in the large open spaces of the city generated a sense of insecurity in the community. Regarding health and the environment, there was an increased interest in installing smart sensors for environmental control and monitoring rising air quality problems. Moreover, during this phase, adjectives such as multipurpose, innovative, accessible, non-invasive, customizable, scalable, adaptable, contextualized, secure, efficient, and dynamic were identified as particularly significant for the users.

It also became evident the importance of a network approach, distributing the services providers throughout the urban area in a capillary manner, especially targeting the under-served areas, where problems related to the accessibility of public services, social inclusion, and safety affect the population the most. Regarding the public sector, the improvement of technologies (physical and digital) with which local administrations collect, process, and communicate data can enable them to achieve better decision-making based on real-time pictures of the territory's dynamics (e.g., identification of main mobility flows, use of public services and their distribution, critical issues, among others). Based on this information, it was possible to define a set of tangible and intangible functions that formed the basis for the prototype's design phase.

At this stage, two models were considered: the 'extended' one of the digital island and the 'compact' one of the single-equipped element. The two compositional-spatial models can configure the same set of physical equipment (seats, fountains, distributors of goods) and digital devices (sensors and cameras, to name a few). In an initial phase, the project explored the digital island model, thanks to a prototype built by Telecom Italia in its Turin office. The island, occupying a large surface area, makes it possible to locate all the functions and services that can be provided in the urban environment to improve accessibility and social inclusion and reduce the digital divide. However, the island can be challenging to integrate into the urban environment precisely because of its size and the lack of opportunities for spaces and areas to intervene. Therefore, the work team chose the single-equipped element as the

principle to design the Vertical Ring prototype.

The Vertical Ring and its open design concept

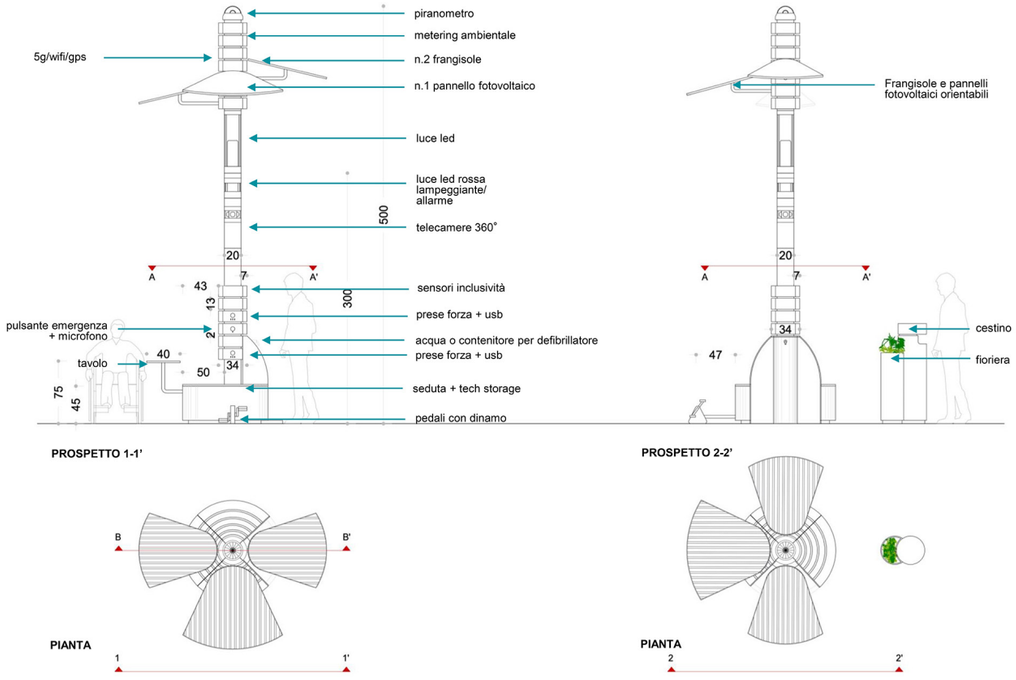
For defining the Vertical Ring concept, the Politecnico di Torino team collaborated with the Senseable Lab of the Massachusetts Institute of Technology (MIT) within the framework of the MITOR Project[3]. Some Senseable Lab students engaged in elaborating their thesis on a concept for the cities of Dallas and Turin (Figure 3). For instance, one of the ideas was to integrate trees as the support structure for minimal technological elements, which consisted of a pavement and a ring. The aim was to contribute to monitoring environmental data and urban phenomena with IoT sensors capable of interacting with users through smartphones. The different results of this significant experience supported the definition of the Vertical Ring final design.

The Vertical Ring prototype relied on an 'open design concept', a community-driven approach emphasizing openness, collaboration, inclusivity, and public engagement. This notion allowed the design of a formal model based on current urban conditions without removing the possibility of improving the provided services or proposing the implementation of new ones according to the feedback of the different types of users. In this phase, the project consists of two main components with different definition levels. The first involved the design of the basic prototype and defining its executive project (Figure 4). Simultaneously, a functional abacus was developed to provide a detailed overview of elements and functions that could be included in potential future scenarios (Figure 5), as well as possible additions to adapt the prototype for various urban settings (Figure 6).

3 - An international collaboration and eschange program between Massachusetts Institute of Technology (MIT) and the Politecnico di Torino (POLITO) For more information, see http://web.mit.edu/mitor/.

Figure 3- Proposal for the Turin's S[m2]art concept, developed in Alice Birolo's Master's Degree thesis entitled 'Urban furniture for senseable cities' in collaboration with MIT.

The vertical ring model can be better integrated due to its compactness and scalability. It is also potentially land-zero, as it could replace (rather than add to) the existing street lighting poles already integrated into the built environment. The basic prototype includes a support structure with a pole



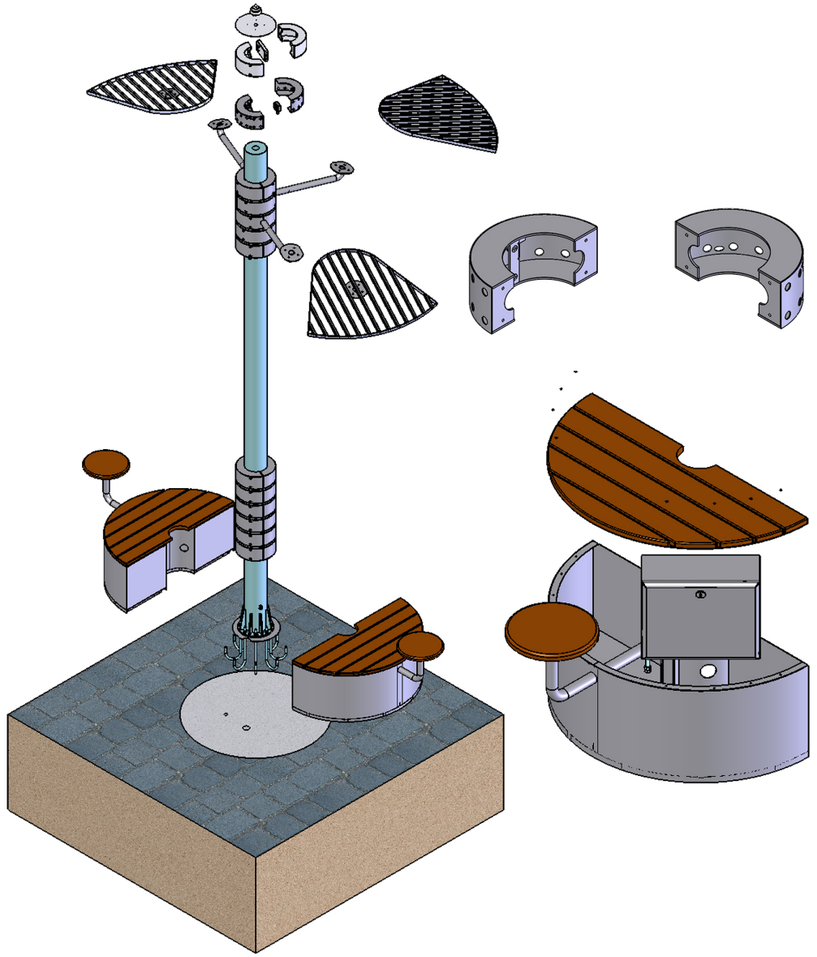


Figure 4. Plan, sections, plans (above), and axonometric exploded view of the basic prototype (right). Sources: GTP, DAD and Metalco Deliverables.

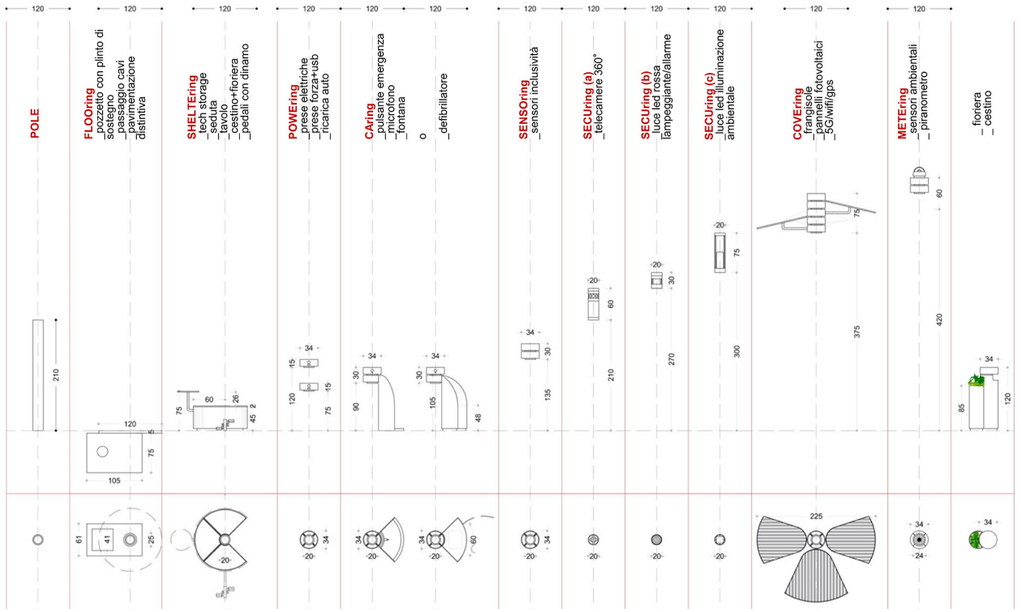


Figure 5. Functional abacus of elements. Sources: GTP and DAD Deliverables.

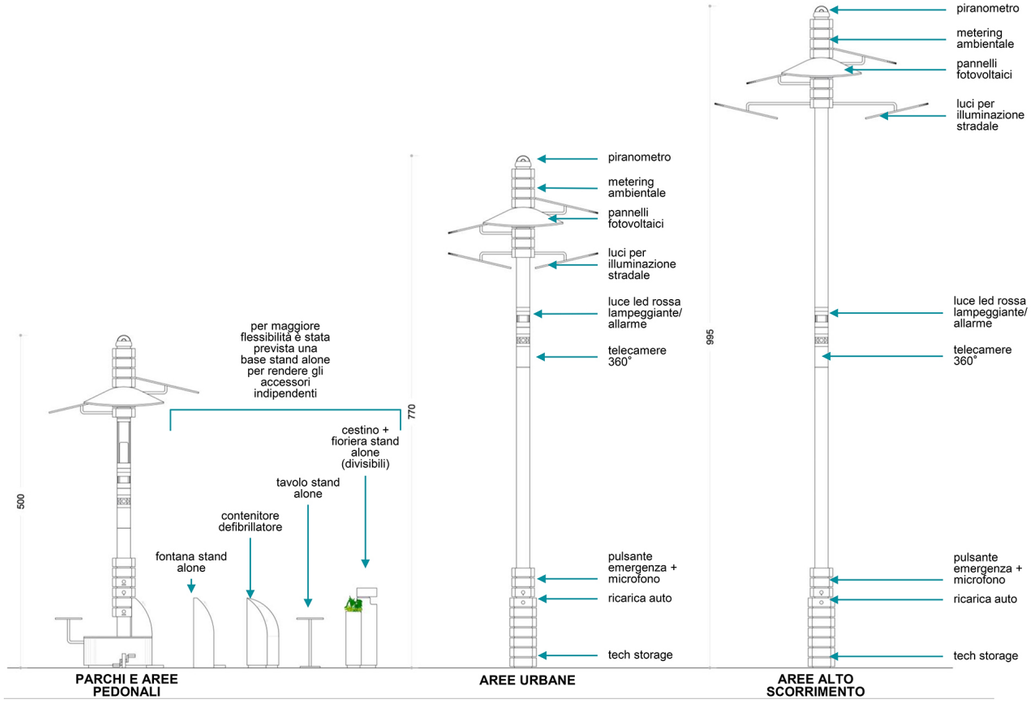


Figure 6. Possible integrations in different areas. Sources: GTP and DAD Deliverables.

that can progressively be equipped with specific devices for physical and digital services (the 'Rings'). Each Ring is a separate compartment structurally attached to the central pole, which contains the electrical system of the system as well as the hydraulic equipment in case there is the possibility of installing a drinking fountain. In each Ring, it is possible to install devices and sensors according to the changes in the urban environment and, therefore, in the needs of the citizens and the public administration.

As part of the last stage of the project, the prototype developed was built and installed in the Politecnico di Milano's Bovisa site (Figure 7) and the Politecnico di Torino's central campus. The integrated sensors will enable gathering a vast collection of heterogeneous data that, in various aspects, characterize the quality of the urban environment and the behavior of citizens.

Environmental and urban monitoring

Once the 1:1 scale prototype was built and installed in Turin and Milan, the team could start the monitoring phase. To achieve reliable data, the correct installation of the sensors was crucial. These IoT devices are currently measuring, collecting, and communicating information about several environmental factors (temperature, humidity, air quality, solar radiation). Regarding the prototype's acceptance, a user satisfaction button was activated to obtain information related to the use of the prototype. By scanning a QR code, users can access an online platform that provides information about

Figure 7. Vertical Ring at the Politecnico di Milano (left) and the Politecnico di Torino (right). Source: H&S Engineering S.r.l. (left); MultimediaLAB – Politecnico di Torino (right).

the various project phases. Furthermore, they can complete a brief questionnaire regarding the usefulness and benefits of the services (or Rings). This data will enable the research team to identify the most valued services and the users' preferences for integration into the Vertical Ring. (Figure 8).

The launch of the web portal aligns with the principles of FAIR Data and Citizen Science, enabling the ongoing enhancement of the Vertical Ring to meet the needs of both citizens and PA. Additionally, embracing an IoT approach will facilitate simple and immediate information sharing among diverse city stakeholders. Moreover, this integration will pave the way for future projects, ensuring the Vertical Ring remains adaptable and open to potential collaborations.

Further Steps

Moving forward through open planning requires a flexible and innovative approach to identifying new services. Although the Vertical Ring is an essential formal reference, it should allow for exploring and developing new solutions to respond to emerging urban phenomena. Thus, the future goals are to propose new services that adapt to the community's changing needs. Smart is not a static concept but is open and constantly evolving, and it needs to be developed in an active and participatory way. An opportunity to achieve this could be the organization of new workshops, offering the possibility to involve experts, citizens, and stakeholders and to explore the potential of 'digital twins' as a visualization and analysis tool to improve the planning and management of urban furniture.

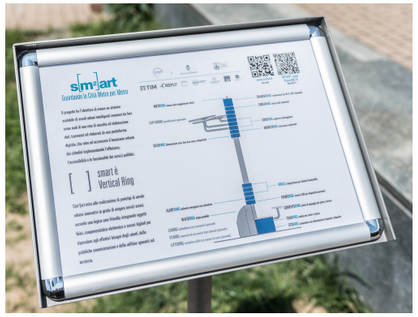


Figure 8. Explanatory display board with QR code and web-site for questionnaire https://sm2art-progetto.it/. Sources: MultimediaLAB – Politecnico di Torino (left); H&S Engineering S.r.l. (right).

Conclusions

In recent years, ICT systems capable of delivering services to citizens have significantly evolved due to the availability of new technologies and applications. The availability of distributed digital equipment, mobile devices equipped with sophisticated sensors, and the spread of social networking applications enable the collection of vast amounts of data. In addition, the development of innovative solutions for collecting and storing data, and processing it, makes it possible to extract a variety of helpful information to enhance the urban well-being of citizens.

The S[m2]art project sought to contribute to developing a network of intelligent and sensitive urban furnishings distributed throughout the territory. To achieve this, the research was based on an 'open design concept' which considers street assets as a system instead of as singular objects. This comprehensive approach, together with the specific competencies of the partners involved in the project, made developing the 'Vertical Ring' prototype possible. Moreover, the different international and local workshop experiences supported the elaboration of the compositional design of the Vertical Ring, stimulating the transition from the digital island to a minimalist urban intervention and a compact solution, more manageable from the point of view of integration with the built environment.

The S[m2]art project team installed two Vertical Ring base prototypes in different locations: the Bovisa campus of

the Politecnico di Milano and the central campus of the Politecnico di Torino. Each generates a new point of reference and a place of socialization, reinforcing the social fabric and face-to-face interaction. They also contribute to the digital transition of the cities thanks to their technological characteristics and features. Vertical Ring went beyond its passive nature, becoming a provider of physical and digital services such as monitoring different environmental factors, including air quality and solar radiation. The integration of IoT devices makes the functions easily managed through a virtual platform, providing information and data exchange between citizens and the public administration. In addition, the division of the Rings makes it easier to change their composition, allowing the addition of new sensors and devices for future needs. By realizing what was in goal, the S[m2]art project stands as a powerful tool for disseminating the Smart City culture.

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