Universidade de Aveiro
2021

Departamento de Engenharia Mecânica
Departamento de Comunicação e Arte

SARA SANTOS FIGUEIREDO

A CITIZEN-CENTRIC SMART CITY: DESIGN OF AN URBAN FURNITURE COLLECTION.

UMA CIDADE INTELIGENTE CENTRADA NO CIDADÃO: DESIGN DE UMA COLEÇÃO DE MÓVEIS URBANOS.

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Dissertation presented to the Aveiro University to fulfil the requirements in order to obtain a master's degree in Engineering and Product Design, developed under the scientific guidance of Doctor Teresa Franqueira, Professor in the Department of Communication and Art at the Aveiro University, and Doctor Kalevi Ekman, Professor at the Engineering Department of Aalto University.

the panel

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acknowledgements

With all humility and gratitude, I would like to acknowledge all the support and help that I have received throughout this project's development.

First and foremost, I would like to acknowledge the LuxTurrim 5G steering group, Pekka Wainio, Markku Heino and Sami Huuskonen, whose expertise was precious during the project development. I would like to express my appreciation and gratitude for their openness towards all of the novel design concepts and methodologies embraced during the project. I would also like to acknowledge all the consortium parties and entities contributing to this project´s development.

I cannot express enough thanks to my advisor, friend and mentor, Professor Kalevi Ekman, whose empathetic support, patience and dynamism pushed me to sharpen my thinking and helped our research team to bring our work to a higher level. Thank you deeply and sincerely for your trust, for the opportunity to participate in this research project and for welcoming us into the Aalto Design Factory community. It is a great honour to study and work under your guidance.

I would like to express my sincere gratitude to my advisor, Professor Teresa Franqueira, the first professor that I met at Aveiro University, who supported me along my educational journey. Thank you for your support in this research project, but mostly, for encouraging me to participate in Medes (Master of European Design) an international master program, which had a tremendous impact on me, both professionally and personally.

Additionally, this research project could not have been accomplished without the support of my dearest team members, Manuel Rosales, Petteri Heinonen and Sushant Passi. I would like to thank you all for your passionate work, for your empathy and especially for the marvellous episodes and memories that we have experienced and cherished. I would also like to show my deepest gratitude to all the design factory community for their kind assistance at every stage of this research project. I would like to offer my special thanks to those who have supported and "suffered" with our team in our final week of work, my kindest thanks to Shreyasi Kar, Jasmin Xie, André Santos, George Atanassov and Eetu. I would also like to emphasise my sincere gratitude for the support from the Machine shop staff, who helped our team to make our prototypes real.

Finally, my biggest thanks to my family for all the support you have shown me through this research, the culmination of three years of studying abroad.

For my partner, Carlos. Thank you for your warm support and encouragement when the project presented challenges. This was deeply appreciated and noted daily. It was a great comfort to know that you were always available and willing to help, even from afar. I would like to express my gratitude to my older brother, who has always supported me, acting as a role model and provoking a profound impact on my perspectives and goals. And to my tender little sister, who could always bring joy and happiness to any grey day. I would like to extend my sincere thanks to my grandparents, whom I have always deeply cherished, and who have inspired me to improve myself. I would also like to express my deepest gratitude to my dear friend and relative José Fonseca, for his kind support during my educational journey.

I dedicate this work to my supportive and caring mother and father. Carla, my dearest mother, thank you for inspiring me to dream big and believe that the only borders are the ones we set to ourselves. Pedro, my dearest father, thank you for encouraging me to never turn my back to any challenge and to smile at any obstacle.

My sincere thanks to all who have supported and contributed to this research work directly and indirectly.

keywords smart-cities, smart furniture, 5G, human-centric, city services, urban design

abstract

The LuxTurrim5G project, led by Nokia and Spinverse, in Finland, started by designing a Smart Pole whose functionality, besides lighting, was to support an infrastructure to install a new network for sensors, but mostly 5G equipment. The granularity of the pole locations was adequate to guarantee the spacing among 5G cells, thus enabling smooth integration of this technology in the urban fabric.
In the second part of this project, a design team from Aalto University was involved in enlarging the technological project's scope. The first part of the work consisted of analysing the apparent tendency to often catalog a city as a Smart City, which repeatedly occurred from the installation of any technological facility, even if citizens did not perceive its value. From the research conducted, it was verified that it is imperative to take a holistic view of the city and, second, to change the paradigm from technology-centric to citizen-centric to develop a Smart City that promotes quality of life and well-being for its citizens.

These findings resulted in the developed work, whereby the initial LuxTurrim5G pole evolved to become an innovative product-service ecosystem in which the products and services were merged to support citizens intrinsically, promote well-being, a better use of resources, and enhance civic participation and social cohesion in the city life. The Smart Pole triggered the conception of a Smart Urban Furniture Collection concept that was designed to offer support for the installation of new technologies as well as space for a robust set of services tailored to citizens and cities. These services range from safety and emergency, city management, transport and mobility, and citizen engagement. These were considered to be the essential set of service parameters in the Smart City context.

The Smart Urban Furniture Collection was designed to adapt to the city's DNA and urban cultural heritage. Four different collections were designed, each with an interpretation of, besides the Smart Pole, a Smart Bus Stop, a Smart Bench, a Smart Trash Can, and a novel element; a Smart Hub, developed to increase social inclusiveness and fruition of public spaces.
Besides coordinating the Aalto Design Factory team task force, the author of this dissertation proposed one of the four collections, in particular the Loop Collection. This collection, inspired by minimalism and emotional design, offers a modular approach based on an aesthetic motif, a rounded rectangular shape, leading to a significant number of easily configurable versions of the different urban furniture elements.

This paper describes the basic research that led to the above-mentioned concepts and the Loop collection, presenting a thorough description of the ideas supporting the different design decisions or approaches. It also details the different activities in which various stakeholders such as citizens, municipality managers, consortium partners and other representatives were involved prior to the design phase defining the process' strategy and evaluating the results.

palavra-chave cidades inteligentes, mobiliário inteligente, 5G, human-centric, serviços da cidade, design urbano

resumo

O projeto LuxTurrim5G liderado pelas empresas Nokia e Spinverse na Finlândia, teve como objetivo inicial conceber um poste de iluminação inteligente que, além da função base, serviria de suporte a sensores e à infraestrutura para uma célula da rede 5G. A distribuição dos postes de iluminação pela cidade oferece uma excelente granularidade permitindo implantar as células 5G sem necessidade de instalar infraestruturas adicionais.

Depois da primeira fase, este projeto prolongou-se para uma segunda fase na qual foi envolvida uma equipa de design da universidade de Aalto com o intuito de alargar para outras visões o cariz eminentemente tecnológico inicial. Na primeira parte do trabalho foi analisado o conceito de cidade inteligente tendo sido concluído que, aparentemente, a tendência para catalogar uma cidade como inteligente provém essencialmente da instalação de alguma tecnologia de qualquer espécie, mesmo com os cidadãos não se apercebendo do valor intrínseco correspondente. Assim, conclui-se que será imperativo trabalhar com uma perspetiva holística da cidade, mudando o paradigma de centrado nas tecnologias para centrado nos cidadãos. Só assim uma cidade inteligente será apercebida como tendo condições para promover a qualidade de vida e o bem-estar para os seus cidadãos.

Esta perspetiva macroscópica deu origem a que o poste inteligente da 1ª fase do projeto LuxTurrim5G evoluísse para um ecossistema de inovação com uma forte interligação de produto-serviço, permitindo promover uma simbiose entre elementos de mobiliário urbano e os sistemas com base tecnológica que eles suportam. Esta simbiose, quando orientada para os cidadãos, além da promoção do bem-estar, permite melhorar a utilização de recursos, promover a participação cívica e facilitar a coesão social. Assim, de um poste de iluminação chegou-se ao conceito de Coleção de Mobiliário Urbano Inteligente o qual deve ter condições para instalar tecnologia e para oferecer um conjunto significativo de serviços para os cidadãos e para apoio à gestão da cidade. Esses serviços deverem incluir áreas diversas tais como segurança e apoio a emergências, gestão dos sistemas da cidade, mobilidade e transporte e, muito importante, compromisso e envolvimento dos cidadãos.

A Coleção de Mobiliário Urbano Inteligente foi projetada para se adaptar ao ADN das cidades e à sua herança cultural. Assim, foram projetadas quatro coleções distintas, com a sua interpretação da melhor adaptação a uma cidade inteligente. Cada coleção incluiu, além do poste inteligente, uma paragem de autocarro inteligente, um banco inteligente, um caixote do lixo inteligente e, adicionalmente, um elemento novo, designado por “Smart Hub”, ponto central inteligente, destinado a promover inclusão social e fruição de espaços urbanos.

Além de coordenar a equipa da Aalto Design Factory o autor desta dissertação projetou uma das coleções, designada por Loop. Esta coleção, inspirada em técnicas de design minimalista e emocional, sustenta-se num módulo base como motivo estético, em particular uma forma de retângulo com vértices arredondados, com o qual se consegue obter um número significativo de versões do mobiliário urbano fáceis de configurar e de adaptar às necessidades da cidade e dos cidadãos.

Este documento reporta, assim, a fase de pesquisa que levou aos conceitos macroscópicos referidos e à coleção Loop, apresentando e discutindo as ideias que conduziram às diferentes metodologias e decisões de design. Também são apresentadas as atividades que permitiram levar em consideração os inputs dos diferentes stakeholders tais como cidadãos, responsáveis do município, representantes dos membros do consórcio e outras entidades relacionadas com a cidade. Este envolvimento deu-se não só no início desta fase do projeto, mas também no fim, permitindo neste caso obter feedback e uma avaliação preliminar do trabalho realizado.

acronyms

ADF	Aalto Design Factory
AI	Artificial intelligence
CCTV	Closed circuit television
HMI	Human machine interface
ICT	Information and Communications Technology
IT	Information Technology
IOT	Internet of Things
MVP	Minimum viable product
R&D	Research and development
SDG	Sustainable Development Goals
UX	User experience
VR	Virtual reality

“WHAT IS THE CITY BUT THE PEOPLE?”

SHAKESPEARE (1605-1608)

fig.1: What is the city but the people?

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1

Introduction

1.1 Background

1.2 The problem and its practical relevance

1.3 Goals and objectives

1.4 Motivation

1.5 Introduction to the dissertation structure

1.1 Background

Since its conception, the term 'Smart City' has been widely used by academics, usually technicians, and politicians. Whenever any IT or IoT based infrastructure is deployed, the expression is applied, as a way to enhance the image of the city governance. As a result, any city wide system such as bike sharing, smart irrigation, hot-spot availability, a piece of e-governance or similar subsystems, even if deployed individually, often leads to claims that a city is a 'Smart City'. The frequent use, and sometimes abuse, of the expression and, occasionally, poor results in what concerns servicing the citizen, has led to its depreciation. To overcome this situation, which erodes the beauty of the concept, a more holistic approach which focuses on the services and benefits that are available for citizens rather than the supporting technologies is nowadays proposed. What constitutes a Smart City is by no means agreed, but in what concerns this study the understanding of city "smartness" de emphasises technology and values the provision of services to citizens.

"A city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens. Smart city generally refers to the search and identification of intelligent solutions which allow modern cities to enhance the quality of the services provided to citizens" Giffinger, et al. (2017).

This Smart City definition highlights the major role that services provide in the urban ecosystem and places the citizen at the heart of the smart city strategy. The British Standard Institute extends the Smart City definition as the one "where an effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens" British Standards Institute (2014), as cited in Hilton. , et al., (2017).

The key insights that can be concluded from these various interpretations of the concept of Smart Urban environment is that the implementation of technology alone doesn't make a city smart. Smart cities are not technology-centric, on the contrary, they are citizen-centric.

One of the main problems with installing cyber-physical systems in the urban environment is the need to supply energy to the electronics and communications. Energy harvesting techniques are only able to gather small amounts of energy, thus they are not adequate to energy greedy subsystems. When we look at the infrastructures that populate a city, one will immediately notice the lighting. City lighting is pervasive, installed all over the city area, with a reasonably short distance among lighting points. It is also a locale where energy from the mains is easily available. The fact that most of the lighting points are supported on poles offers an additional opportunity to install further subsystems that require energy, height and protection from vandalism.

The inclusion of 5G technology in the city will change the way some services operate. This technology enables real-time, consistent, and reliable data transfer with near zero latency for wireless devices. The transition towards a smart city, in terms of technology, implies first that the city's infrastructure and platforms must be upgraded to provide this level of network connectivity. The 5G service trade-off for speed at mmWave frequencies has a limited range, of approximately 500 meters from the basestation. As higher frequencies are used a dense network of base stations is needed, due to shorter signal propagation length (Heino et al., 2020).

The current condition of this technology will necessitate an extensive propagation of 5G basestations in the urban environment, since various 5G infrastructures will be required to allow for standalone 5G deployment. The current constraints of this communication technology motivated a trend towards more flexible architecture of

5G basestations. With the decomposition of the 5G basestation, we can create new logical elements in the urban environment that can be deployed easily, by using and aggregating existing infrastructures and boosting additional functionalities with a minimal footprint. In order to meet the requirements for 5G connectivity, sensors are installed on traditional light poles, which makes intelligent use of the short distance between, and availability of power supply at, poles. This logical redesign and re-use of light poles has initiated a contemporary re-interpretation of the usability of this feature of the urban environment which has generated the concept for the Smart Pole. This small cell technology placed in smart poles network has created an alternative to the traditional cell tower. The Smart Pole design, placement and network based technology have been utilised to effectively create a viable standalone 5G network.

With this technology cities are one step closer to becoming truly smart, but the integration of technology in urban spaces does not rely strictly on technology and can be perceived as a complex process, which engenders diverse opinions. In one interview for the Damnº39 magazine (Lagos, 2013) the social scientist Saskia Sassen has expressed her concerns on how the mass integration of technology in urban settlements can de-urbanise the city, since there is a high and accelerated risk of obsolescence.Therefore, this network based technology architecture should be designed based on a modular and customisable approach that will be able to in-house the coming technological advances and innovative city based services. Nevertheless, the sophisticated structure of contemporary cities demands an innovative urban infrastructure that is able to reinvent itself and adapt to various requirements. According to social scientist Saskia Sassen, cities are complex and incomplete, since cities can keep reinventing themselves. One microcosm in the European context is London that has buildings that are 800-years-old and perfectly upgraded for the contemporary office and hotel use. This serves as an example of re-inventing and re-coding the urban environment.

Therefore there is a clear need to create an innovative network of urban infrastructure that can not only leverage 5G mobile network but can also support cities and walk side by side with the city's constantly evolving needs. This city network should provide the backbone for a smart city strategy that reduces the friction of everyday life by providing a healthy and safer environment. The general wellbeing will increase as both citizens and cities flourish. Based on a human-centric approach, this network should be designed to enhance citizen's wellbeing and urbanise technology in order to improve city management and operations, increase efficiency with fewer resources and lower environmental impact.

1.2. The problem and its practical relevance

Cities have always been the major centres of human and economic activity. They create the space for building synergies, allowing constant progress in various fields and generating diverse opportunities to their citizens. Nonetheless, as cities grow in size and complexity, they face a wide range of challenges, such as the growing urban population.

Nowadays, 55% of the world's population lives in urban areas, a proportion that is expected to increase to 68% by 2050, according to the United Nations estimates (United Nations, 2018). This shift of the population's spatial distribution from rural to urban areas will increase the level of urbanisation and size of urban settlements. This megatrend foresees the need to rethink the traditional city infrastructure and methods of urbanisation in order to house more inhabitants, promote an efficient use of resources, and optimise city space and service operations.

Simultaneously, climate change is a severe phenomenon that impacts the urban environment and life on a global scale. The rise of global temperatures will damage

urban settlements in various ways, including sea level rise, increased occurrence of extreme weather events such as floods and storms, and cause health related issues, for example the spread of tropical diseases. Climate change will have negative impacts on cities' infrastructures, basic services, quality of life, livelihoods, and health conditions, among other concerns. In addition, cities are also major negative contributors to the environmental conditions, since most urban activities generate a large scale of greenhouse gas emissions. "According to UN Habitat, cities consume 78 per cent of the world's energy and produce more than 60 per cent of greenhouse gas emissions. Yet, they account for less than 2 per cent of the Earth's surface" United Nations, (2020).

There is a clear need to transform cities into an intrinsic part of the solution in fighting climate change and promoting a good use of natural resources. Therefore digitalisation is a relevant tool, or possible solution to overcome these challenges and help cities to reinvent their daily operations and meet the sustainable development goals (SDG) set by the UN.

Several cities are already using renewable energy sources, cleaner production techniques, implementing regulations or promoting green incentives to limit industrial emissions in order to reduce local pollution, better use existing resources and tackle the current difficulties. But in order to support and design solutions for the complex cities of the future we need to generate a comprehensive and holistic overview of city infrastructure, consider governance initiatives and citizens' needs and embrace technologically driven solutions. There is an urgency to merging these different layers and relating them to specific city challenges in order to generate innovative services and solutions for the urban space. For this reason cities need to integrate a holistic approach to address urban challenges through digital innovation for the sake of innovative civic governance, planning, infrastructure investment, citizens' wellbeing and quality of life.

1.3 Goals and objectives

The technological evolution of our civilisation is a significant source of excitement, namely when one anticipates the fantastic achievements that can be realised due to newly available technological solutions. As a designer, I also feel this excitement but, as many others do, I become disappointed when the deployment of those solutions are not enough to promote recognisable well-being and improvements in quality of life for citizens. The case of smart cities is clearly one such situation where most of the deployed solutions are currently partial and the benefits for citizens are not always clearly noticeable, thus leading to a devaluation of the concept. Also, the majority of these solutions are often too technologically driven and do not take into consideration other important inputs from the social sciences, architecture, and design.

The LuxTurrim5G project, described summarily in the next section, did not, fortunately, follow this narrow technological approach. After a first proof of concept where technology was the main focus, the project gathered a set of different expertise from which design was the most significant. When I became of aware of this project and was offered the possibility to join the team, I anticipated that an enormous opportunity would emerge from a tight collaboration between technology and several areas of design such as product design, service design, and user centric design. I also anticipated that urban furniture could help to materialise the smart cities concept, by combining technology and infrastructure with a win-win objective that would serve citizens so that they could better live in and experience smart cities. A holistic view of these three components, technological support, urban furniture and services, could considerably improve the perception of a smart city as a place where everyone would aim to live.

In consequence, the main goal of this work is to look to a smart city as citizen-centric, instead of being technology centric, thus taking into consideration the needs and desires of its users. In order to pursue this goal, and connecting to the Luxturring project, one could make use of the “technologically enabled” smart pole of the project to be the center of a collection of infrastructures devoted to serve citizens.

The objective was, then, to extend the potential of embedding technology in infrastructures to facilitate its deployment, on one hand, and to increase the availability of services to citizens on the other. Although light poles are probably the largest set of urban furniture in cities, it was found that other units such as benches, bus stations, and trash cans, could also serve this endeavour.

Finally, these urban furniture resources that could be used to implant technology and support services should integrate well into their cities, taking into consideration their specificities and cultures while also appealing to their users, thus promoting an early and simple adoption of their respective uses. This last objective is, probably, the main objective as far as design is concerned and thus kept my attention and, consequently, led to my specific collection proposal, the Loop collection of urban furniture.

1.4 Motivation

My educational and professional path as designer was strongly marked by the Medes program (Master of European Design). This exchange program has not only enriched me on a personal level, and broadened my opportunities, also changed my comprehensive and holistic perspective of Design.
I began at my home university, Aveiro University in Portugal, where I obtained the general foundations of design from graphic to product and service design. In my first year of exchange at Politecnico di Milano I sharpened my product development and design critical thinking skills. Then, in my second year of exchange at Aalto University, Finland, I have been able to combine relevant learnings on a systemic level, from product to service and UX design. Simultaneously, in this last year of studies I’ve widened my perspective on the path of design based projects and merged project management with design creative thinking, pragmatism and a strategic organisation of ideas.

After taking part in a one year product development course at Aalto Design Factory (ADF), which required empathic leadership and design critical thinking, I was given the opportunity to work on a research based project at ADF. In this technologically driven project targeted to the urban environment, a comprehensive understanding of complex ecosystems and user needs, based on design thinking, was extremely relevant.

My diverse experiences during my studies have built my cohesive and multidisciplinary approach to design. The beauty of any design project is to understand the different angles of its identity and organically answer to its needs based on the different fields of design.

Therefore, understanding the complex structure and needs of the city, using the multidisciplinary perspective that I have obtained seemed a natural and extremely captivating process, both for its own sophisticated composition but also for its plasticity. The opportunity to participate in the LuxTurrim5G project which works towards “a Nokia driven innovation ecosystem developing and demonstrating fast 5G network based on smart poles with integrated antennas, base stations, sensors, displays and other devices” LuxTurrim5G (2020) strongly increased my interest in this area of design. This initiative will be further detailed in the coming sections.

Taking part on this project was, thus, a fantastic opportunity to embrace my comprehensive and holistic perspective of design but also to challenge my own skills and to continually grow my professional competences, making the most of the project development path

In conclusion, cities are on the edge of change. Being part of this transition, in any capacity, was unique and fulfilling. Being part of the fast-paced urban environment means that there was a need to be in sync with every technological initiative, governmental strategy, urban framework, and innovativation as they were released.

1.5 Introduction to the dissertation structure

This dissertation is divided into six main chapters.

This first chapter provides a general review of the project, by presenting the project background which introduces the concepts of citizen-centric smart city and technology urbanisation based on the practical relevance and problem urgency.

The second chapter provides a clear overview of the project context. The role of the Luxturrim5G consortium is explained and the collaborative project goals and challenges are presented as well as all of the parties involved. The Nokia driven innovation ecosystem development is illustrated, demonstrating how to build a fast 5G network. This chapter also emphasises the link between the original concept of the Smart Pole from the LuxTurrim5G consortium and the Smart Urban Furniture concept. This infrastructure can support cities and their citizens and accompany the city's constantly evolving needs. This chapter also contains a brief introduction to Aalto Design Factory collaborative research project and team member roles The general research project path, methodologies, goals, deliverables and main outcomes are described. At the same time, the project coordination strategy and the holistic perspective of the research work are highlighted.

The third chapter is an extensive analysis of the Status Quo of the Smart City concept. It visualises the complex city structure based on different perspectives of its urban zones. It highlights the city as a complex organic abstraction, and defines the concept of Smart City from the citizen-centric perspective. The role and point of view of the citizens is highlighted, using the outcomes of the users' workshop organised to collect under the scope of the LuxTurrim5G project. The topic of this workshop was focused on the urbanisation of technology and notion of smart cities based on citizens' needs and concerns. It emphasises the value of re-using and rethinking cities' public spaces, as an opportunity to impact and support citizens. On the other hand, this chapter revolves around the Smart City service provision and underlines the main service clusters present on the city environment. Additionally, in this section a clear link is established between the service and holistic realm with the product ecosystem, in other words, the material and material context. This link between service-products serves as an enabler of a city's transformation into a Smart City. This section lists the values and needs of the required infrastructure to deploy a smart product-service network. The main conclusions of this chapter emphasise the core principles of this study.

The fourth chapter introduces the notion that each city has its own genetic code and cultural heritage, which promotes the place identity and, therefore, the citizens' psychological attachment. This can incite a profound emotional and physical impact on their wellbeing and sense of belonging.
For that reason, in this chapter, the four collections of Smart Urban furniture are introduced. Those convey different values and therefore easily adapt to various city identities or requirements. In this section the Loop collection of Smart Urban Furniture will be further detailed based on its minimal and neutral characteristics,

which holds emotional design as the core of its uniqueness. This chapter illustrates the product development path from the preliminary conceptual sketches to the product architectures and solutions of the collection. This part adds a more technical perspective on the product development, since it analyses the conceptual identities of different products, from modular architecture and technical drawings to material selection and general technology integration. All of the industrial outlook was based on generating a good interaction and usability between the user and the product, and ensuring ease of maintenance, as well as preventing technological obsolescence. In what concerns the material selection, these decisions were based on environmental impact and durability in order to try to combine efforts to meet the sustainable development goals (SDG) set by the UN. In conclusion, this chapter shapes the infrastructure that will enable the service-product ecosystem for Smart Cities.

The fifth chapter emphasises the interconnectivity of the service-product ecosystem from a systemic overview. Cities are complex and divided into several layers of infrastructure-based systems. This chapter illustrates comprehensive product service systems based on the integration of novel technologies, which can empower citizens and answer to new urban needs. In this chapter we present product as the facilitator and technology as the enhancer of a service network. This chapter emphasises the value of product creation as the “front door” for new systemic innovation, that integrates new platforms or service networks. This analysis merges the smart city service clusters ideated in the third chapter and the product developed and introduced in the fourth chapter through the integration of emerging technologies. This study also illustrates use case scenarios that identify citizens motivations, necessities or blocks when interacting with the Smart Urban Furniture products.

The final chapter is the conclusion of this research work. It includes a relevant outline of the contents of this master thesis and evaluates the results of the work developed. The main achievements of the work development are summarised and the open points for further work are identified.

2

Overview and Context of the project

2.1 Context of the dissertation project

2.2 Introducing the Aalto design factory team, methodologies and approach

2.3 Introducing the LuxTurrim 5G project challenges and goals

2.4 From a Smart Pole to the Smart Urban Furniture inhabiting concept

2.1 Context of the dissertation project

fig.2: Aalto Design Factory logo.

This dissertation was developed from January 2020 to December 2020. Within the context of a research based project and internship at Aalto Design Factory. The internship rests on the LuxTurrim5G project, developed by a consortium of companies led by Nokia and Spinverse in Finland. This project has established a first generation pole that incorporates street lighting, various sensors and the electronics for small 5G cells. My role and contributions are based on the expansion of the Smart Pole context to the Smart Urban Furniture collection concept. This concept integrates new technologies and rethinks the usability and urban impact of street furniture. The core of this project is focused on urban renovation and sustainable development of the future of our cities.

The development of the LuxTurrin5G work is directed towards an effective product network based on urban furniture, and poses several design challenges. One challenge is how to define a holistic solution that considers the integration of technology in the urban environment and defines technological needs and goals for products upfront and based on user needs and environmental requirements. Therefore, design takes a fundamental role in the synthesis of a technology driven ecosystem with the city services. This approach to systemic design was taken in order to build a comprehensive and inter-linked product-service network for smart cities. During the project development many challenges had to be addressed in order to establish a holistic balance between human needs and environmental and urban preservation.

This research is the result of academic research work based on the LuxTurrim5G project and consortium partnership. Increased competition and globalisation motivates industry and academia to join forces in order to enhance the impact of the research conducted. Collaboration between different parties with various views can be very enriching, however, it can be very challenging to combine all the inputs and meet different expectations. Design takes an important role in merging the interests of different partners and building a macro and user-centric understanding of the big picture of the project. In this context the value of design research was focused on the strategic lens to explore, and try to better understand, our complex and sophisticated urban structures, in order to address social, economic and environmental decisions.

This research has benefited from the Aalto Design Factory environment, an interdisciplinary product design and innovative learning hub. At ADF innovation through collaboration is embraced in order to respond to stakeholders' complex and interdisciplinary challenges.

According to the European Journal of Education, the goal of innovation is often linked with the need for collaboration, since it provides practical values through diverse perspectives. Today's innovation comes through collaborative channels and networked creativity that often requires navigating challenges that are linked to interdisciplinary approaches and the dynamics within teams (Björklund et al., 2019).

This project embraces this creative collaborative approach since it has benefited from a synergetic environment but also a multicultural and multi expertise design team that has developed the Smart Urban Furniture concept during the research phase. This dissertation is the reflection of this collaborative work, focused on the strategies for a citizen centric smart city from a comprehensive design perspective that urbanises and humanises technology and culminates in one minimal collection of urban furniture products.

2.2 Introducing the Aalto design factory team, methodologies and approach to the project.

The Aalto Design Factory research team was composed of four designers from various backgrounds. From those, two were master students and two recent graduates. This team has worked collaboratively during one year, and merged their creative backgrounds in order to build a holistic perspective on the project, taking into consideration the challenges and goals stated by the LuxTurrim5G consortium. It should be emphasised that the work presented on this dissertation could not have been achieved in such a systemic and comprehensive manner, without the passionate work of this research team that included, besides myself, Manuel Rosales, Petteri Heinonen and Sushant Passi.

fig.3: Alto Design Factory team. From Left: Petteri Heinonen, Sara Figueiredo, Manuel Rosales and Sushant Passi.

This design team was guided and supported by Professor Kalevi Ekman and supervised by the steering group of the LuxTurrim5G consortium composed of Pekka Wainio, LuxTurrim5G+ Project Leader; Markku Heino, LuxTurrim5G Ecosystem Coordinator; and Sami Huuskonen, Tehomet design manager. The steering group has closely followed the project on a biweekly bases, regularly discussing progress and defining next steps. This steering group valued the holistic design view of the research team and mentioned several times that this comprehensive view was of extreme value to various project partners. The consortium was always welcoming warmly the different ideas and perspectives on the project generated by the Aalto Design Factory research team.

fig.4: Aalto Design Factory team at the Smart Bus Stop prototype. From left: Prof. Kalevi Ekman, Sushant Passi, Manuel Rosales, Sara Figueiredo, Petteri Heinonen.

All the team members were engaged with the project through its entire life cycle and focused on different aspects of the research work. Therefore the collaborative work and task division were distributed in a flexible manner in accordance to the expertise of each team member and the necessities of the project. Based on this approach it was possible to identify each team member's strength and divide the roles into four characters and mindsets, namely:

- An optimistic design team coordinator: responsible for coordinating team activity and resource planning, supporting the team by drawing out the objectives

and path while also using a versatile approach to identify the work required and complete it on behalf of the team.

• An analytic and grounded moderator, providing a logical eye, making relevant judgements in order to effectively scrutinise the work.

• A hands-on and highly creative contributor, capable of identifying unconventional solutions to solve the successive problems encountered throughout the iterations of the work.

• A gifted experimenter and visual maker, offering an inquisitive nature to find ideas to bring back to the team, and able to communicate those ideas in an effective way through appealing visuals.

It should be emphasised that all the design team members have generated design content, and collaborative work in all stages of the project. In this context, my personal role beyond design driven tasks was to coordinate, motivate and support the team in an empathetic way. The design coordinator was also responsible for generating effective communication between the different project parties. Even thought it was a challenging year due to covid-19 circumstances, the transition towards remote work was smooth and the team has always co-operated effectively, closely and successfully.

In order to keep a comprehensive and summarised view of the project, the methodologies applied throughout the development of the work are represented in the double diamond model, illustrated in the figure 5. Annexe 01 and 02 further detail the project timeline, milestones and activities.

The design research team strategy during the development phase was based on a systematic review and desk research in order to contextualise challenges and goals, and identify best practices adequate for the project. This research approach quickly progressed into a meta-analysis method, since it was found that the complexity of a city would require a macro and systemic understanding from diverse fields and perspectives.

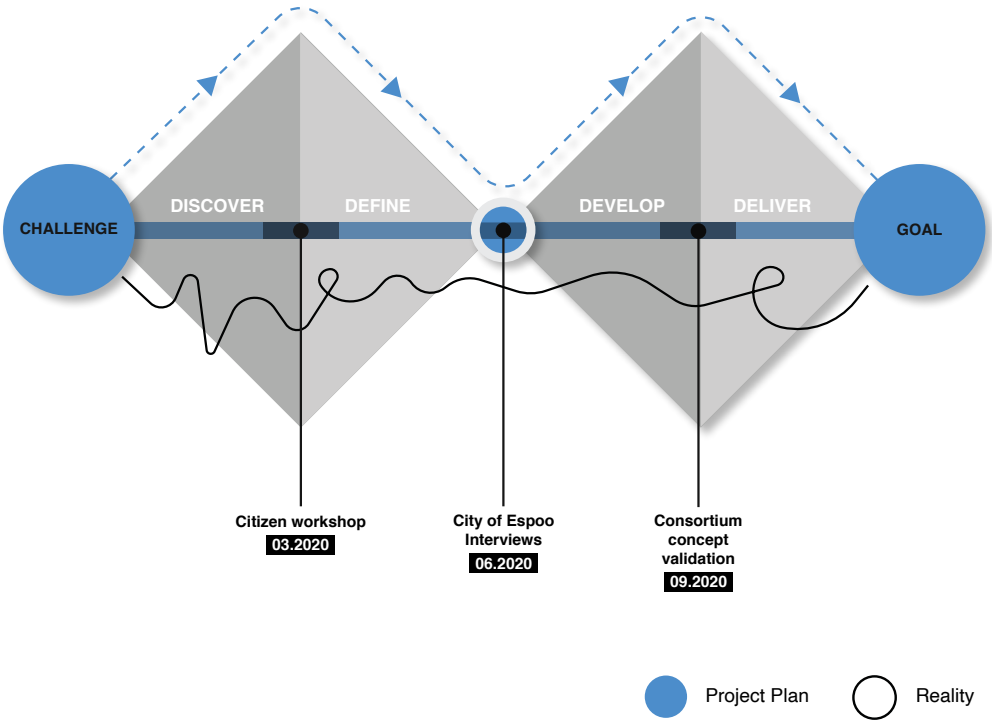


fig.5: Double diamond as a visual representation of the project path.

As a result, after the research phase, a workshop with citizens was organised to discover and validate a new set of city services and urban opportunities that could be provided within the scope of the project, and be relevant for users (citizens). These services were then mapped onto a set of prospective urban furniture and a final definition was then agreed to with the aid of specialist from the city of Espoo through several sequential interviews. The development of the functionalities and thus the specification of the urban furniture elements were validated by the steering group of the consortium partners in a series of meetings with the design team. Upon the approval of the specifications, the work consisted in designing the final elements and in prototyping the most relevant of them. In particular the work focused on the Smart Pole, Smart Bus Station and Smart Bench which were considered the most relevant to illustrate the achievements of the project. The prototypes were useful to test user interactions in real scale models.

Beyond the prototypes, the project included a set of additional deliverables such as a virtual reality application to create a model of the urban environment populated by the products conceived and serving to test user interaction without having to build all of the product variants. An online platform was deployed which not only shows the products but also explains the concept, motivation and scope of the project. This platform is also intended to be a tool for the consortium and a repository of the project deliverables.

The most significant moment in the project timeline was the final workshop - presentation where the prototypes were revealed, inspected, used and briefly tested. This event was organised in a hybrid fashion with some onsite participation as well as a significant number of remote attendees.

2.3 LuxTurrim 5G - Challenges and Goals.

The LuxTurrim5G, is a continuum project that was started in 2017. This project has gathered a significant group of Finnish companies, led by Nokia, around the problem of installing a 5G network in cities in order to enable the deployment of services and infrastructures requiring time critical, real-time communications.

fig.6: LuxTurrim5G logo and consortium partners.

Considering the pervasiveness of lighting in a city, the project focused on light poles as potential hosts of a variety of technologies and services, giving origin to a “smart pole”. The main outcome of the project was the prototype of the smart pole which integrates different elements to support a 5G cell, elements for a position system, surveillance cameras, wi-fi, traffic radar, information and user interface display, sound system, alarm button and, obviously, intelligent lighting, among other features further explained in this research.

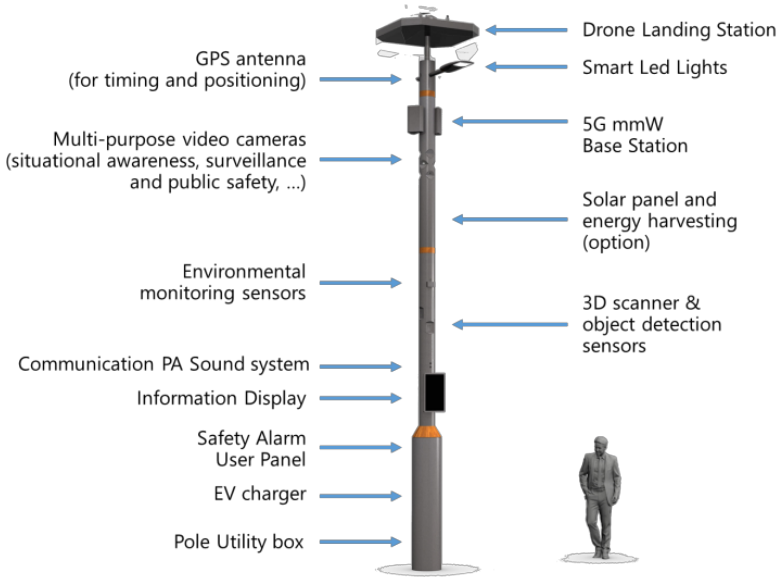


fig.7: LuxTurrim5G smart pole and features.

During the LuxTurrim5G project it became evident that the smart pole with enriched functionalities was like the tip of an iceberg and that contained an enlarged concept that could be worked around and behind this piece of urban furniture. In consequence, the presentation of the project moved from an emphasis on the smart pole to an emphasis on an innovation ecosystem, as stated in the official project summary: “LuxTurrim5G is a Nokia driven innovation ecosystem developing and demonstrating fast 5G network based on smart poles with integrated antennas, base stations, sensors, displays and other devices” LuxTurrim5G (2020).

This change in the project strategic direction was then reinforced in the project continuation which was organised in 2 tightly coupled new projects: LuxTurrim5G and the Neutral Host Pilot, both led by Nokia and Spinverse, the first company with the overall project coordination and the technical coordination in what 5G is concerned, and the second being, “the Nordic leader in innovation consulting, specialized in driving open innovation ecosystems, arranging funding and commercializing emerging technologies” Spinverse (2020), with the role of project and ecosystems coordination (LuxTurrim5G, 2019).

These 2 new projects should propose and prove the concept of a new digital backbone for smart cities by developing holistic solutions integrating the smart pole and sensor network, the data platform and need-based data-driven services. The results should not only help cities to face the challenges regarding urbanisation and sustainable development, but also to create new business opportunities in the context of real smart cities. In consequence, the “LuxTurrim5G innovation ecosystem” should face 4 key challenges:

- To attenuate the effects of climate change and growing trend of urbanisation, as now more than 75% of global energy consumption and carbon emissions are originated from cities.

- To promote digitalisation as a tool to overcome previous challenges, in order to build holistic solutions in a fast-paced rhythm, supported by novel infrastructure and a truly digital ecosystem.

- Finally, keeping the core of the first project, the fourth challenge consists in finding solutions to implement the dense networks of antennas and the new requirements for the network infrastructure capable to support small cell 5G radio frequency technology, and even higher frequencies, so that services and users can have access to fast connectivity and high capacity needs (LuxTurrim5G, 2019).

Inspired by these challenges, the project consortium defined 4 goals and correspondent expected results:

• To further develop and improve upon pilots of the smart pole based 5G infrastructure to enable the connectivity based on this standard and to create the infrastructure of a city-wide IoT & sensor network.

• To develop a data platform in order to promote new operating & business models, as well as service innovations, so as to enable state-of-the-art smart city services.

• To support the creation of an open access ecosystem for developing the envisaged new digital services.

• Finally, in order to show the potential of the overall project results, pilot digital services should be deployed, aiming for fast commercialisation on selected thematic areas that require attention, such as first & last mile logistics, autonomous transportation, public safety & situational awareness, information sharing & advertisement, weather & air quality monitoring and healthy living.

The progression of the first LuxTurrim5G to the two following projects, and the evolution of the goals and expected results clearly show a transformation from a closed end project to an on-going research and development activity with a much wider spectrum of target areas than initially envisaged. This transformation is even more visible in the enlargement of the project partners in both companies and academic institutions. In fact, the project carries on a highly multi-disciplinary R&D activity working first on several technologies that were essential to the initial project, such as new materials, smart pole design, miniaturised 5G base stations, a variety of sensors, data processing & analysis. In addition, the project seeks to integrate these together and build a base for new businesses as well as ongoing research in disciplines such as product design, service design, urban planning, traffic engineering, legal and regulatory issues, and more.

The work presented in this dissertation was performed within the scope of the LuxTurrim5G + project and will be detailed in the following chapters. However, it should be mentioned that due to the enlargement of the scope of the project and the holistic view that emerged from the work done, the design team led by the author of this dissertation, assumed a project management role, making connections among the involved areas and partners. From the design perspective this was clearly an exciting challenge, from the large dimension and extension of the project, to the diverse nature of the issues faced, the various collaborative environments and mostly the opportunity to engage and co-create with different experts and colleagues.
The design team also made several contributions to the second project, Neutral Host Pilot, which focuses on data-driven business and service development, intelligent network construction and operating models. However, these were loose contributions derived from the main work on thinking the Smart City and Smart City services carried on by the design team. This project is clearly very broad and will go on, beyond the time span initially planned. A summary of the ideas and extension of this project can be observed in the following quote by Heidi Himmanen, from the Finnish Transport and Communications Agency Traficom's 5G Momentum ecosystem:

"Neutral Host models could allow cost-efficient building of 5G network services in cities and along transport routes. Building out 5G extensively will probably require new approaches to, for example, business models and infrastructure sharing between operators, as well as telecom and spectrum regulation enabling these new solutions. We see clear socio-economic benefits in co-operative models of building the future digital infrastructure".
Our contributions to the Neutral Host Pilot Project, significant though they were, are not discussed in this work report, so this topic will not be addressed further in this dissertation.

2.4 From a Smart Pole to the Smart Urban Furniture inhabiting concept

As referred, the LuxTurrim5G Project evolved from a Smart Pole to a Smart Pole based innovation ecosystem. The technology which was the focus of the first project changed roles, from the objective, to an infrastructure supporting novel services. It should be recalled that, in spite of the role change, the smart pole is a very rich piece of urban furniture as it offers illumination, energy, communications, sensing and Human Machine Interfaces (HMIs). Considering the novel services that can be supported in the Smart Pole based technology and looking at them with a macroscopic and holistic view, we have arrived to the conclusion that this model of a Smart Pole could be generalised to a novel model: Smart Urban Furniture. The pole not only serves as an example of what a smart piece of furniture could offer, but also as a provider of other infrastructures required to transform different pieces of furniture in smart artefacts. The extension of this concept led to the Smart Urban Furniture notion which encompasses, in the scope of the project, and besides the Smart Pole, the following elements:

- Smart Bus Stop
- Smart Bench
- Smart Hub
- Smart Trash Can

The project has also taken into consideration the diversity of cities. It is unlikely that a piece of urban furniture designed to fit a city environment will also fit immediately in another urban context, another country, another continent, populated by people with different cultures. Therefore, four collections of Smart Urban Furniture were developed resulting in a total of 57 product variants. These products were designed to fit the requirements and heritage of various cities.

The potential of this concept and its interpretation were well stated by LuxTurrim5G ecosystem coordinator Markku Heino from Spinverse, by saying: “Embedding technology in city infrastructure in a way that it is unobtrusive but functional and responds to the needs of users is an important and not an easy task. The great work of the ADF team on scenarios, concepting and practical prototyping has given important background for the development of the smart pole family and related services and a lot of food for thoughts in smart city planning” Heino (2020).

During this dissertation we will describe the work that led to the emergence of this concept and the design work around the smart pole and the urban furniture pieces designed. Three of the collections will be briefly presented and a special emphasis will be given to the fourth, the “Loop Collection” as its conception was essentially worked by the author of this dissertation.

3

Smart Cities as Ecosystems

3.1 The Smart City

3.1.1 The Smart City Abstraction, definition and composition

3.1.2 The future of citizen-centric cities, remote user-workshop

3.1.3 Rethinking public spaces and citizens urban participation

3.2 The City on a systemic level

3.2.1 Smart city structure and future services

3.2.2 City infrastructures principles, based on product-service system

3.1 The Smart City

3.1.1 The Smart City Abstraction, definition and composition

Cities are complex and sophisticated, consistently changing in a fast-paced rhythm. Nevertheless the transition towards a Smart City is not only perplexingly complex but also chaotic. What might constitute the Smart City notion and/or definition is rarely agreed, there have been various attempts from industry, governments or academia to provide a clear interpretation of this concept but, unfortunately, these definitions tend to differ significantly in emphasis. This has led us to describe the Smart City as a chaotic concept.

City services are crucial to maintain the city's daily operations and generate the base for the Smart City Ecosystem. Therefore, these services are highly linked with the city's composition and needs of different urban areas. At the same time, the development of new services relies on the inclusion of 5G technology in the city, since this technology enables real-time, consistent, and reliable data that will reinvent the city on a systemic level. For this reason, the transition towards a smart city implies first that the city's infrastructure and platforms must be upgraded to provide this network connectivity. This explicit influence of technology in the urban settlements emphasises the core value of this research. In fact, the central theme of this research is to explicitly de-emphasise technology and emphasise service provision and citizen wellbeing.

What makes a city smart is not the implementation of technology; smart cities are not technology-centric, on the contrary, they are citizen-centric. A smart city invests resources - human, social capital, transportation and communication - to fuel sustainable economic growth and citizens' well-being, with prudent management of natural resources, through participatory governance (Caragliu et al., 2011, as cited in, Hilton et al., 2017).

Under this citizen-centric approach, the value of services is focused on citizens as customers (represented by city management entities) and end-users. Wellbeing will increase as both citizens and cities flourish. Technology is used to improve city management and operations, aiming to increase its efficiency with fewer resources, but the value capture resides with citizens. It is citizens who benefit from efficient, integrated and targeted place-based city services; co-creating value through social cohesion, engagement and participatory collaboration.

In order to improve the understanding of the services that the smart city ecosystem should provide in the different parts of the city, first, it was necessary to clarify and validate the city's general structure and complex urban layers. This investigation was done in order to create a holistic analysis of the standard urban arrangement and the division of key functions therein.

The outcome of this analysis was an infographic to visualise the city's overlapping urban areas, and analyse the distribution and focus of the various services that a Smart City ecosystem could support. This infographic was subsequently used for service ideation and later validation with the city's users, its citizens. It is important to emphasise that planning and zoning of cities differs greatly both from city to city and internationally. It would be impossible to produce a detailed, generalised, overview of how different functions correspond to different parts of a city. In reality, the areas of a city have considerable overlaps: for example, residential areas often have commercial functions embedded in the form of ground-floor stores and other services, especially in central areas. Furthermore, industrial areas are often interspersed with commercial parks, and green areas frequently exist in conjunction with residential or public-sector areas, such as campuses and governmental buildings.

The mixing of functions is also evident in rising international urban planning trends

and spatial geography innovation. One of the most popular movements that is the core responsible behind an urban regeneration is often called Innovation Districts. These districts are often described as geographic areas where leading-edge anchor institutions and companies clusters are connected with start-ups, business incubators, and accelerators. They are also physically compact, transit-accessible, and technically-wired while also offering mixed-use housing, office, and retail. These districts can be considered the manifestation of mega trends, that are altering the location preferences of people and firms and, in the process, re-conceiving the very link between economy shaping, place making and social networking (Katz et al., 2014).

fig.8: Innovative District: Barcelona District 22@.

We designers often speak about the beauty of accidental inter-mixes and collaborations, in order to generate diverse perspectives and meaningful co-creation. This is the core of urban regeneration in the Innovative district context, as the senior writer and consultant Pete Engardio has expressed at Bloomberg Businessweek “The trend is to nurture living, breathing communities rather than sterile remote, compounds of research silos” (Katz et al., 2014). This concept began in the early 2000’s with Barcelona’s District 22@ and Boston’s Seaport Innovation District. Other cities have followed this initiative, and more are added each year.

fig.9: Innovative District: Boston’s Seaport.

In the Finnish context, and also linked with the LuxTurrim5G+ project, the new plan for Espoo’s Kera, which will act as a pilot program for a future Smart City, proposed services deliberately mixed with residential blocks in order to bring the services to the residents. Thereby, the Kera plan avoids unnecessary commuting, generates new business opportunities, enhances social wellbeing and spurs innovative, collaborative, initiatives.

fig.10

fig.11

fig.12

fig.10: Kera plan for the new residential and working areas, from Studio Puisto.

fig.11: Kera Area city plan from B&M Architects Ltd.

fig.12: Kera as the new ecological local centre of the city of Espoo.

Rather than attempting to provide an all-encompassing representation of a complex reality, in this city canvas and visualisation we set out to create an abstraction in which those functions would be represented by discrete zones, referred to as “layers”, which stand in for areas and functions which may or may not overlap in reality. The locations of the layers in the chart are likewise abstract, and not indicative of those functions’ physical locations within a city: the placement and segmentation of the layers was done largely for the purposes of visualising the information as understandably as possible.

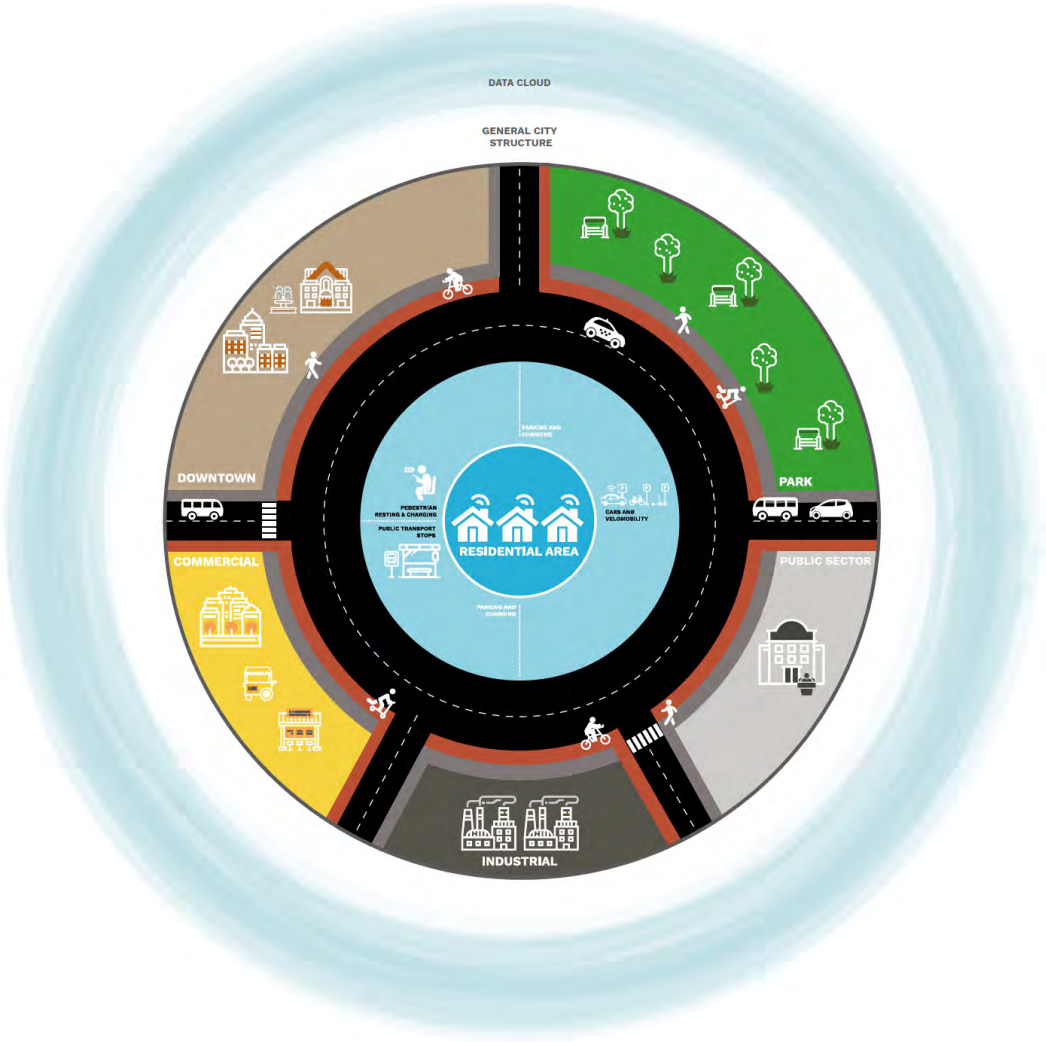


fig.13: City infographic that holistically represents the urban fabric.

The final infographic produced as a result of the urban area analysis takes the form o a series of concentric circles, some of which are further divided into various sectors. The innermost circle represents the residential areas; surrounding it is the parking and charging field, which is subdivided into fields for cars and velomobility, pedestrian resting and charging, and public transport stops. Around them are streets, which represent commuting between the different areas. The next circle is segmented into parks, the public sector, industry, commercial areas, and downtown. Finally, around these sectors are two “meta-layers” that apply to all of the before mentioned areas: the general city structure and the data cloud.

This infographic offers a standardised analysis of the urban areas from a comprehensive perspective, while describing the city from the inside. Each concentric circle, excluding the meta-layers, was design based on the citizen use of the urban environment. The city canvas can be seen as a comprehensive visualisation of the urban layers but also a citizen-centric journey map. This visualisation starts in the residential areas, and portrays the citizens’ movement in the urban environment, as users commute from these areas to public transport stops and or parking & charging areas and, afterwards, use the roads to commute to the main active centres of the city such as downtown, parks, public sector, industrial and commercial sectors. Therefore this infographic not only visualises the city’s complex structure but also represents the flow of the city based on who lives in the urban settlements. This infographic has served as the foundational service and product ideation tool in order to represent different cities contexts.

This design approach was very much based on Ezio Manzini's methodologies, to observe and analyse from a comprehensive perspective, but also from the perspective of the community that lives in the city. Therefore, with this approach, we generate the urban fabric by centralising people and their needs, and consequently building the "city of design".

"Cities can be seen and described by different points of view. The most frequently adopted has been the bird's-eye view: the city observed from the high and from outside. The city you can see in this way is what, traditionally, has been the city of the planners. But a city can be seen and described from inside too. That is, as it is seen by who lives in it: the city of people and communities. And the city made of places, roads and squares, but also of products, services and communication. This city of people and communities is, or should be, the city of design" Manzini (2019).

The city canvas layers will be further described in the following points.

- The **residential areas** are placed in the centre of the chart. This layer represents any form of residence, from suburban detached houses to apartment blocks in city centres.

- The **parking and charging** layer represents the transition from one's residence to commuting to different parts of the city.

- The **roads** indicate commuting between areas, whether it be through roads, streets, or other channels of transit.

- The **parks** encompass all green areas that are part of cities, from thoroughly-maintained public parks within a city centre to forests as in the Finnish urban context.

- The **public sector** encompasses public facilities, such as governmental buildings, hospitals, schools, university campuses, etc.

- Areas covered by the **industrial** layer range from micro-industry to industrial parks, logistic centres, ports, and business campuses, but also pertain to industrial areas in the transition to other functions.

- The **commercial** areas encompass any part of the city primarily dealing with private sector activity, such as stores, shopping malls, and markets, as well as other miscellaneous privately-provided services.

- The **downtown**, as defined in the layer structure, denotes the city's commercial, cultural and historical centre. Specific considerations as to the services in these areas include the high amount of traffic, the presence of tourists and non-permanent residents, as well as cultural landmarks.

- The **general city structure** is the first meta-layer, which surrounds the function-specific layers. It encompasses services that exist universally in all areas of a city.

- The **data cloud** layer represents services that do not have a direct physical presence in any part of the city, but instead exist digitally within the smart city ecosystem. While thus "invisible" to the regular citizen, this layer is a crucial consideration when planning the smart city services, as it forms the digital backbone of a smart city.

Having briefly characterised these layers we can detail those which were more closely scrutinised in our project. The data cloud is where city data management resides - processing and aggregating the vast amounts of data from across the city into a useful form, dispensing it to the proper parties, and, providing the means to

manage the systems through which the data is gathered. Dividing certain outward-facing services by area helps ideate and define those services. A meta-level view of the entire digital ecosystem is also necessary to understand how these services fit together, as well as how they are managed. Therefore, although the main focus of this research is to build a clear understanding of the citizen-centric Smart City, work remained on the physical infrastructure that will be further explored and described. The data cloud layer was seen as an important factor in what form that infrastructure may eventually take. However, the details about this layer are out of the scope of this dissertation and thus will not be further discussed in this document.

This analysis of the city layers and composition has elucidated what type of services and physical infrastructure could be used in the different urban zones, specifically pertaining to the features that would be incorporated into that infrastructure in different areas. This canvas was not only used as the board for service-product ideation within the traditional research methodologies, but it was also used to brainstorm and validate new concepts with the city user that will be described below.

3.1.2 The future of citizen-centric cities, remote user-workshop

Workshop strategies, methodologies and goals.

People are the core of this project, therefore, it was essential to involve them throughout the research process. With this in mind we have embraced Leonard and Rayport's approach to spark innovation through empathic design. These professors from Harvard Business school have described empathic design as innovative techniques that require unusual collaborative skills, such as open mindedness, observational skills, and curiosity, and the use of visual information along with having a clear perception of companies' capabilities. They get closer to the customer by observing with fresh eyes the user in it their own environment (Leonard et al., 1997). We embraced this approach in order to expand the borders of traditional design research and generate meaningful creative interactions and knowledge creation.

"Traditional researchers are generally trained to gather data in relative isolation from other disciplines; empathic design demands creative interactions among members of an interdisciplinary team" Leonard et al. (1997).

With this in mind we used empathic design methodologies in order to try to soften the border between design and research, and embraced the user perspective, experience and expectations on the future urban environment.

fig.14

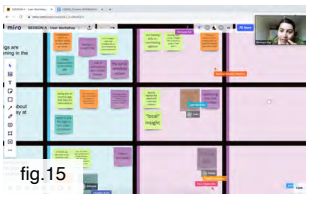


fig.15

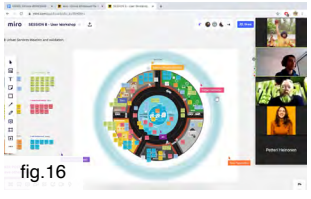


fig.16

fig.14: User-workshop participant on a Zoom call: first workshop session.

fig.15: Workshop participant interacting in the first activity.

fig.16: Workshop participant interacting in the second activity.

We intended to organise a user based workshop on-site. Unfortunately due to the challenging covid-19 circumstances, there was a need to switch this workshop to remote on the 24th of March 2020. We used the Zoom and Miro platforms in order to interact and facilitate the user workshop sessions. Due to these circumstances the user workshop was divided into three main sessions of one-hundred minutes, with an approximate participation of five stakeholders per session. The majority of participants were part of the Aalto Design Factory community, a multicultural and diverse community in terms of age and professional field in the academic environment.

fig.17: QR Code for remote user workshop teaser.

In the sessions we aimed to collect a comprehensive understanding of the 2 layers of sensitivity and empathic design. Namely, Sensitivity toward humans, by gathering inspiration, information and making sense of people and their experiences and contexts. Sensitivity toward design, seeking potential design directions and solutions based on the users' perspective (Mattelmäki et al., 2014).

With this approach, we not only collected generalised findings and additional perspectives but we also generated a clear perception of the citizens' user experience in their urban context. Additionally, we established a new potential design direction based on the citizens' attitude towards the urban context.

In order to gather this holistic perception of the users needs we used design based visual tools and collaborative methodologies to address and enhance co-creation. In other words, we used the 2 other layers of empathic design in order to facilitate the workshop, namely "Sensitivity toward techniques, application of generative, prototyping, and visualising tools to communicate and explore the issues, and sensitivity towards collaboration, tuning the process and tools according to co-designers, decision-makers, and organisations alike" (Mattelmäki et al. 2014).

Therefore, to organise this user workshop we embraced the 4 sensitive levels of empathic design described in the paper "What Happened to Empathic Design?" by Tuuli Mattelmäki, Kirsikka Vaajakallio, Ilpo Koskinen. This perspective, and the approach to address users' needs have offered new ideas and identified new touch points for action. Design starts from the citizens, from the places where they live and the actions they perform. This approach leads to a new form of urban planning.

The main objectives of this workshop were to identify strategies for smart cities and to ideate and validate services that the city users, our citizens, will be interested in within the smart city context. Based on these analyses we aimed to identify, in a collaborative environment, service action points and touch points, and how to provide or facilitate these services in different city areas based on urban products or initiatives.

Workshop structure and activities

The different sessions of the workshop were divided into 2 main sections, namely: Welcome and Introduction and Collaborative and Practical Section. In the first part of the workshop, the participants were kindly asked to introduce themselves and take part in some ice-breaking activities. Also, we introduced the Smart City concept. In this part of the workshop, three main activities were designed in order to engage the different participants, collect their perspectives and generate new ideas based on the urban context.

Activity 1: Interactive Citizens and Users Journey Map. In this activity, the participants were each assigned individual post-its and groups were provided with a User Journey Map. This user Journey map illustrated 3 moments in the life of John, a designated persona, on a Saturday morning. This Journey map illustrates John's path during various city events and happenings at the city parks.

The participants were required to consider John's user journey in three specific moments, firstly the moment when John becomes aware of the various city events, secondly the moment when John selects the events that he is most interested and the third moment when John commutes to the selected events. The participants were required to write about the problems and needs that John might face while he experiences the different moments of this user journey. The participants were also provided with questions that they should consider while examining the user journey, as described in the figure 18 below.

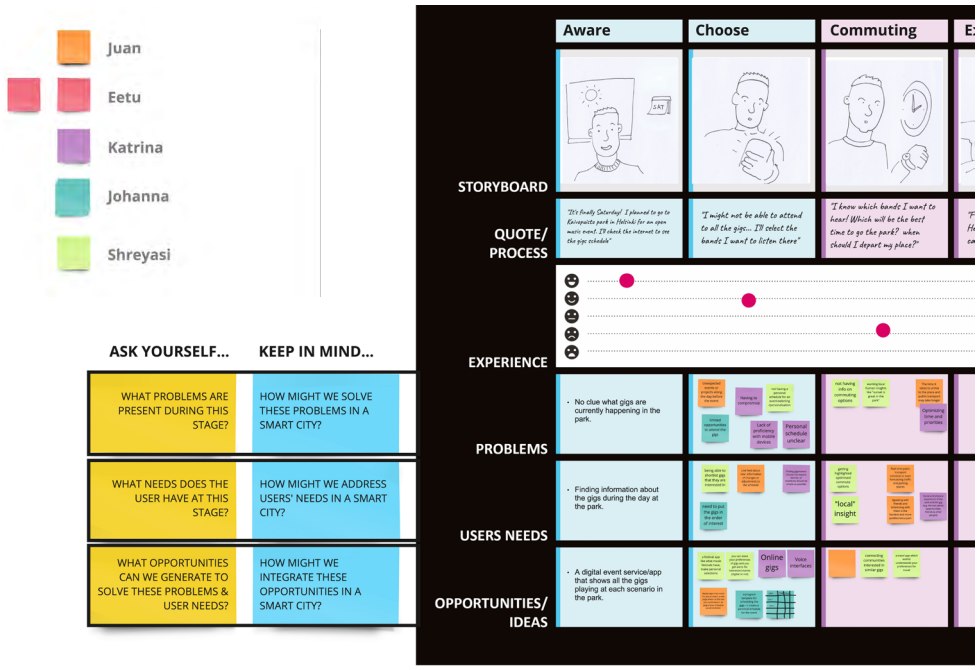


fig.18: Workshop activity 1, interactive citizens and user's journey map.

The Problems identified in session A were based on digital concerns, since the participants notion of the Smart City was initially very digital-centric. As a result, accessibility could become an issue for minorities or older citizens. The participants also identified the lack of awareness and information regarding the city events, the possible conflicting schedules of the events and therefore the difficulties in programming their activities. This discussion highlighted possible scheduling conflicts between people, their priorities and their time management. It was also noted that there was a lack of peer-to peer information and especially human insights that could offer a valuable understanding of the citizens' needs and community interests. Lastly, a persistent lack of information on the most optimal commuting options, from public transport, to path optimisation for private vehicles based on the urban circumstances and city events, was highlighted.

The users' needs as determined by the participants in session A stress the need for easy access to information, preferably tailored and customised to each citizen. The use of signs and notifications, in digital and physical media, in order to guarantee the easy access to information was also highlighted. Commuting and navigation were also determined to be a major need and criteria for a functional city. The need for real time information on public transport, traffic, parking information and optimisation of these services was identified. Finally, one of the most interesting insights on the user needs was the value of peer-to-peer knowledge sharing on social and physical experience of places and events. This insight emphasises the need to create conditions and opportunities for users to develop their relationships and have the experiences that will give them a sense of belonging and community.

The opportunities and ideas, generated by the participants in session A, were diverse and enriching for the research. The participants have highlighted the use of various user interfaces in order to be inclusive and to consider accessibility in the new digital context. Due to the covid-19 circumstances, and lockdown measures

implemented by the government in Finland one week before the organised remote workshop, digitalisation was a hot topic in this session. Therefore, providing digital and online versions of events was a topic of conversation due to the global context of 2020. In this session, participants also commented on the value of providing tailored information on an app and webpage that could be linked with signs and notifications which could be digital or not. The possibility of creating a web page or app that could help citizens to optimise their schedules based on the city's specific circumstances in this specific case, cultural events was raised.

Based on the community prospects and enhancing the sense of community determined in the previous user needs, the participants proceeded to ideate about possible ways of connecting people and communities based on similar interests. As an example, music genres and bands could be considered as criteria to connect people based on their cultural interests. Additionally, in order to enhance the sharing of human insights, participants highlighted the value of a platform that could share personal insights based on the urban places and events in the cultural context. The participants' also contemplated the value of obtaining personalised advice on commuting and traffic management. The possible creation of a traffic app that would be aware of the city's conditions and events, and could manage the user routes based on their personal preferences but also on city conditions, was also discussed.

Activity 2: Urban services ideation and validation. In this second activity, the city canvas was introduced to the participants, as a holistic and comprehensive visualisation of the city that would serve as the playground of the activity. Afterwords, each participant was assigned a category of services that had been previously defined by the research team. Each category of services had an array of possible sub services and product based solutions in the form of post-its.The service categories were defined by a designated colour-code, namely: City monitoring (dark blue), Safety and Emergency (green), Culture (yellow), Transport and Mobility (pink), Public Maintenance (light blue) and Urban Infrastructure (orange). New ideas and concepts integrated by the participants were visualised in purple. The participants were required to drag and drop their respective post-it into our city structure canvas, into the areas of the city that they thought were appropriated and needed. The participants were then required to grade their favourite product and service based solutions. Subsequently the participants were requested to iterate and discuss with each other their decisions and perspectives on the urban services city canvas.

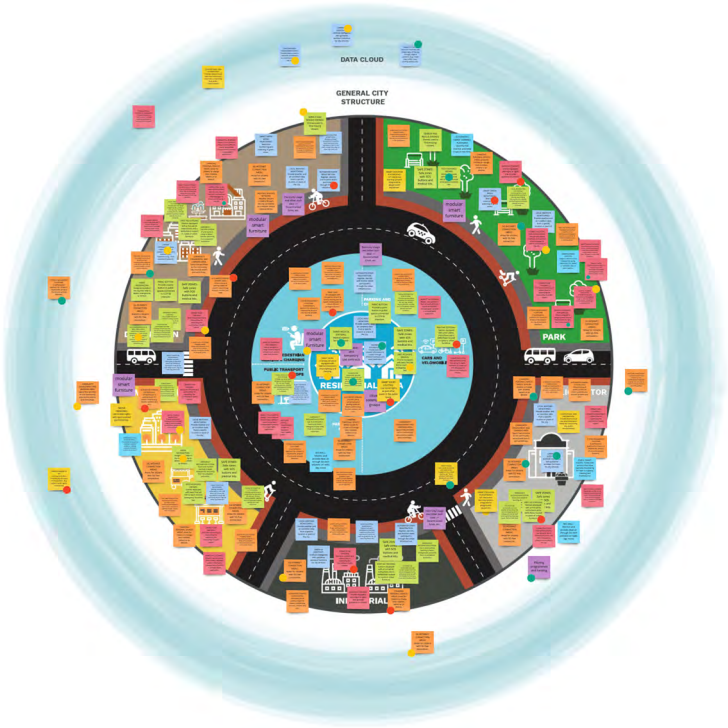


fig.19: Workshop activity 2, urban services ideation.

The most interesting findings of activity 2, Urban services ideation and validation, will be listed below and some of the most appealing results of the sessions B and C will be summarised.

Interesting findings in Session B.

• The implementation of green modules, such as bio-walls and carbon capture mechanisms, were considered very valuable in the urban context. The application of this concept in industrial areas with heavy transports, and public transport stops as buses, was emphasised, since these are critical places of greenhouse gas emissions. Therefore these can be considered critical spots to capture CO2 and refresh the air, in order to improve the air quality level of the city and general health conditions.

• The integration of automated urban farming was also considered as a good source to improve social interaction. Participants suggested that this concept should be implemented in public places where the facilities can't be privately owned, such as Downtown areas or Commercial areas. Urban farming was portrayed as a possible business opportunity for local businesses by harvesting

• City monitoring and emergency services, such as a panic button connected to CCTV was considered less interesting. This was likely due to a low interest in added surveillance.

Interesting findings in Session C.

• One of the participants mentioned that there was a lack of strategic-level services or solutions, since from his perspective, most of the discussed and proposed solutions were focused on data and/or technology.

• The topic of piloting programmes and funding was discussed as an idea that could be explored on a strategic level, since pilote programmes can be considered as a key factor to trigger technological innovation. If city planners pursue a program providing funding for pilots, this initiative could be seen as a tool to enhance innovation, without necessarily having to facilitate it from the governmental level.

• The general perception of citizen engagement, and consequent ideas were strongly encouraged. The idea of semi-public spaces, which could be used under temporary contracts for diverse purposes, was explored.

• The value of open city data was emphasised, since this open access can be seen as a solution to provide citizens with the opportunity (via open city data in an API format) to come up with new solutions to problems that the city has not considered before. This open access could provide citizens with the opportunity to create something useful and entrepreneurial. The Amsterdam pilot, where data is being shared openly and made equally accessible, was mentioned as a model.

• Participants discussed the use of artificial intelligence(AI) for public policy design and communicating with the public. This idea was considered in lieu of the amount of data that can be collected and processed to make decisions. This could result in quick and efficient policy design in order to include all citizens, which could be structurally flexible, since they could change on a day to day basis. The participants have highlighted that the existing governmental city policies are archaic, e.g. constitutional rights were designed more than two hundred years ago, and therefore need updating.

• The participants also emphasised the need to rethink city transportation and commuting from a pragmatic perspective, namely from their angle. According to the group, citizens should be able to use new mobility services, literally, on the

move. If future smart mobility service required citizens to stand for more than thirty seconds, they will not use those, and they will prefer to use existing options

Activity 3: Ideation of future Urban products and scenarios. In this activity the participants were encouraged to be imaginative and creative and to ideate about future urban products and/or scenes that could exist in their vision of a future smart city. The participants had access to a playground where they could find a bank of shapes and features represented by illustrations and vectors. The playground tools could be used to build their products and scenarios concepts. In this section the participants were also encouraged to draw and use any other tool existing on the workshop platform to visualise their innovative ideas. Below we can see some of the concepts and drawn by one of the participants (figure 20).

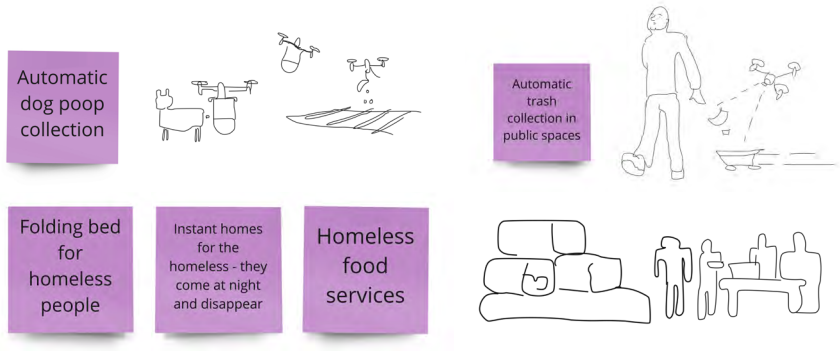


fig.20: Workshop participant sketch on the future of urban products.

The most interesting findings of activity 3, Ideation of future Urban products and scenarios, will be listed below and some of the most appealing results of sessions A, B and C will be summarised.

Interesting findings from Session A.

• One of the participants has suggested a Smart Homeless System. This concept illustrates folding beds and shelters that could be activated during night, and therefore enhance safety and well-being for all citizens.

• Smart real time recycling was a concept illustrated by one of the participants that could automate trash management in public areas, specially parks, and possibly reuse it as fertiliser in green areas.

• One participant explored the idea of revitalising residential areas. Their concept uses ideas like smart forums, local events and local workshops in residential areas. This idea rethinks services that were originally ideated for busy urban zones, such as downtowns and commercial spaces, and turns these services into useful concepts for residential areas. One suggestion was to locate a citizen engagement forum in a residential neighbourhood. The participant suggested that this concept could be modular, and therefore used for various purposes as workshops, conferences and diverse forms of community engagement. Additionally the participant has expanded this communal space into an area that could serve the citizens, providing a space for health checkups, first aid, recharging, chill, de-stressing and also provision civic amenities.

fig.21: Workshop participant idea: Revitalising residential areas.

Interesting findings from session B

• Two participants ideated about features of Smart Bus Stops. City transport navigation was highlighted, specifically the topic of commuting to bus stops. The participants suggested the enclosure of e-bikes and/or e-scooters charging points near the bus stop so that citizens would have a designated place to leave their scooters and avoid city cluttering. Rental bikes or scooters could also be provided at the bus stop, in order to centralise mobility and commuting services.

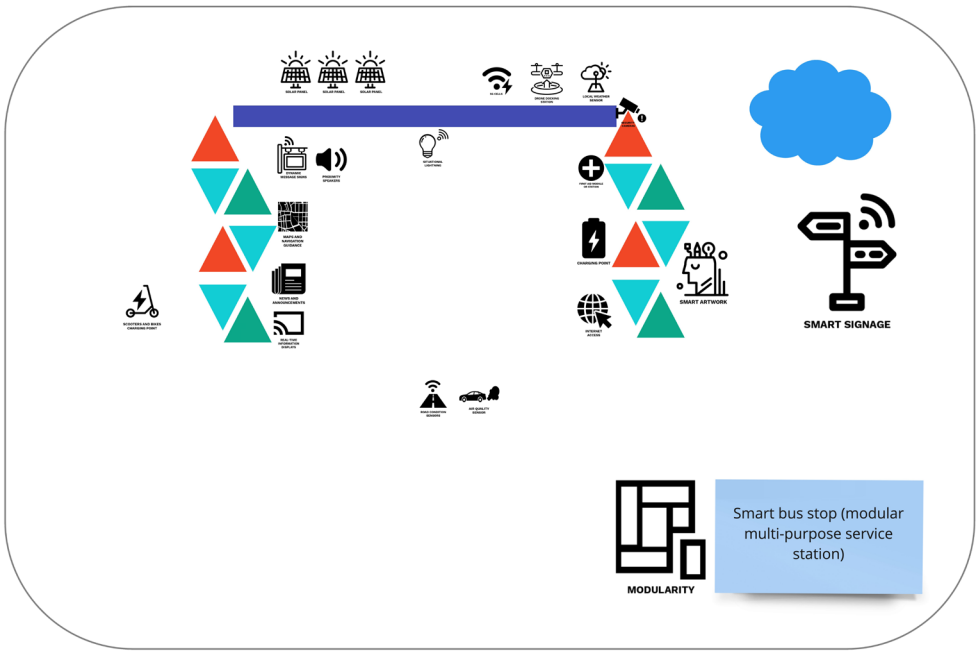


fig.22: Workshop participant idea: Innovative feature-based bus stop.

• One of the participants has suggested an integrated traffic system capable of identifying and acting on various traffic violations. This was an interesting concept that was discussed to reduce the spend of city resources on police vehicles to monitor traffic violations.

Interesting findings from session C

• The Urban Lab was a concept illustrated by one of the participants. The participant suggested the creation of a public space with innovative services and access to high connectivity open for people. All of the innovations and varied projects generated in this space could be used by people from diverse groups, such as academia and the public sector. This suggested co-working space could facilitate collaboration between different parties to create various sorts of innovative solutions, including art and technology.

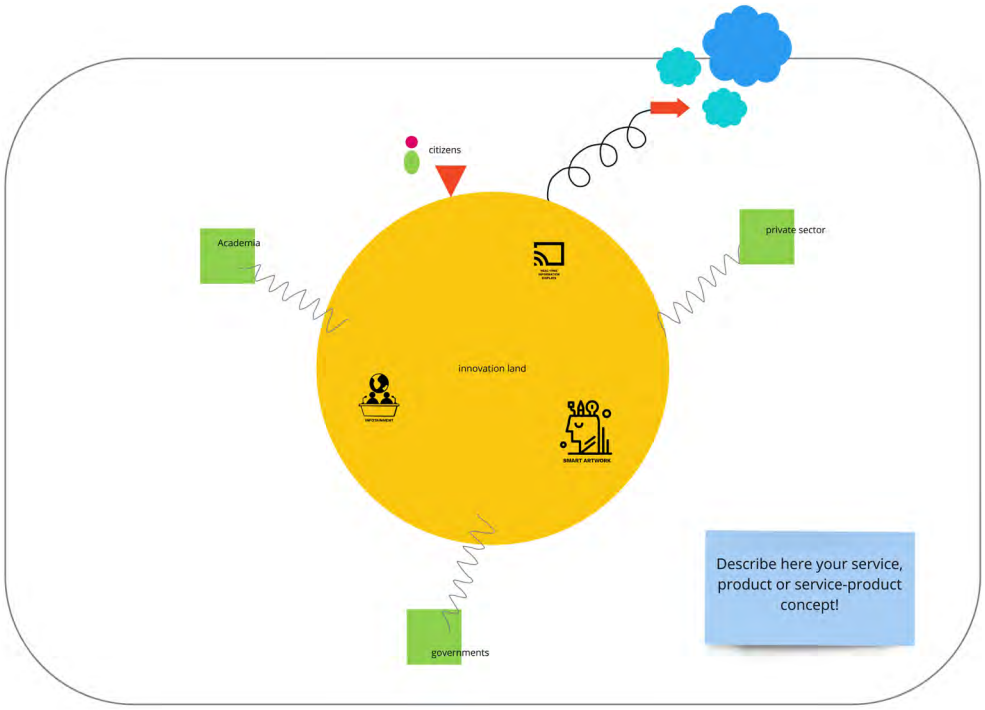


fig.23: Workshop participant idea: Urban Lab, a public space with novel services and high connectivity open for people.

• One of the participants suggested the Modular Smart Trash Can concept. This vision for a Modular Smart Trash Can would allow tracking of the bin's capacity. Additionally, through an internet connection, the product would be able to communicate to the public waste disposal services, and send notifications when the trash can is full. The participants suggested that this product would be capable of recognising different sorts of trash, and instructing people on what should be thrown in it.

• The Smart Lighting Installation was a concept explored by one of the participants. The participant suggested the use of technology to make the immaterial visual and tangible. In other words, the participant proposes to takes an average "mood-level" from an open space, such as a train station, through different sensors and CCTV cameras, and then respond with animation, ambient lights and tone, to balance the psychological atmosphere. This product could influence people to calm down, or to accelerate their movement for example.

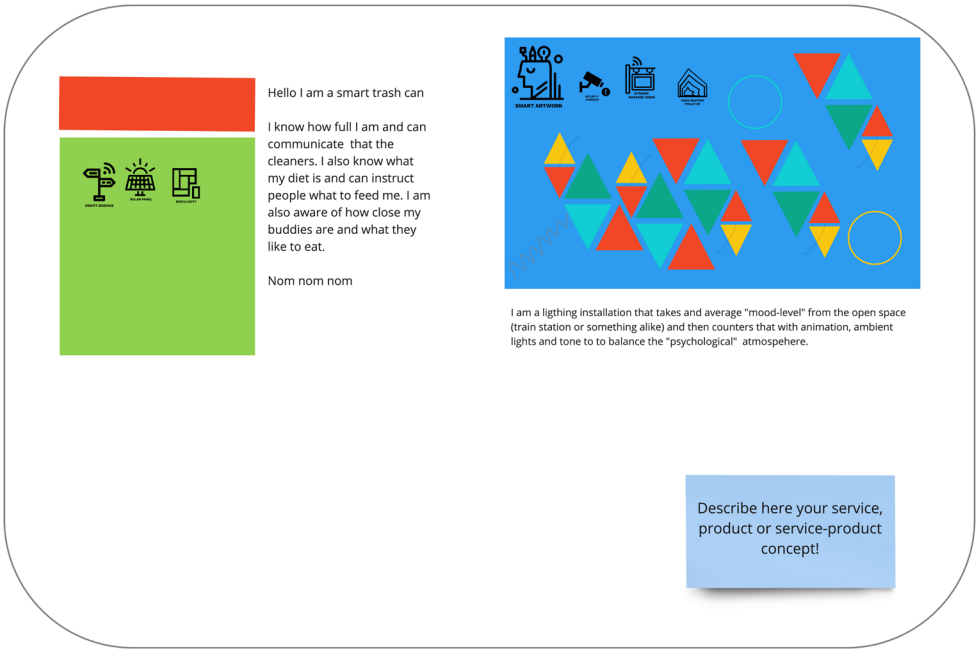


fig.24: Workshop participant idea: a modular Smart Trash Can and Smart lighting concept.

Conclusions and Main Outcomes.

The remote workshop had a good level of engagement from participants, and the discussion was a major influence on the direction of research Therefore, the event was considered very successful. There were a few technical difficulties at the beginning of session A, due to the remote conditions. However, the rest of the sessions were conducted smoothly over the course of the day after making a few changes in the agenda.

Activity 1
Through the course of this activity, a variety of problems, user needs, opportunities and ideas were identified by the participants. A lack of personalised information and personalised scheduling was seen as a primary issue that could be tackled through technological intervention in various ways. The participants identified a need for personalised and real time information with peer to peer/ socially generated inputs. The participants ideated solutions in the form of platforms and apps that can provide personally tailored and real time information and scheduling. Some of these solutions can also be influenced by like minded peers or through a communal basis.

Activity 2
A key feedback from this activity was that many of the services ideated were considered on a more functional and technological level, but lacked strategic direction. The participants had additional layers of justification and new perspectives to where our services could be considered for implementation in the city structure. New ideas, some of which were on a more strategic level, like smart policy design and piloting programmes for citizens, were also discussed and recommended. Ideas surrounding surveillance were not considered favourable. This might have been due to a negative perception towards the idea of having city-wide surveillance that could result in a loss of privacy. The placement of the services across the city structure and their justification shared many similarities with the way the research team designed the city structure service map, and therefore served as a positive validation of our line of thinking.

Activity 3
Activity 3 was seen as the most fun and creative part of the workshop. This section served as inspiration and validation of some of the urban furniture concepts, such as the smart bus station, that will be introduced later in this dissertation. These

concepts also generated a new perception of service-based systems in the city environment. More than one form of smart traffic management and smart waste management concepts were also envisioned by participants, which further validated some concepts that the research team was already developing. There were a few new ideas and perspectives that were interesting to our project as well, namely Revitalising of Residential Areas and the Urban Lab, which highlighted the value of community and citizen engagement.

Overall, the remote workshop had an immediate motivating effect. People left the workshop feeling like they can have a positive impact in their cities. We aim to design cities as citizens for citizens. Therefore, there was a collective authorship, based on the outcomes of this event, that guided further design decisions and the direction of the project. With this approach we have embraced "a deep, empathic understanding of users' unarticulated needs (that) can challenge industry assumptions and lead to a shift in corporate strategy" Leonard et al. (1997).

3.1.3 Rethinking public spaces and citizens urban participation.

Civic engagement in the digital urban context.

Citizens are the backbone in shaping the Smart City. The city must address their needs. To achieve this, the city must ensure that citizens participate meaningfully in the practice regarding the city's urban planning process, working alongside businesses and other stakeholders.

Civic engagement is a relevant factor in todays governance, according to the Organisation for Economic Co-operation and Development (OECD) and the Better Life Index. Cities enact better policies to better lives. OECD is trying to shape policies that foster prosperity, equality, opportunity and well-being for all. Civic engagement in the urban context relies on social cohesion and well-being and, mostly, in governmental trust.The formal process for public engagement in developing laws and regulations is one way to measure the extent to which people can become involved in government decisions on key issues that affect their lives. The level of stakeholder engagement in five different countries is listed below. The OECD average of this indicator is 2.4 (on a scale between 0 and 4), (OECD, 2020a).

- In Portugal, the level of stakeholder engagement in developing regulations is 1.5, lower than the OECD average, (OECD, 2020b).

- In Spain, the level of stakeholder engagement in developing regulations is 1.8, lower than the OECD average, (OECD, 2020c).

- In Finland, the level of stakeholder engagement in developing regulations is 2.2 , slightly lower than the OECD average, (OECD, 2020d).

- Norway, the level of stakeholder engagement in developing regulations is 2.2, slightly lower than the OECD average, (OECD, 2020e).

- Australia, the level of stakeholder engagement in developing regulations is 2.7, higher than the OECD average, (OECD, 2020f)

On average the most diverse countries often present a low rate of stakeholder engagement and therefore a poor civic engagement rate. It is important to regenerate our urban policies and, instead of planning for people, the cities should plan from people. New ways of thinking will generate new opportunities for citizens,

since those will allow people to exchange values, concepts and practices, enabling meaningful involvement of citizens in urban governance. This is how cities are becoming spaces designed for citizens by citizens. Citizens often create, negotiate and test ideas and solutions in this context, collectively contributing towards shaping the future urban condition (Sassen, 2010).

To do so many countries have embraced digital innovation to transform democratic decision-making. Several public administrations are currently experimenting with mobile applications to provide citizens with real-time information, using online platforms to collectively generate ideas, and testing algorithms to engage communities in day-to-day administration. Digitalisation can be used to legitimise the public sector, re-engage citizens in politics and promote civic empathy.

On the other hand, it is also important to reflect on a key matter: what technological breakthroughs means for governance systems created long before digital disruption. However, the details of this topic are out of the scope of this dissertation and thus will not be further discussed in this document. Listed below are some best practices and initiatives, based on digitalisation, from different backgrounds and countries:

• In Spain, the provincial Council of Biscay is committed on engaging citizens locally. This province aims to increase co-operation and social participation. They have embraced the concept that "a modern institution has to be close and be accessible to its citizens". The Council created an easy-to-use website, as well as a smartphone application ("app"), to give people a real role in improving local policies that affect their everyday lives (OECD, 2020c).

• Finland has launched a pilot project for an online "opinions service" (lausuntopalvelu.fi) to improve the formal online consultation. It allows different parties to participate in open discussions during a consultation, namely: representatives of ministries, agencies and organisations, as well as citizens. They are able to use the designed platform in order to browse and issue opinions, and also comment on the statements made by other users. The initiative aims to efficiently help regulators to collect and analyse information received from stakeholders (OECD, 2020d).

• Australia has created a tool for civic engagement. YourSAy is an online consultation hub that involves South Australians in policy making. People use this tool to participate in discussions and vote in polls to impact government decisions. This application shows how a digital tool can impact everyday life. YourSAy was initiated in 2010, and it is one of the largest community consultation programmes in Australia. It was originally targeted for 10 000 users, and exceeded that original target, reaching more than 42 000 users of the online community. YourSAy is an useful feedback tool for the government. The Ministry of Education has incorporated feedback from online consultations in their policies. This consultation feedback is also expected to influence the state's Strategic Plan for development (OECD, 2020f).

There are different private and public initiatives that aim to combat civic apathy and enhance citizen engagement. To quote CitizenLab: "If citizens don't come to your town hall...we bring the town hall to your citizens", Citizenlab (2020). We have wondered, can we enhance citizens' participation not only on the strategic and governmental level, but also in their tangible perception of the urban fabric? Can we rethink the urban spaces for our users in order to enhance citizens engagement and, therefore, wellbeing?

Following the city making directions described by Ezio Manzini, city-making projects can be designed "to solve practical problems and, at the same time, to improve the physical environment and regenerate the social fabric and the urban commons. In other terms, city-making projects can be conceived and developed to revitalise a neighbourhood, integrate migrants and new comers in the social fabric, reintroduce

farms and production activities in the urban contexts, and imagine and implement new economic models. Even though this direction is not the main one, several cases of social innovation show that it is viable. In other words, they tell us how city-making projects can become agents of city regeneration strategies" Manzini (2019).

From this, we understand that an action on the physical infrastructure level in urban areas or public spaces could revitalise the urban fabric and generate social innovation.

Public spaces in the urban fabric.

When we look into several initiatives in the urban public spaces of different urban contexts, we can quickly verify that exceedingly often many city projects "end up in increasing inequalities, segregation and the commodification of the urban commons. In fact, today, dominant ideas and economic forces tend to orient city-making projects towards initiatives resulting in reduction of public spaces; displacement of poor, middle class, small businesses outside the city; self-segregation of the rich in protected zones; and historical neighbourhoods transformed in tourist attraction and theme parks. The main driver of these processes is the idea of city-as-a-commodity. And its consequent commodification, intended as the transformation in marketable goods of everything in the city has been public and common" Manzini (2019).

Ezio Manzini has emphasised what governmental entities and city project makers should repudiate the segregation of the urban commons, and on the other hand, emphasise the liberation of public goods. Therefore there is a need to rethink the impact of the public space in the urban context.
We should design urban spaces with people in focus, taking into account their perception and interaction with the public areas. This will entail re-inventing the urban territories and communal places, since those are the platforms for social innovation. In order to analyse the impact of the public space in the urban fabric, it is first important to understand the relationship of people with environment, and how we can enhance this interaction. The relationship between people and their environment starts with architectural or environmental determinism, where the physical environment has a determining influence on human behaviour. By shaping this idea, M.Dear and J. Wolch in 1989 claimed that social relations can be:

- Constituted through space, where site characteristics influence settlement form.
- Constrained by space, where the physical environment facilitates or obstructs human activity.
- Mediated by space, where the friction-of-distance facilitates or inhibits the development of various practices.

Therefore the relation between people and their environment is "best conceived as a continuous two-way process in which people (and societies) create and modify spaces while at the same being influenced by them in various ways… Hence, by shaping that built environment, urban designers influence patterns of human activity and social life" (Carmona et al., 2003).

In other words, public space is an opportunity to impact human behaviours, regenerate public affairs and design for social cohesion. This research approach towards public spaces is mainly based on its social dimension and impact; not only on the urban fabric, but also social fabric. We aim to build a product-service system that can generate social links between different citizens and bridge social differences. This approach is not only relevant from the city management perspective but also valued and eagerly anticipated by citizens as Jan Gehl and Helle Soholt have described:

"The fact that people in all parts of the world respond eagerly and enthusiastically to these new opportunities for walking and participating in public life in public spaces, indicates that walking environments and other types of public spaces where people

can meet are important assets in present day society. In a world being steadily privatised public spaces are gaining in importance" Gehl et al., (2002).

Public spaces are where physical and social resilience meet. Public space designers and managers should embrace social fabric in these communal spaces and also take into consideration the urban impacts of climate change. Public spaces can be seen as crucial tools to mitigate and adapt to rising temperatures and extreme weather conditions. A well-planned city-wide public space system can create green networks to regenerate ecological systems and restore environmental connectivity with wildlife, water and biodiversity in urban settlements. Therefore, the role that public spaces can play in the provision of ecological services is extremely relevant in the mitigation and adaptation strategies to climate change (UN-Habitat, 2016).
Cities that have a comprehensive understanding of the public tend to be committed to improve the quality of life for their citizens by providing adequate street space, green areas, parks, recreation facilities, and other public spaces. Public spaces are a vital basis for successful cities, they are areas that help build a sense of community, civic identity and culture. They facilitate social capital and economic development and incite community. Having access to sustainable public spaces is a first step towards civic empowerment and a way to achieve a greater access to institutional and political spaces (UN-Habitat 2016).

"Public spaces contribute to define the cultural, social, economic and political functions of cities. They continue to be the first element to mark the status of a place from a chaotic and unplanned settlement to a well-established town or city" UN-Habitat (2016), as it was described by Dr. Joan Clos Under-Secretary-General, United Nations Executive Director in the Global Public Space Toolkit.

In conclusion, the implementation of a smart city is not limited to the use of innovative technology but goes much further. It is rather a philosophy and ideology to ensure constant improvement in quality of life of citizens. Small changes in our way of constructing and how we understand public spaces can have important repercussions for the people who inhabit urban settlements. This is why it is important that a city is not smart only in name or in the image it wants to commercialise, but in its urban essence. We see the public space in the Smart Cities as an opportunity to impact our citizens and the city service systems.

3.2 The City on a systemic level.

3.2.1 Smart city structure and future services.

"Cities can be seen and described by different points of view. … The city made of places, roads, squares, products and infrastructures, and, the more and more, of services and communication" Manzini (2019).

As Ezio Manzini described, there are many ways to look at the city, due to its complexity and interconnectivity of urban layers. The city can be seen as its infrastructural nucleus, services and communications. Cities are complex and can be perceived from their various layers, therefore there is a need to develop horizontal strategies that integrate the various nuclei of the urban settlement. Based on this urban complexity we aimed to design a product service ecosystem that could consider the different dimensions of the same problem, from various perspectives, such as economic, social, environmental, and physical, and take into account all possible connections and externalities.This approach radically changes the perception of the city and urban management methodologies, since it facilitates the cooperation of different departments and structures within the local authorities. Based on this approach, there is a need to break silos and analyse the smart city main services and operations from a holistic and systemic angle.

Geoff Mulgan and Charlie Leadbeater have defined the need and relevance to analyse complex structures from a systemic view. The growing complexity and interdependence of modern societies and economies rely increasingly on systems, infrastructures, and platforms in order to smoothly run their operations. Simultaneously, the steady advance of technology has enabled some systems to be largely based on machines, and machines talking to other machines. Other systems are entirely based on people, but most of the systems combine some mechanical and automated elements with some human ones. As technology evolves the long term trend is for the machine part of systems to rise in importance. This forces attention to the interfaces between people and machines, and therefore it forces attention to questions of system design and its impact (Mulgan et al., 2013).

"We can define systemic innovation as an interconnected set of innovations, where each influences the other, with innovation both in the parts of the system and in the ways in which they interconnect" Mulgan et al. (2013).

Rather than looking to the city as a combination of various institutional levels, independent services, and architectural infrastructures or local products, we have considered the entire system as an interconnected whole, creating a comprehensive solution to meet the challenges of future cities. Due to the incorporation of 5G and other digital tools, the Smart City can be described as the merging system that integrates the operations of the urban infrastructures and various services. From the technological layer and its impact on the urban environment the Smart City can be described as a city that:

- Allows real-world urban data to be collected and analysed by the use of software systems, server substructure, network infrastructure, and citizen devices.

- Implements solutions, with the support of instrumentation and interconnection of sensors, actuators, and various devices.

- Can combine service production and an intelligent environment, exploits accessible information in its activities and decision making and adopts information flows between the municipality and the urban or business community (Novotny et al., 2014).

Therefore the mega-trend of city digitalisation allows the reformulation of innovative city services, network infrastructure and various systems. Digital services become crucial in order to enhance city efficiency and reliability for daily life and, mostly, to strengthen wellbeing in cities around the world.The various urban zones define specific services that citizens and the city need to operate. However, as urban areas share some spaces in the city, services within the city are shared too. To differentiate services by their purpose in the smart city, clustering them by their functions contributes to a better understanding of what needs they cover, independently of the urban areas where they are present.

An extensive collaborative ideation and analysis has resulted in the clustering of the urban services, firstly in six main categories, namely: city monitoring services, transport and mobility services, cultural services, safety and emergency services; and public maintenance services. Figure 25 represents these 6 clusters and services applied in the urban context after several internal ideations.
Subsequently, city services were re-iterated and organised in four more general clusters that could better integrate the city's needs and sophisticated systems.

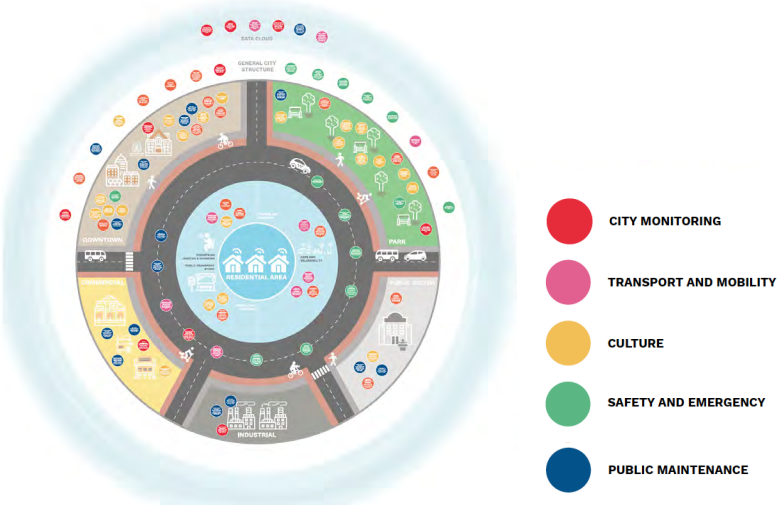


fig.25: Preliminary clustering of urban services.

These service clusters were used further in the Smart Urban Furniture concept development, that will be described later in this document. The services are categorised in four clusters representing the different areas they are focused in. Each cluster presents a list of sub-services that were identified and evaluated by the team and various stakeholders, in the Smart City context. These stakeholders included different LuxTurrim5G partners and representatives of the city of Espoo. The four city service clusters are described in the coming pages:

Safety and Emergency.
These services are used to provide safety and security for the citizens, as well as to facilitate a timely response to emergencies. The safety and emergency sub-services are described below:

fig.26: The Safety and Emergency sub-services.

City Management.
Services used for managing the city's general operations and maintenance, predominantly developed by the city personnel. The city management sub-services are described below:

fig.27: The City Management sub-services.

Transport and mobility.
These services are designed to facilitate transportation and mobility across the city, from pedestrians to bikes, cars and new forms of transport such as autonomous vehicles. The transport and mobility sub-services are described below:

fig.28: The Transport and Mobility sub-services.

Citizen Engagement.
These services are designed to enhance the citizens' day-to-day lives on an experiential level as well as introducing new ways technology can empower and involve the citizen. The citizen engagement sub-services are described below:

fig.29: The Citizen Engagement sub-services.

After identifying valuable services for the Smart City urban context it was also important to analyse the customers' services segmentations, and the impact of each service on each stakeholder.

Therefore, we started to define a customer segmentation and we concluded that three main customer segments could be identified as they would capture most of the value of all services provided. These are:

• The city that, from a general perspective, benefits from an optimised network system and an efficient infrastructure.
• The citizens that often benefit from the improved well-being and quality of life.
• Businesses and private corporations that, from a general perspective, benefit from a more efficient infrastructure and better city ecosystem for innovation.

Following this customer segmentation, below we can find some visual representations that describe the impact of each service on a specific stakeholder. Due to the complexity and extension of this research, we only describe a few examples.

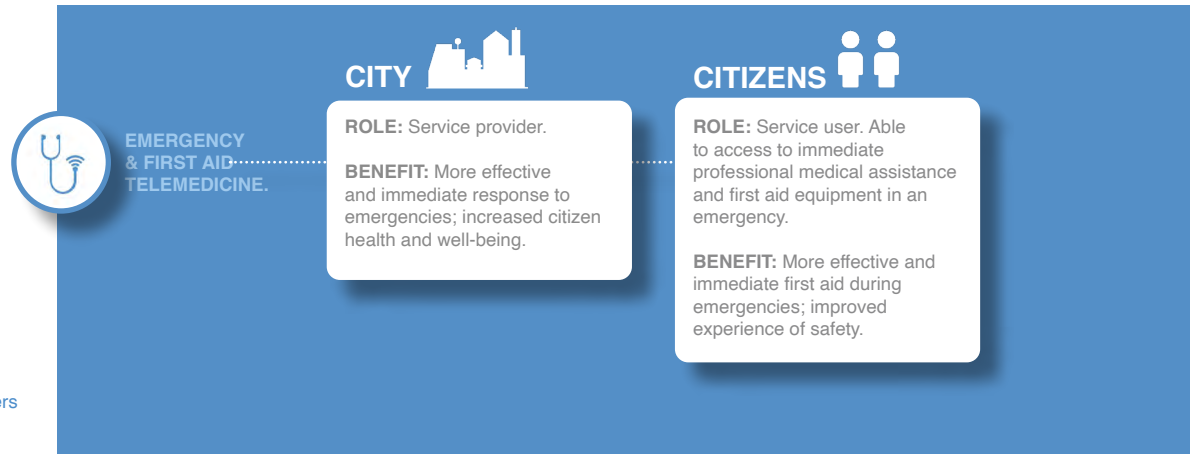


fig.30: Emergency & First Aid Telemedicine, review of stakeholders roles and benefits.

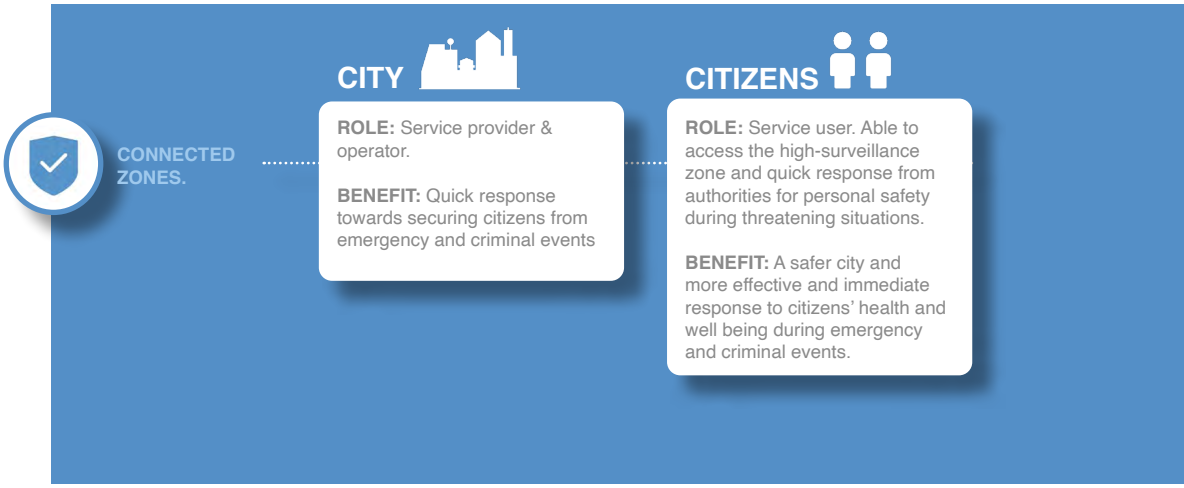


fig.31: Connected Zones, review of stakeholders roles and benefits.

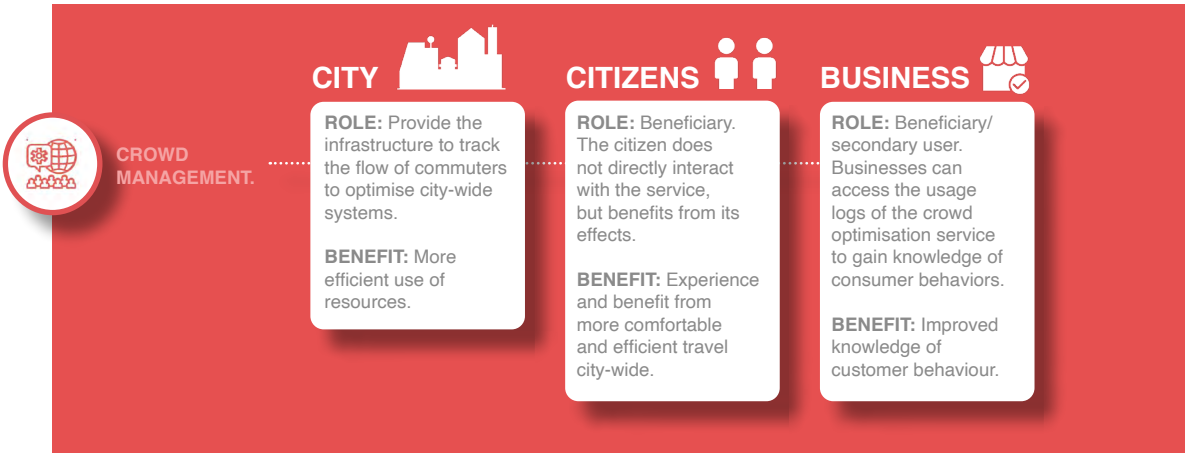


fig.32: Crowd management, review of stakeholders roles and benefits.

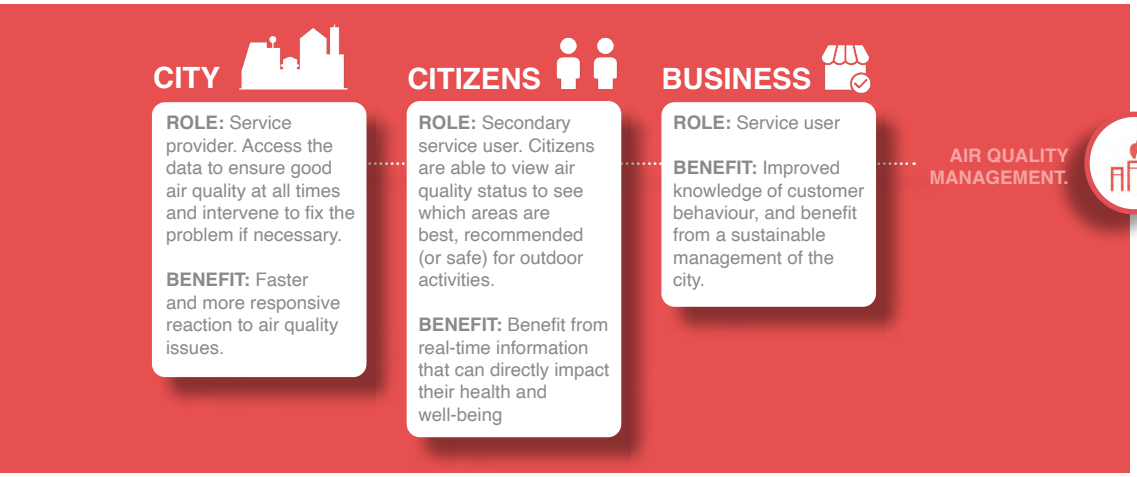


fig.33: Air Quality management, review of stakeholders roles and benefits.

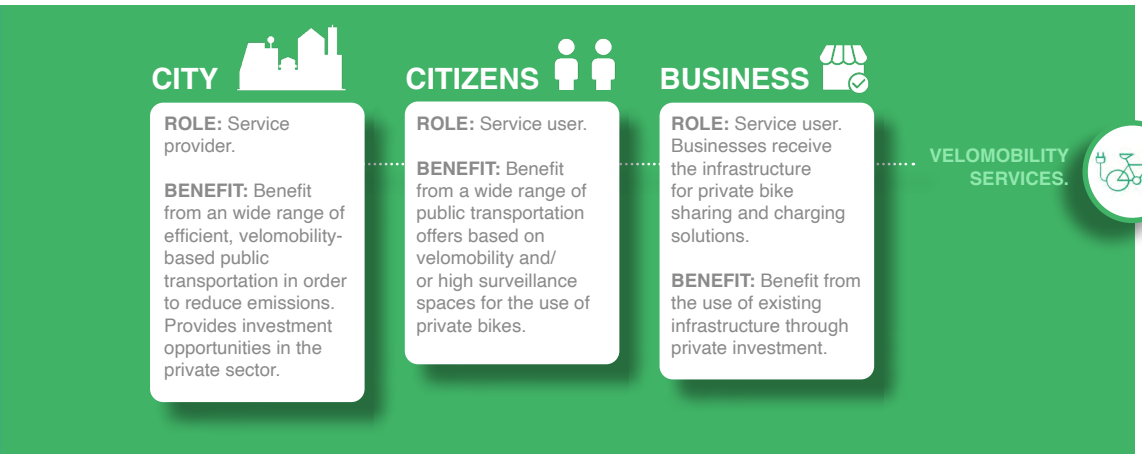


fig.34: Velomobility services, review of stakeholders roles and benefits.

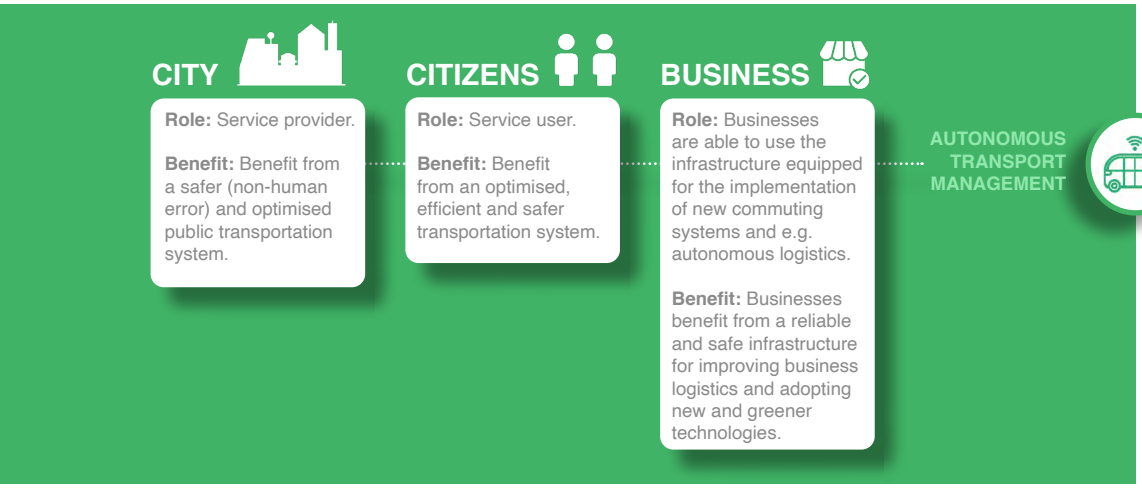


fig.35: Autonomous transport management, review of stake-holders roles and benefits.

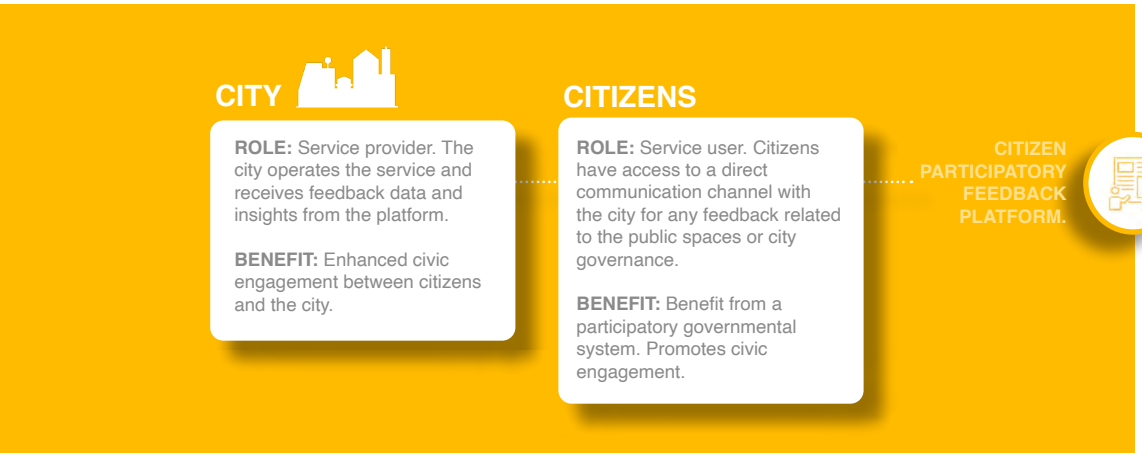


fig.36: Citizen participatory feedback platform, review of stakeholders roles and benefits.

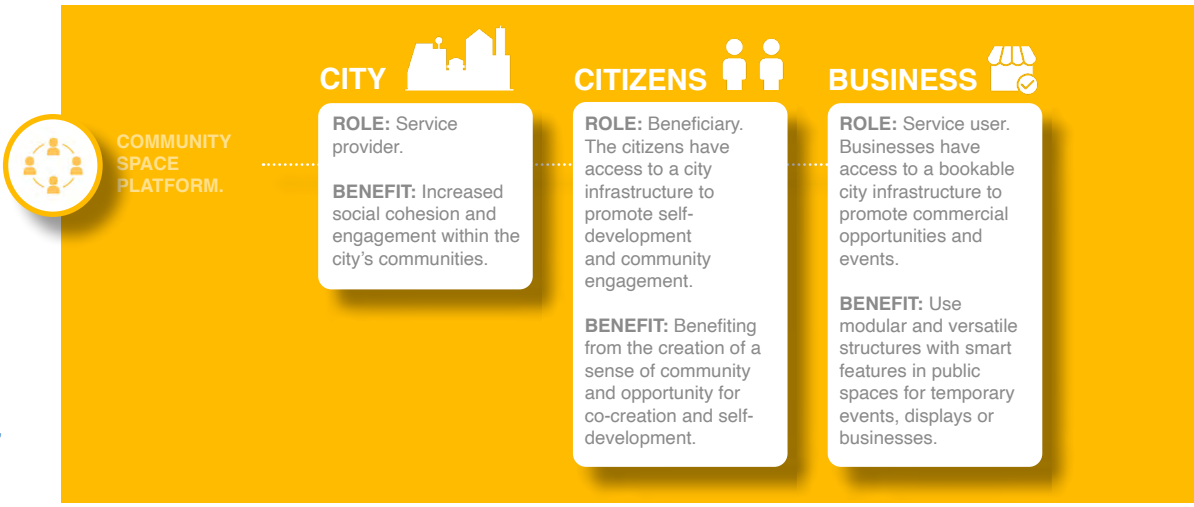


fig.37: Community space platform, review of stakeholders roles and benefits.

With this analysis we have not only gained a comprehensive understanding of the stakeholders involved, their roles and benefits, but also a holistic grasp of the impact of the services in the urban context. We have, first, explored the potential of systemic innovation, and thought about services in the urban context. We have identified these services and urban calls for action and shifted our paradigm to define the infrastructures that will set up these services and trigger urban innovation. After identifying the services and their trigger points we have developed urban infrastructures that will equip the cities of the future: the Smart Urban Furniture Collection which will be further explored in this document.

"…this emerging design culture is the one that most radically calls into question the tradition of product design. By experimenting with the possibility of rethinking the entire production system, it offers the opportunity of redesigning all material products by answering one simple question: what would they be like if they were entirely or for the most part produced for well-defined clients and as near as possible the place where they will be used?" Manzini (2014).

Our research-based process embraced Ezio Manzini's notion of open design, described in the Strategic Design Research Journal, namely: "Design in a changing, connected world". We have first built a systemic understanding of sophisticated cities, we have interpreted the city's calls for action, and most importantly the citizens' needs, by identifying the services that our products should first address. This design approach cultivates and elevates a holistic design culture.

3.2.2 City infrastructures principles, based on product-service systems

In the cities of the future, urban goods, public spaces, and innovative services should be positioned in the core of the city in order to advance towards the Smart City vision. Therefore, based on this central core, we could create "more collaborative services and more public spaces (that will) generate better urban commons where collective design capabilities can emerge and thrive" Manzini (2019). These cities, often called collaborative cities by Ezio Manzini, were drawn in order to enable complex ecosystems that could trigger or support various initiatives of different dimensions and essences.

Based on this approach we have valued the urban infrastructure as an opportunity for further development that could enable hybrid synergetic platforms in this context. But so did the DESIS Labs, that have recognised the value of this topic based on design activities for social innovation. This research institute has identified this

valuable point of action, in the urban context, towards collaborative cities, and has described it as:

"Improving the enabling ecosystem with a hybrid collaborative platform: a city making intended as creating ecosystems where, thanks the existence of an appropriate material and immaterial infrastructure, a variety of communities and social networks can thrive. These projects starting point is one or more (existing or to be realised) physical artefact(s) that, when realised, could trigger and support different activities and communities. Operating in this way, these artefacts can be seen, by all means, as an infrastructure, and the design process as infrastructuring. As a whole they propose the idea of a city intended as ecosystems where a variety of communities and social networks can thrive. And where design can mainly work as co-promoter of a new generation of material and immaterial infrastructure" Manzini (2019).

We have embraced this urban opportunity and created the concept of Smart Urban Furniture: urban infrastructure, the elements of our cities that connect, inform, offer support, involve, evolve and improve. With this concept we urbanise and humanise technology in order to enhance the city's interconnectivity, in pursuance of linking the material and immaterial infrastructures of the urban environment. As the greek philosopher Heraclitus said: "the only constant in life is change". Urban infrastructure should be rethought, redesigned and therefore changed to enhance the citizens quality of life.

Nonetheless, urbanising technology, an expression often used by the professor and sociologist Saskia Sassen, corresponds to a concept that highlights the need to readapt to technology in the urban context, since the rapid development of technology is here to stay. Nevertheless, to embrace this urbanising trend we should first organically deurbanize cities and embrace their complexity and incompleteness, "because they're incomplete they can keep reinventing themselves, being remade. They're mutants" Sassen (2012). Cities can keep reinventing themselves in order to avoid obsolescence.

The question of technological obsolescence is also embraced by Sassen, who considered this another critical issue, due to the rapid deployment of new technologies and, therefore, an elevated rate of obsolescence. "So the more widespread the use of intelligent systems in a city, the more the city itself is at risk of becoming obsolete. What do we get? Dead cities" Sassen (2012).

The rate of obsolescence in the Smart City context is a major concern that should be addressed. The fast evolving nature of today's immature IoT solutions amplifies the risk of quickly outdated infrastructures. Therefore, there exists a need to develop a pragmatic design approach that will be future-proof, and allow for re-inventing infrastructural designs. Based on this perspective we have generated a list of principles that should ensure resilient and functional infrastructures in the urban context.

• Design for Modularity. In principle, this design approach subdivides components into smaller modules that can be individually created, modified, exchanged or replaced between different systems or circuits. In the Smart Urban Furniture context, we have embraced modularity principles, in order to easily maintain technological components or replace outdated items. Additionally, we have developed, with a modular approach, the integration of diverse systems and features to personalise our product services and functionalities according to the city's needs in different contexts. We have concluded that modular designs are an excellent basis for continuous product renewal and personalised feature (or service) based systems in urban settlements.

• Design for Customisability. We have identified the need for two levels of plasticity, when formulating the requirements for Smart Urban Furniture in the urban

context. Firstly, the principle previously presented, of modularity, is used to guarantee the replacement of different components and a personalised use of features and services. Secondly, we reflected on the placement of products in urban public spaces. For the sake of the organic integration of our products in the various areas of the city, we have considered customisation to tangible needs of the city, since it is different to place one product in a highway area, a downtown square or a small pedestrian road. The core of this principle is to develop a mass-customisation-oriented product family architecture with a meta-level design process that integrates and unifies products in the urban context.

• Design for Interconnectivity. Connecting diverse ecosystems to work collaboratively in harmony expands the range of new possibilities in the urban context. The power of interconnectivity takes away the need to have various expensive, single-purpose, connections, through the availability of one single connection that links various products. A relevant feature of these new technologies and digital products is that they involve recombination which, as Leah A. Lievrouw and Sonia Livingstone described, is “the continuous hybridisation of both existing technologies and innovations in technical and institutional networks” Lievrouw et al. (2006). What we see in new media and smart innovation is that they entail recombination of material and digital technologies, communication, cultural, social practices and economic establishments. Therefore interconnectivity can be seen as an opportunity to grow seamlessly in business and to achieve global solutions. We have embraced this interconnected approach and developed collections of products that are interlinked and use single purpose connections and platforms. With this approach we aim to interconnect the various layers of sophisticated cities , in order to provide a smooth experience of the city to its citizens and generate new economic growth and business opportunities to various parties.

These design principles are the result of accumulated knowledge and research based experiences of the Smart City concept. These have served as guidelines, biases and design considerations, applied with discretion when developing the Smart Urban Furniture products. With our solutions we aim to foster flexible and incremental Smart City planning.

4

Product Development for Smart Cities

4.1 Conceptual Development

4.1.1 Material and immaterial systems, product and service ecosystem

4.1.2 Cities as living organisms with genetic code

4.1.3 Introduction to the Smart Urban Furniture identity concept and collections

4.1.4 Minimalism and emotional design as core of product development

4.2 Practical aspects on the product design: Loop collection

4.2.1 Phase I: General form exploration

4.2.2 Phase II: Bus station and smart pole architecture and development

4.2.3.1 Architecture development

4.2.3.2 Product technical considerations

4.3 Phase III: Product family expansion

4.3.1 Smart Bench

4.3.2 Smart Hub

4.3.3 Smart Trash Can

4.4 Smart bus station prototype

4.1 Conceptual Development

4.1.1 Material and immaterial systems, product and service ecosystem.

Mikal Hallstrup, the chief officer of Designit, has said "The world doesn't necessarily need more products, it needs better solutions" Interaction Design Foundation (2020).

While a solution might often be a product or a service, in many instances today it is more likely to be a combination of the two. The nature of recent challenges often forces a move from traditional product and service design to a systemic design approach. Therefore there is a need to engage with unique, complex and ambiguous challenges and integrate systemic practices to tackle those.

"Most of the planet lives in cities and modern, urban people can only live together on a mass scale in a civil way if they are supported by many unseen and increasingly interconnected systems. Systems help to make life more efficient, seamless and productive", Leadbeater (2013).

In other words Charlie Leadbeater has identified that systems make the contemporary society possible. He has also identified in his work that these systems can make users life more efficient or, on the other hand, harder, depending on the way the systems function. Friction emerges from the growing mismatch between the systems that are often inherited from the industrial era, and the more contemporary ones that value seamless operations and emphasise the need to satisfy the users needs, experiences, and quality of life. According to some futurists we stand on the verge of creating entirely new systems. Therefore Charlie Leadbeater has also identified a powerful combination that can generate systemic innovation, namely:

- Services and technologies.
- Infrastructures that make these innovations widely available;
- Alliances of partners who provide complementary services, software and assets;
- Consumer norms and behaviour, which often emerge peer–to–peer, through a process of social learning, copying and emulation (Leadbeater, 2013).

In this dissertation we have explored two systemic topics, described by Leadbetter, that aim to foster the Smart City development. We have, first, conducted a comprehensive analysis of the immaterial service network of urban settlements and, secondly, developed material infrastructure that provides and makes available strategic services for Smart Cities. These infrastructures led to a collection of a so called "Smart Urban Furniture" which will be proposed as the cornerstone for urban innovation in this research.

The third and fourth topics explored by Leadbetter, namely the collaborative alliance of partners and consumers (or users) norms as major drivers of human behaviour, as a materialisation of social learning, are out of the scope of this dissertation and, thus, will only be briefly discussed in this document, in the future work section. Hybrid design based on material and immaterial infrastructure, provides the spaces and opportunity for social networking and citizen engagement. For this reason, this project provides physical artefacts that can trigger contemporary city strategies, collective innovation, optimised operations and an efficient use of resources, but mostly increases citizens wellbeing by supporting communities. In other words we have generated hybrid product-services that blur the material and immaterial boundaries, in order to address the sophisticated, fast-paced, challenges of Smart Cities, such as the rise of information and communication systems, cloud computing, mobile devices, objects loaded with radio frequency identification (RFID), and other digital innovative trends.

The Media Lab, in a lecture during Beijing Design Week, described hybrid design as a “strategy that incorporates elements and processes from diverse fields that are in todays design practice, not always perceived as compatible. This is a method to generate new design visions”, Beijing Design Week (2015).

We have embraced this approach to generate the Smart Urban Furniture concept. This hybrid design fuses products and services into a single entity in order to generate the vanguard of hybrid infrastructures for the urban context. In order to provide a modular, customisable, and interconnected hybrid product ecosystem, it was first necessary to understand the plasticity and uniqueness of different cities. In the following sections we will discuss the city as a vivid organism, with unique needs and cultural heritage, and, secondly, the development of the Smart Urban Furniture products.

4.1.2 Cities as living organisms.

“Cities are the most complex artefact created by human beings and their most significant investment“ Landry (2020). According to Charles Landry, the author of Creative Cities, these urban areas are the place where civilisations manifest. Cities can both drive cultures and incorporate their values. In other words we designers, urban planners, and architects have the opportunity to first shape cities, and thus shape us, the citizens.

Unfortunately what is known about cities as the habitat for human beings is considered sometimes ambiguous, unknown and unclear, as the Danish professor and urbanist, Jan Gehl referred in one lecture at Aalto University, citing Enrique Peñalosa, Mayor of Bogota: “we know very much about good habitat for siberian tigers and mountain gorillas, but only very little about good urban habitat for homo sapiens”, Gehl (2017).

It is difficult to understand the human habitat due to its complex systems and the overlap of its miscellaneous uses and functions. Additionally, every single city is unique on its own various ways. This uniqueness might be considered as a difficult obstacle to building a standardised understanding of cities that represent different cultures, religion and heritages. Furthermore our urban settlements are currently in the midst of redesigning the world and all its systems, as mentioned in the previous chapters of this research. Smart Cities will redesign our legal, political, ethical and economic systems, as well as our infrastructures, for a digital age with information and communications technology (ICT) as the future urban backbone. Yet our built environment has been designed for how we lived and worked over the last centuries. There is a need to adapt the hard-engineered fabric of future Smart Cities with our fragile and organically built existing urban fabric. This integration should be done naturally and seamlessly.

Based on this approach we have wondered how could we respect the unique character of cities that is expressed by their architecture and arrangement of streets and open places, and their culture, when designing the future of cities and their transition towards smart cities. From our perspective it is appropriate to build an analogy based on the work of a variety of authors, and state that cities can be seen as living organisms, that keep reinventing themselves and changing in a fast paced rhythm. Therefore, as living organisms, cities might have a genetic code or DNA structure.

In this research the DNA of a city is first explored as the architectural and spatial characteristics that contribute to the city identity and heritage. This methodical approach was based on an interview with City of Espoo architects and urban planners, who emphasised the relevance of respecting the identity and cultural

heritage of any city when designing infrastructures for urban settlements. Therefore, when designing the smart urban furniture for future cities, we should somehow respect the common arrangement and architectural forms in order to fit into the urban context, and respect this “genetic” code. The interpretation of this “genetic code” should reflect in some level the existing aesthetic and architectural patterns, or re-interpretate the existing patterns in a contemporary expression.

By interpreting the existing cultural heritages of the city we can plan for the smart integration of innovative complex systems and, therefore, a positive embrace of digitalisation in the urban fabric. The hardness of a city’s identity and design guidelines vary depending on the city or urban zone. From the urban planning perspective, these guidelines help to build a coherent urban fabric and city identity. On the other hand, from the perspective on urban psychology, these guidelines must be established to preserve the characteristics that perhaps citizens most deeply identify within the urban context. The “Place identity and place attachment theory from environmental psychology demonstrates how and where we live has profound emotional and physical impacts. It influences our sense of self, belonging, purpose and meaning in life (or lack of it)” Landry (2020).

Therefore, we aim to create smart urban infrastructures that enhance the city identity and avoid alien architectural forms that can be disruptive and overpowering in this habitat. By absorbing the existing heritage and values we try to maximise the social potential of the urban community, by promoting the sense of self, belonging and wellbeing. When conceptualising the Smart Urban Furniture collection, we excluded architectural fashions that are international in scope from our design approach. We have targeted our approach to providing diverse responses that could answer to the needs of a specific cultural context. In other words we have focused our design approach in the DNA structures or urban identities that were reflected in architectural and spatial characteristics, the city’s identity and heritage. By absorbing the existing heritage and values we try to maximise the social potential of the urban community, by means of promoting the sense of belonging and wellbeing, and therefore generating a cohesive urban fabric that can fuel community engagement.

With this approach the LuxTurrim5G design research team generated four collections of Smart Urban Furniture that could better fit the future of smart cities, by respecting their heritage and identity. These collections will be further introduced in the coming subchapter.

4.1.3 Introduction to the Smart Urban Furniture concept and collections

Cities have unique essences and DNA structures, therefore various architectural and spatial characteristics that define their identity, culture and heritage. The city’s genetic code provides the correct pattern and direction to organically build a cohesive urban fabric, based on its core cultural characteristics. In urban settlements with well defined identities, the intervention of new, disruptive, artefacts can mark the city positively, but also negatively if their presence is overpowering. Inappropriate artefacts are not always identifiable simply by their proportions and materials, but also from the value that they convey in context. Our research team has developed four different collections that convey different cities’ identities, values and aesthetics in order to enhance citizens’ belonging and wellbeing. These collections of products were all designed to equip cities for the digital age, optimise cities’ operations and efficient use of resources, and most of all to enhance citizens quality of life.The Smart Urban Furniture collections are introduced below:

- Ambit, which stands for timeless urban identity.
- Edge, which stands for modern urban identity.

- Flow, which stands for organic urban identity.
- Loop, which stands for minimal urban identity.

In the figure 38 an imaginary city is visualised with the integration of the four districts and four collections. Each district conveys a city's DNA and its specific collection of products.

Each collection of urban artefacts integrates five main products:

- Smart Bus Station
- Smart Pole
- Smart Bench
- Smart Hub
- Smart Trash Can

These products were designed in order to integrate the services ecosystem and Smart City strategic network explored in the previous chapter 'Smart Cities as Ecosystems.' After identifying the needs for this urban furniture, we have developed variants that can better fit the cities' needs and requirements according to the different city zones.

Each collection was designed by different members of the research group. The Loop collection conveys values such as neutrality, calm, and tranquility in the urban context, and will be further explored in the coming sections as it was principally conceived by the author of this dissertation.

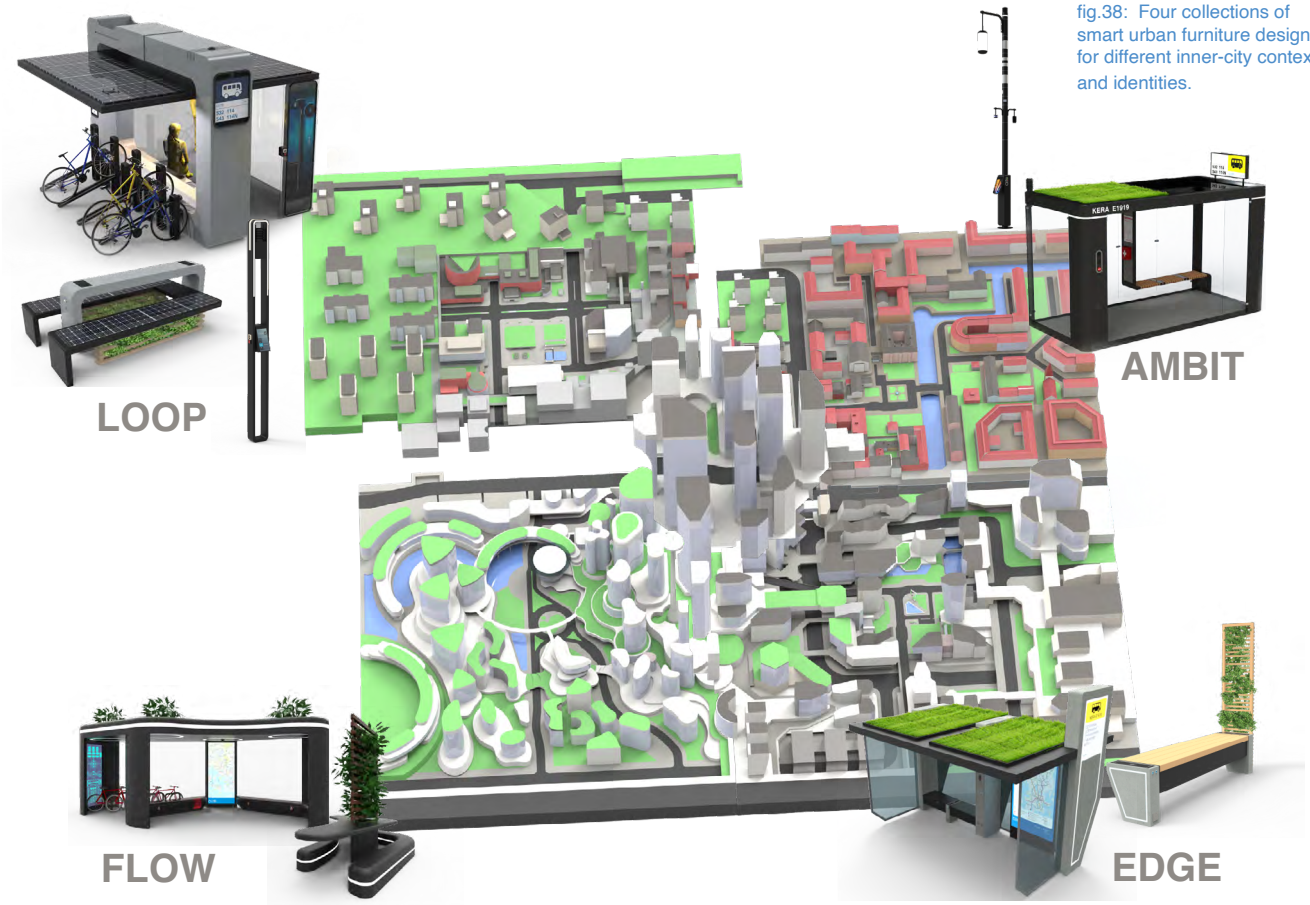


fig.38: Four collections of smart urban furniture designed for different inner-city contexts and identities.

4.1.4 Minimalism and emotional design as the core of product development.

Emotional design as core

When designing for relevance, there is a need to consider more than structural and functional properties. Therefore, the Loop collection places an equal emphasis on functional structural integrity and on the user experience of the product through its aesthetic and haptic qualities. Both the constructive or functional and ornamental or aesthetic elements represent a fundamental part of the larger assembly, that includes the integration of emotion in products in order to anticipate various users needs, and improve their experience.

Nevertheless, the first phase of the Loop collection development was initially targeted to answer to the users needs when interacting with the proposed products (also, on a meta-level, with the service ecosystem). In this phase of the project our focus was on guaranteeing a functional product that could help and support the citizen in the urban context, and, therefore, promote a functional integration of technology and efficient interaction with the city. Therefore, this first design approach was based on a logical and integral answer to the users and cities necessities. Nevertheless, it was quickly understood that products generate responses, which are naturally emotional due to our human condition, and thus the emotional design can be perceived as a natural evolution of the functional design.

“Design is really an act of communication, which means having a deep understanding of the person with whom the designer is communicating” Norman (2013).

Ultimately, design can be seen as a way to communicate and produce emotion. According to Professor Donald A. Norman, emotions might have a major responsibility in the way users perceive and understand the environment, and how they grasp and tackle new things.

Donald A. Norman has also noted that the cognitive sciences have recognised that emotion affects how the user feels and behaves while also improving decision making capability. The affective system works independently of conscious thought, and the affective system impacts everyday decisions. The neuroscientist Antonio Damásio studied various patients with mild brain injuries that impaired their emotional systems. Despite the patients normal appearance, they were unable to make decisions, and therefore to function effectively in their world. The patients could describe in detail how they should have been functioning, but, unfortunately, they were not able to build the most ordinary judgments such as: where to live and what to eat. From these facts one may conclude that the common belief that decision making is the heart of rational thought is no longer true.
Contemporary research shows instead that the affective system provides critical assistance to decision making. When making decisions the affective system accepts or rejects notions. By doing so, it expresses emotions and builds an intrinsic relation with human behaviour that links the body’s response to the given situation. Based on Norman’s perspective, aesthetically pleasing objects appear to be more effective and beneficial, due to their attractiveness. This phenomena is based on the affinity that the users might feel for an object that appeals to them, since it triggers an emotional connection with it (Norman, 2004).

“Attractive things do work better - their attractiveness produces positive emotions, causing mental processes to be more creative, more tolerant of minor difficulties. The three levels of processing lead to three corresponding forms of design: visceral, behavioural and reflective. Each plays a critical role in human behaviour, each has an equally critical role in the design marketing, and use of products” Norman (2004).

This author has highlighted the impact of emotional design on everyday products, and positive behavioural response of the user. Norman also emphasises that, to reach a meaningful emotional impact, to generate pleasure and to turn critical moments into positive emotional experiences, designers should first address three levels of cognitive responses, namely:

• Visceral design represents an elusive layer where features such as look, feel and sound dominate. In other words, the user builds a first impression of the specific artefact. We have embraced this first visceral level in order to build a positive perception and impact of the Loop collection artefacts. To achieve that, we have generated a minimal collection that brings neutrality and comfort to the user in the complex, cluttered and fast-paced cities of the present and future. With this approach we have tried to enhance trustworthiness and an easy user perception of the products, when the user first interacts with the artefact.

• Behavioural design, portrays the level of performance, or usability, and evaluates how easily the users can achieve their goals, needs and requirements. The Loop collection has absorbed these values in order to enhance the satisfaction of the user when interacting with the product. This collection consists of a multitude of products that can generate a harmonious experience in the city context. This harmonious experience can be generated in two levels, first based on the intuitive and functional design of every single artefact, and, secondly, on the interlinked ecosystem of innovative variants of products, that can easily adapt to specify instances and provide interconnected services to the user.

• Reflective design integrates an intangible layer of message, culture and meaning of a product for its use. After encountering and interacting with the artefacts, users will consciously analyse their performance and benefits. Ultimately, if they feel happy with the overall experience, they might form an emotional bond with it, which will generate personal satisfaction and positive memories. Therefore, in the Loop collection, we aimed to achieve visually and functionally pleasing products that could contribute to a perception of improved performance and quality (attractive things work better).

By embracing Donald A. Norman's approach to emotional design, we aimed to achieve a meaningful design that builds on how users feel and experience the product. Every product or service interaction has an elusive emotional layer, thus the incorporation of emotion should be considered as a key element when designing products. As rational as we may like to think that humans are, emotions are at the heart of how we all interpret our world and, therefore, should be included in the design process.

Minimalism in the urban fabric

The different collections of Smart Urban Furniture, introduced in the previous subchapter, convey different aesthetic values based on the city genetic code, thus spatial singularities, architectonic character, overall culture and heritage. Figure 39 illustrates a canvas that was built on the top of a brainstorming framework, where the research team has positioned quick sketches that were used to defined valuable characteristics of street furniture. These sketches and thoughts were positioned in the canvas according to their aesthetic identity and the values that they seem to convey. Therefore this analysis and experimentation opened the door to recognising the themes and aesthetic identities required by different cities.

This canvas also serves as a visualisation of the identity of each collection, since each smart urban furniture family was positioned in different chart frames, according to their characteristics, therefore:

• The Ambit collection denotes a classic and smooth approach, timeless at its core.
• The Flow collection denotes a futuristic and smooth approach, organic at its core.
• The Edge collection denotes a futuristic and angular approach, modernist at its core.

The Loop collection denotes a minimal approach, taking into consideration that cities are becoming more complex, increasingly crowded, and mostly cluttered. This collection embraces minimalism in order to bring neutrality and tranquility to citizens in the urban context. With a minimal approach we will not only engage and enhance the identity of the city and its heritage, but also provide citizens with the opportunity to focus on the right things. Either on a personal level or in the urban context, where eliminating distracting visual clutter enhances the perception and Experience of the city, this contemporary collection stands for “Less” intervention in the city, and, consequently, “More” harmonious prospects of the city.

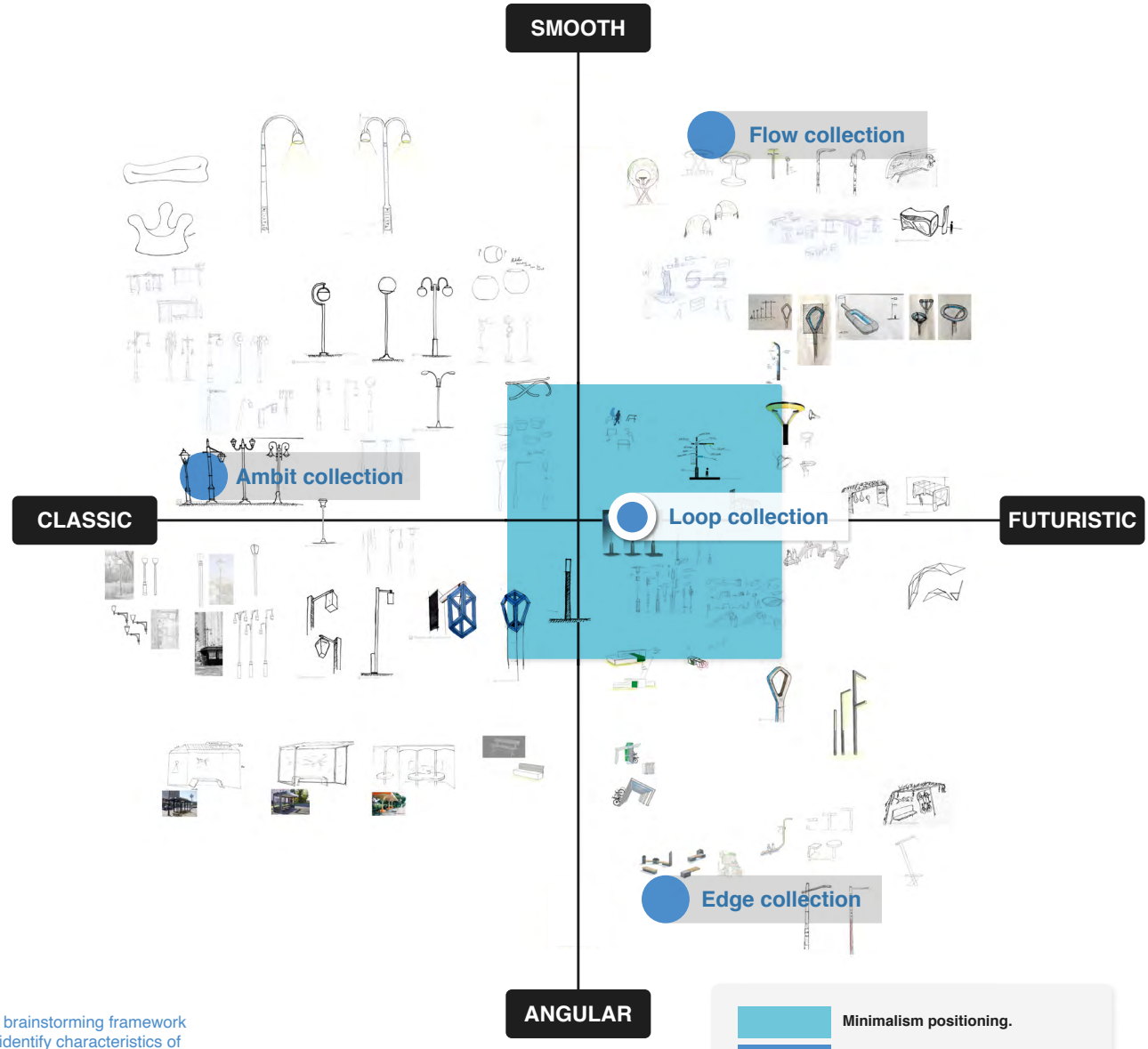


fig.39: A brainstorming framework used to identify characteristics of street furniture and the collections aesthetic values.

In the visualisation mentioned above, the contemporary interpretation and positioning of minimalism in this work is illustrated in the chart as light blue. This aesthetic and mindset movement was positioned in the central area of the graphic leaning on the futuristic side, since, in this work, minimalism represents more than its colloquial reference to anything that is spare to its essentials. It represents the production of democratic objects for everyone's use, "making things lighter not heavier, softer not harder, inclusive rather than exclusive, generating energy, light and space" Morrison (2010).

Minimalism, as commonly linked with usability and functionality was embraced in this collection. Nevertheless, its design, in the urban context, aims to generate meaningful, impactful and mostly pleasurable experiences. The author Patrick W. Jordan has noted that, once users interact with functional and usable products, they will soon want something more, they will want "products that are not only merely tools, but which are living objects which people can relate to. Products that bring not only functional benefits but also emotional benefits" Jordan (1999).
The artefacts of the Loop collection were designed to be easy to use and functional, but mostly to enhance the citizens experience in the urban settlement and, therefore, generate significant and impactful emotional experiences and induce pleasure.

The author Patrick W.Jordan has written that, to achieve the product pleasurability, "requires an understanding of people - not just of their physical and cognitive processes - but as rational and emotional beings with values, tastes, hopes and fears" Jordan (1999). Therefore, to understand the users' emotions in this context, we should first understand how people relate to products, what are the properties that might trigger emotional responses, and how can a product convey a particular set of values. This author noted the work developed by the anthropologist Lionel Tiger, and used his framework to address four types of human motivations or pleasures that help to quantify and generate emotional responses, the types are: physio-pleasures, socio-pleasures, psycho pleasures, ideo-pleasures. These motivations or pleasures often address topics as bodily pleasures derived from sensorial experiences, pleasures that arise from meaningful relations on a societal and personal level, cognitive and emotional pleasures, and, last bus not least, pleasures that connect people to values and personal aspirations (Jordan,1999).

In conclusion, these four levels of pleasure demonstrate that people will always have and will always seek pleasure even if unaware of it. The products that surround the users are potential sources of pleasure. Therefore the Loop collection artefacts were designed with a view on how they could provide pleasure to those who experience them.

4.2 Practical aspects on the product design: Loop collection.

4.2.1 Phase I: General form exploration.

Minimalism embodies the well-known concept of "less is more", a phrase first stated by the architect Mies van der Rohe in 1947. Minimalism is a concept that intersects our lives in various ways, some people perceive it as a lifestyle and a mindset, others see it as a cleaner looking aesthetic.
In the design field, minimalism is often seen as one of many art movements that describes a form of content. The Cambridge Dictionary has defined minimalism as "a style in art, design, and theatre that uses the smallest range of materials and colours possible, and only very simple shapes or forms" Cambridge (2021). In the Loop collection, we have conveyed minimalism in the form of content but also on its intrinsic values, in order to reduce clutter and generate a better user experience. In other words, we have not only embraced the simple shape approach but also the inherent values and mindset that are linked with the user's emotional experience of the city.

Design for a collection of products can be quite challenging, since each product has its own characteristics and form content, based on its practical use. This means that, when we think about a bench, we can easily picture its shape, simultaneously, and when we think about a bus stop, we can easily picture its form, but most likely we will not use the exact shapes that we used to first visualise the bench. Therefore, to build a cohesive collection that conveys minimalism in the core, we first dived into a creative process to find the motif of the collection that could be explored as part of the substance of each product. Sketches were one of the first steps to start this form exploration. The light pole luminaire is often seen as one of the most emblematic points of reference for the aesthetics of this collection, therefore we have first explored this shape in order to find a reference to the remaining products. The smart pole exploration present in Figure 40 helped to make decisions and experiment with different variations of an idea that led to a final versatile rectangular shape that was explored independently in Figure 41.

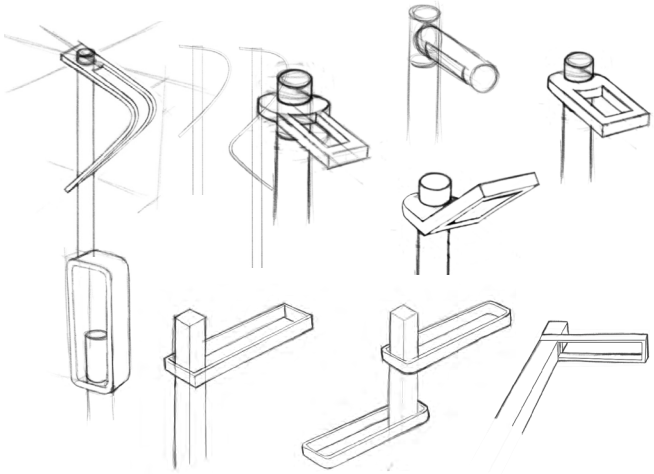


fig.40: Preliminary form exploration of the Smart Pole luminaire.

The smart pole luminaire exploration was developed in the beginning of the project and therefore it was not a decision based on complex analyses of the city or its services, but mostly on exploration of simple shapes that could build the motif of the collection. When we analyse the characteristics of each compound product such as the bench, the bus station, the trash can, the smart pole and others, the luminaire seemed one of the most logical and simple shapes that could be explored in order to advance towards the collection motif. This exploration sought to develop a versatile and minimal shape that could be applied in different directions, implemented for different uses, and provide structural integrity when used in different scales and dimensions.

Based on these considerations we have adopted a rectangular shape with a hollow in-line cut, as a versatile form that could be used in different contexts. The application of round edges was also explored. The final decision of the finishings for these rectangular shapes was made during the development of each product and the application of the shape was based on the needs of the products. In the end, the smooth edged rectangular shape was used as the core structural component and motif of the loop collection, due to its versatile and clean aesthetics that convey the minimalist essence.

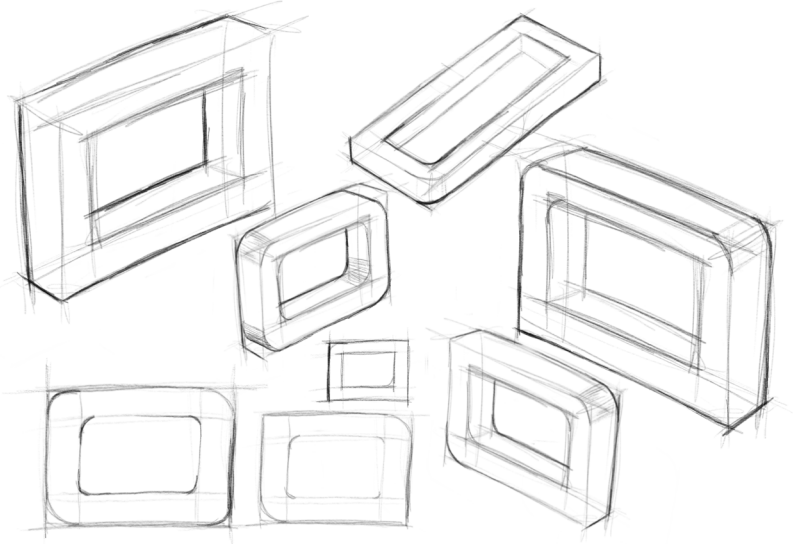


fig.41: Preliminary form exploration of Loop Collection motif.

4.2.2 Phase II: Bus station and Smart pole architecture and development

"The secret of any trade, if pursued with serious intentions, is more than a series of rules and working methods based on logic and experience… They also include a continuous process of observations, thoughts and ideas that are pushed ahead even if, in the beginning, they seem to have no logical basis" Munari (1966). The development phase of this project was based in this creative approach using experimentation, diverse methodologies and design techniques. The Loop Smart Urban Furniture collection is a direct result of our in-depth analyses of Smart Cities and the service ecosystems. Even if not in a logical manner, product development was always under consideration. In other words, product exploration was omnipresent throughout the different stages of the project, especially in the beginning of this work when we were not completely aware of the city's basic service needs, challenges and genetic code.

We have undertook various sessions of brainstorming and form exploration within our team in order to obtain different form solutions. Even if, at an early stage, we were not fully aware of all cities' necessities, we have sketched and drafted possible final solutions for our artefacts. In this chapter product development and architecture will be briefly introduced; from early form exploration, sketching and ideation of the first stage, to techniques, prototyping and, the final products. Due to the wide range of product solutions generated in the Smart Urban Furniture collection, we will explore in more detail the methodologies used for the Smart Pole and Smart Bus Station. In this analysis we have considered that these two products represent the product development process applied for all the artefacts of the collections. The remaining products will be introduced later on in this chapter, in a succinct manner, focused on the final results.

The Smart Pole and Smart Bus Station analyses demonstrate different considerations in different stages of the design process, namely: form exploration, final architecture and modularity, tools and experimentation techniques, final product solutions and variations.

4.2.2.1 Architecture development

Smart Pole: from form exploration to final architecture.

The Smart Pole, included in the Loop collection of artefacts, was initially based on the pilot products developed by the LuxTurrim5G consortium, represented in Figure 42. We have embraced the learning and research developed by the partners in the consortium and therefore aimed to integrate in this solution small cell wireless deployments, configurable housing for different equipment, and streamlining, among other considerations. Despite these technical goals, at this stage of product development, we have aimed for our product to be citizen driven and, mostly, blended with the urban environment and the city's genetic code.

fig.42: LuxTurrim5G Smart Pole pilot.

Figure 43, shows an early stage form exploration of this artefact, based on the camouflage approach. In this exploration we can see various expressions of the motif of the collection, the soft edged rectangular form. Experimenting with different variations of this motif it was possible to improve its aesthetics and functionality. We have first interpreted this motif in a more organic manner that could be used to create a contemporary luminaire.

However, it was quickly understood that this shape distortion could transform a minimal shape into a disrupting infrastructure in the urban context, and therefore it

was not developed further. Afterwords, different variants of the rectangular shape were analysed, some creating various angles with the pole structure and impacting the integration of technology, others exploring different modular supports. In the end, emphasis was placed on meeting the changing needs of the wireless industry, city government, and citizens.

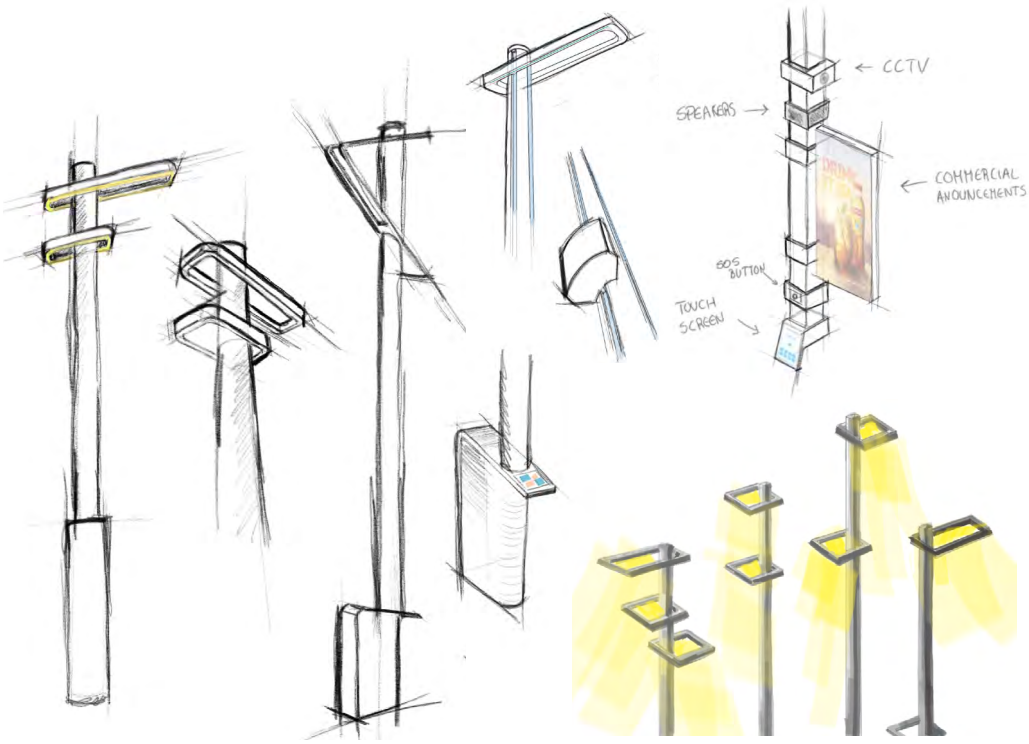


fig.43: Loop Smart Pole form exploration.

Therefore, we have adopted the most simple and modular solution of the integration, the motif “itself” in a single rounded pole. The single rounded pole provides good thermal features and answers to aerodynamic needs. The transformation of the motif into a long rectangular luminaire highlights the appealing minimalist styling, but mostly opens the concept of modular construction.

Modular design is the key to urban flexibility. The intersection of the clean rectangular shape with the rounded pole was seen as a design statement, which inspired a new perception of module integration. In several meetings with the design manager from Tehomet, Sami Huuskonen, partner of the LuxTurrim5G consortium, the challenge of integrating all of the technology in the pole core structure was stressed. Based on this challenge, the Loop collection provides a new product architecture that can integrate technology internally and externally. In other words, we have expanded the intersection of the luminaire and the pole, as an aesthetic characteristic of this artefact, and embraced the integration of external modules as a visual statement.

Nevertheless we have developed our smart pole architecture towards a system that houses all of the active technologies, internally and externally. The final architecture of the pole’s core structure is built based on the combination of different segments that can house different technologies and therefore provide various services to urban settlements. In other words, this product architecture is all about a modular system, this artefact was inspired by LEGO bricks and building blocks that can be assembled and re-assembled in numerous diverse ways. The core structure and segments of this pole will be further explained in the coming section.

This final architecture provides endless possibilities for creative construction. This final product architecture, described in Figure 44, liberates a double level of modularity and customisability, since the city is able to:

• Personalise the core structure of the artefacts based on the service needs in each city location.

• Select additional external modules of temporary or fixed use, in the urban context.

• Customise the assembly of each product segment or model based on the characteristics of the urban space.

• Integrate modular components which will be easy to install and maintain, ready to follow the fast paced rhythm of technological innovation.

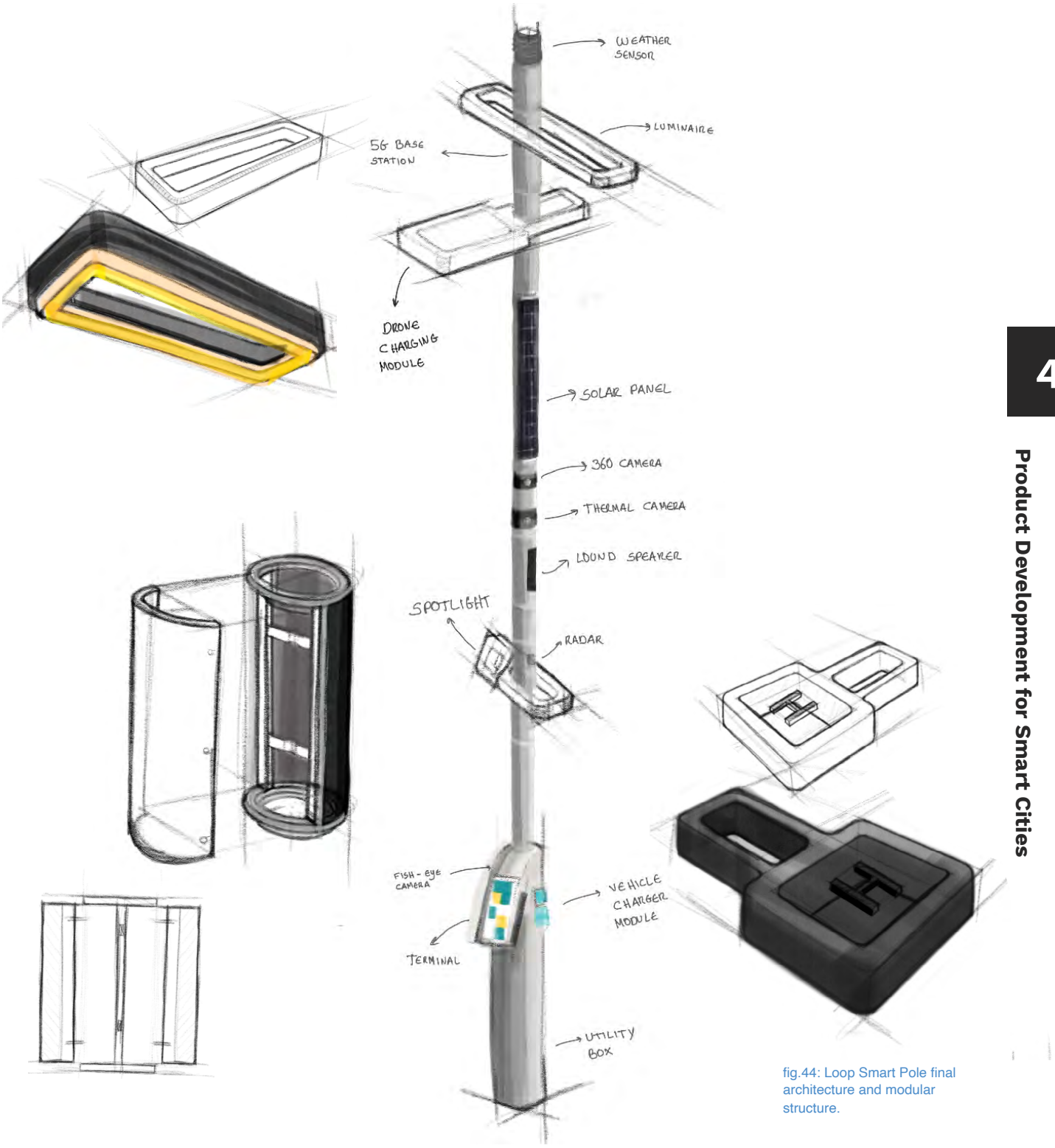


fig.44: Loop Smart Pole final architecture and modular structure.

Smart Pole: internal and core modularity.

The modular design of our product aims to allow for the discrete accommodation of a wide range of smart city services, and therefore technology.

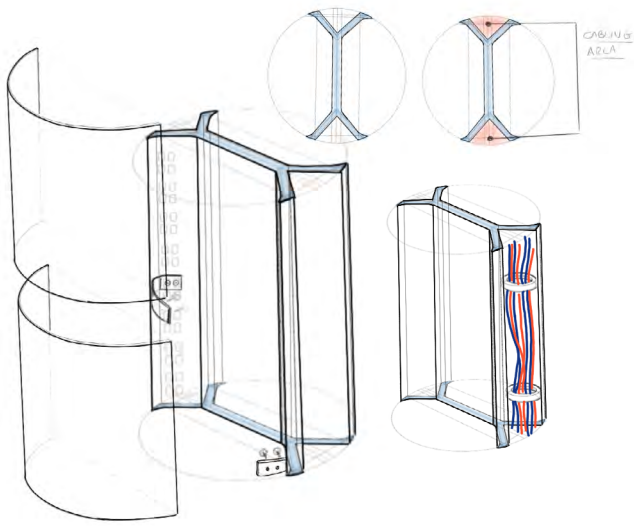


fig.45: Smart Pole - exploration of a sectional core modularity.

The core structure of our modules was collaboratively ideated within the research team. First it was explored the possibility of developing a sectional modular architecture, illustrated in the figure 45. This modular system was elaborated based on a continuous profile with a format similar to the “Y” letter. This profile could accommodate a space for the cabling and provide a non electromagnetic-interference zone, since it would be positioned on the side edges of the profile, as illustrated in the figure mentioned above. Additionally, it would provide the space for technology and sectional modular doors, used to access to the smart pole inner structure. This first approach to a modular solution would provide a good structural integrity to the smart pole. However, it would limit the customisation, and mounting integration on the city perspective.

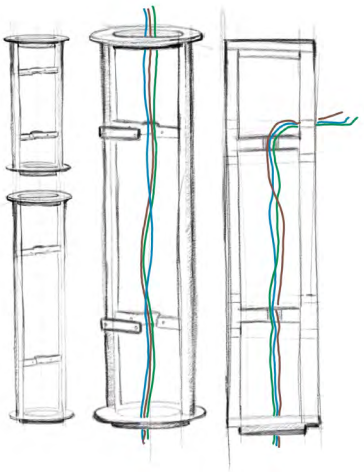


fig.46: Smart Pole - exploration of bus-modular architecture.

Following this first form exploration we have moved towards a bus-modular architecture. In this approach, illustrated in Figure 46, we have developed a segment with an inner structure that resembles a “H” shape, with space allocated for cabling and technology integration. Additionally, we have integrated small cabling exits for the connection of external modules. The pole segment structure was designed based on a joint system or slotting mechanism that always uses the same attachment to the base, and therefore grows vertically. Furthermore, these segments are divided into four main sizes, namely: 250mm, 500mm, 1000mm and 2000mm. These segments are used to provide different services and enclose different technologies to provide the smart city services. The pole architecture of the Loop collection is based on the assembly of a base and a combination of different segments that can be selected by the city in response to local needs.

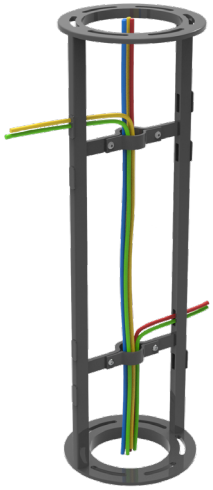


fig.47: Smart Pole - final core architecture and cabling solution.

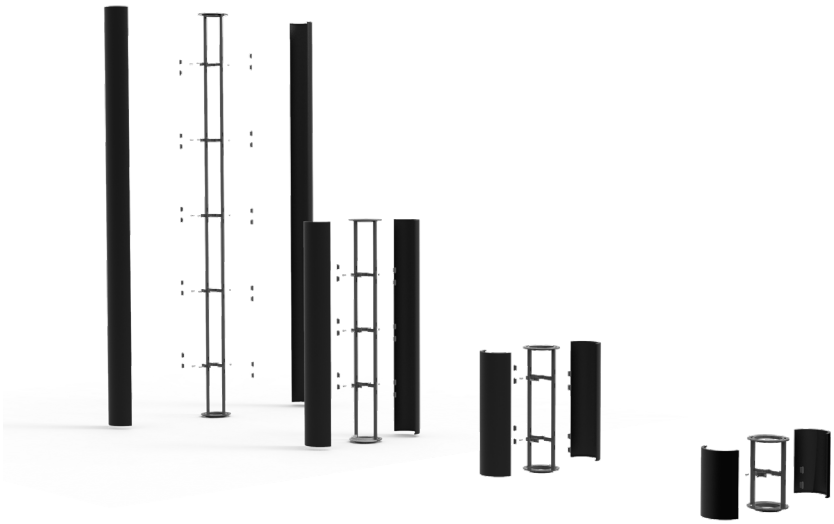


fig.48: Exploded view of Smart Pole core segments. From left: 2000mm, 1000mm, 500mm, 250mm.

The combination of these segments will provide for different heights of poles, and product variants that will be further explained in this document. This modular pole architecture was designed to equip the cities of the future with an evolving infrastructure that can be upgraded with new services while also enabling simple maintenance of existing ones.

Smart Pole: external modularity.

We see modularity as the key enabler for new Smart City services. Our smart pole core architecture provides an infrastructure, based on individual segments, that can be selected in accordance with urban needs.
This product has embraced two levels of modularity and technological integration. Due to the natural challenge of integrating all the technological components in the core of the product, a limited space, we generated an additional layer of modularity with external components that can be added to the pole architecture and provide new services. This approach forced us to rethink the modular integration system, based on the suggestion of the design manager Sami Huuskonen, a LuxTurrim 5G partner. Consequently, in the Loop Smart Pole, we embraced the aesthetic value of the intersection of the luminaire with the pole structure. We have expanded this intersection as a design characteristic and a visual aesthetic statement, making it part of the identity of this product. Subsequently, we have generated nine additional external modules that follow this intersection, and can be added for temporary or permanent use in the pole structure. The referred external modules are illustrated in Figure 50 and listed below:

- **Lidar.** This module takes a major role in the sensor network by providing accurate infrastructure for autonomous vehicles. This sensor is often used to detect objects in-depth.

- **Event projector.** This module serves social, cultural and aesthetic functions in the public space. It can be used for outdoor events and/or video mapping, on a daily or as-needed basis.

- **Road condition sensor.** Collects weather information such as road surface temperature, flooding and other conditions to enhance safety for commuting and transport services.

- **Way-finding sign.** Combines physical signage, maps, symbols, colours and other evolving means of communications to guide a person through a public space, enhancing the user experience.

- **Urban sound camera.** Automatically detects and classifies complex and dynamic urban sounds, providing urban planning soundscape mappings and noise monitoring control, enhancing city operations and safety.

- **Drone Landing station.** Drones can be used for various purposes in the context of the smart city. These wireless charging landing stations can be used to optimise their efficiency to complete various operations.

- **Banners.** The smart pole can host single or double banners for a range of outdoor messaging needs and advertisement, used to promote local events, exhibitions and other happenings.

- **Light Spots.** Additional light spots serving social and aesthetic functions, offering directional decorative lighting on a daily or as-needed basis. Can be used by city planners in a range of lighting initiatives.

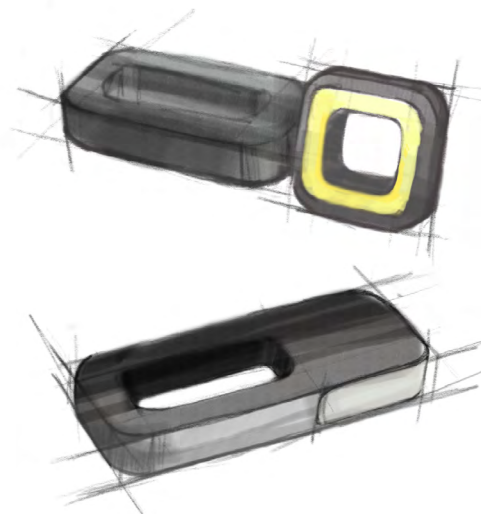


fig.49: External modules sketches and form exploration.

• **Air quality sensors.** Measure air quality index and air pollution, such as particles from industrial activity, exhaust fumes, pollen, and others, which present a risk to citizens and negatively impact health.

It is important to consider that cities are in constant evolution. Therefore the modules referred to here can be updated or redesigned, and new modules can be added, reflecting technological advances or new cities needs. Later in this document, the technology used will be analysed, including the examples mentioned above and others integrated in the core structure of the pole.

fig.50: External modules family and variations.

Smart Pole: product family.

As cities are complex and require different services depending on their local needs, infrastructures should be adapted to the characteristics of the public space and to the product location. Products variants should be considered for use in green areas, central squares, highways or elsewhere.

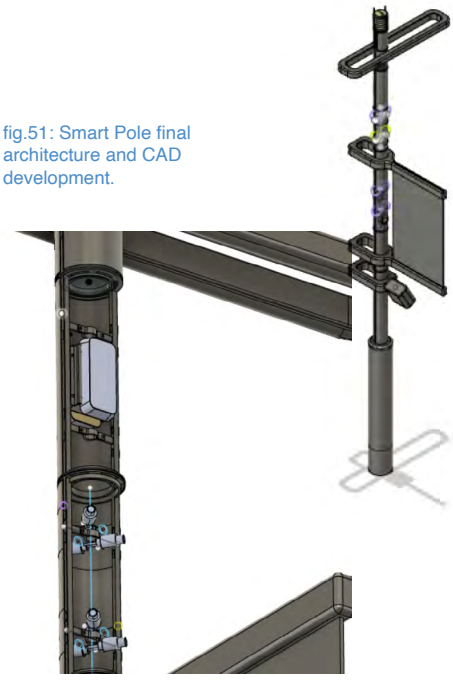


fig.51: Smart Pole final architecture and CAD development.

Consequently, we have expanded our final smart pole architecture, into a family of products that can better fit the different infrastructural requirements of urban spaces. Based on this approach we moved from formal exploration to the final architecture, and thereafter to CAD development. The software used at this stage was Autodesk Fusion 360. We have used this tool to produce the CADs of our modular systems, assembled from the different height variants of the smart pole. Figure 51 illustrates the CAD pole architecture development in the 3D modeling software.

According to the EU LED Street Lighting Procurement & Design Guidelines, the positioning of the pole structure or masts as well as their height are technical decisions. This decision is based on the geometry of the road, ground conditions, characteristics of the pole itself, environmental requirements, space available for maintenance, budget, aesthetics and lighting objectives (EU, 2017). Nevertheless, based on the guidelines provided by the designer manager from Tehomet, Sami Huuskonen, our research team has developed four major smart pole variants based on their height. Namely the standard solutions are:

- A smart pole for pedestrian sides and green areas of approximately 3m height.
- A smart pole for urban areas and residential side of approximately 5-6m height.
- A smart pole for general road in the urban context of approximately 7-8m height.
- A smart pole for wider streets and highways of approximately 10-12m height.

It is important to emphasise that the generic guidelines mentioned above outline possible uses and suggestions. The placement of the smart pole products varies according to the street typology, land use and city planning strategy. Based on this approach we have developed a family of smart poles that is illustrated in Figure 52.

The Loop collection smart pole product family offers a coherent product line, that can enhance the smart city infrastructure. In this collection the three poles of greater height use the same modular system and segments. Our pedestrian sidewalk pole is smaller and uses a different product architecture. During the technological analysis and inspection of the placement rules, it was recognised that most of the technology can not be placed below a height of 3m for the safety of citizens and to protect against the risk of vandalism. Therefore our modular system was not applied in this product. Despite that, we have embraced the motif of the collection and created an artefact that conveys the identity of the product line and provides the basic city services. The general dimensions and technological integration will be further detailed in this document in the coming sections.

In conclusion, the Loop Smart Pole family was designed to enable an adaptive Smart City, and can be adapted to any service requirement or infrastructure condition.

fig.52: Loop Smart Pole Family

fig.53: Loop collection
Smart Pole solutions.

Smart Bus Station: from form exploration to final architecture.

Future transport and mobility services should not be foreseen as stand-alone solutions, these will need to be embedded in wider smart and sustainable city strategies aimed at increasing urban resource efficiency. Therefore smart mobility services and systems will need to interface with multi-sectoral and city-wide strategies in order to optimise the use of energy, spatial, economic and material resources (European Commission, 2020). Bus stops are one of the most common fixtures in the city landscape. The Loop collection reimagines this artefact, and reorients its infrastructure towards a smart bus station. This new product features various smart technologies from smart digital terminals, information screens, and various sensors, but mostly interlinks various mobility services and systems. With this approach we have transformed the bus stop into an oasis of vibrant urban activity. Based on this interpretation of the bus stop concept as an innovative hub for commuting services we have explored different forms that could integrate various sensors and technology, therefore giving shape to this concept. Figure 54, illustrates an early form exploration of this artefact. The presence of the Loop collection motif is clear in this exploration. We have used the collection theme, as a means to drive this exploration, and create different solutions by overlapping and using the motif shape in different directions and test assemblies. In this early exploration it was possible to develop its aesthetics, functionality and attempt new morphological solutions, which could test the structural integrity of the artefact.

The form exploration in the figure described above was first driven by a complex infrastructure that replicated the motif of the collection in its architectural form. Through the sketching process, the composition of the product was simplified. Firstly, two rectangular loops were used as main supports for the roof structure. Secondly, one rectangular loop was used as the core infrastructure of this product. In the end the Loop collection motif was used as the major structural support for the roof, which appears to levitate. In this product exploration we have not only focused on generating a captivating design that could convey the minimal essence of the loop collection, but also generating a versatile infrastructure where modularity could be easily integrated in order to incorporate new technology that can enhance the multi-mobility services in the smart city.

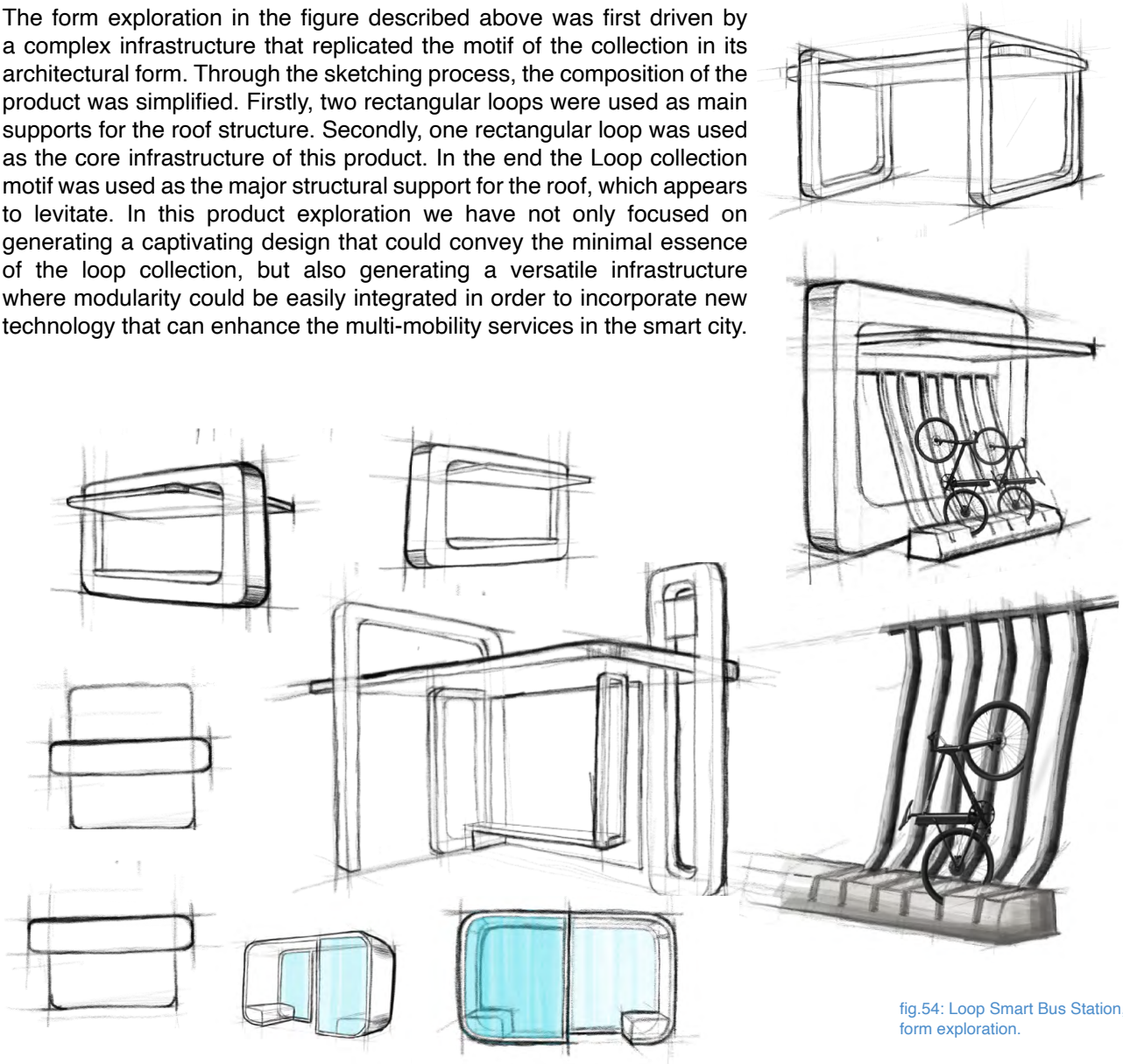


fig.54: Loop Smart Bus Station, form exploration.

The final product architecture, illustrated in Figure 55, clearly stresses the use of the Loop motif. This minimal versatile shape is used to integrate various technical components, such as the drone docking station, and provides space for protection against electromagnetic interference and easy cabling inclusion. The main infrastructure can be also used as the main seating area for the users. The emblematic loop is also utilised as the main infrastructure for tech items, hence providing accessible energy that can enhance new commuting services. Based on this approach we have not only designed a linear solution that can enhance the usability of traditional means of transport, but also integrated a resolution to make green systems of mobility, such as velomobility and e-bike systems, an integral part of the Smart City's public transport. Therefore, in the final architecture of this product we have not only generated a Linear Smart Bus Station but also a Smart Hybrid Commuting Station. This last product promotes cycling in cities and discourages dependency on fossil fuels, congestion from vehicle traffic and pollution.

As such, these products create awareness of the need for environmental sustainability, and signal the transformation of urban infrastructure to include green roofs or green walls that boost biodiversity, improve air quality and reduce the CO2 footprint of transport and mobility services.

In conclusion, the final architecture of the Smart Bus Station family provided by the Loop collection enhances city-wide strategies in order to optimise innovative green commuting services. This coherent product line aims to create cities where a short trip can be taken without always using a motorised vehicle. Therefore, this eco friendly mobility aims to provide cities with an infrastructure where the road is shared by bicycles, pedestrians, buses and cars, hence enhancing quality of life and wellbeing.

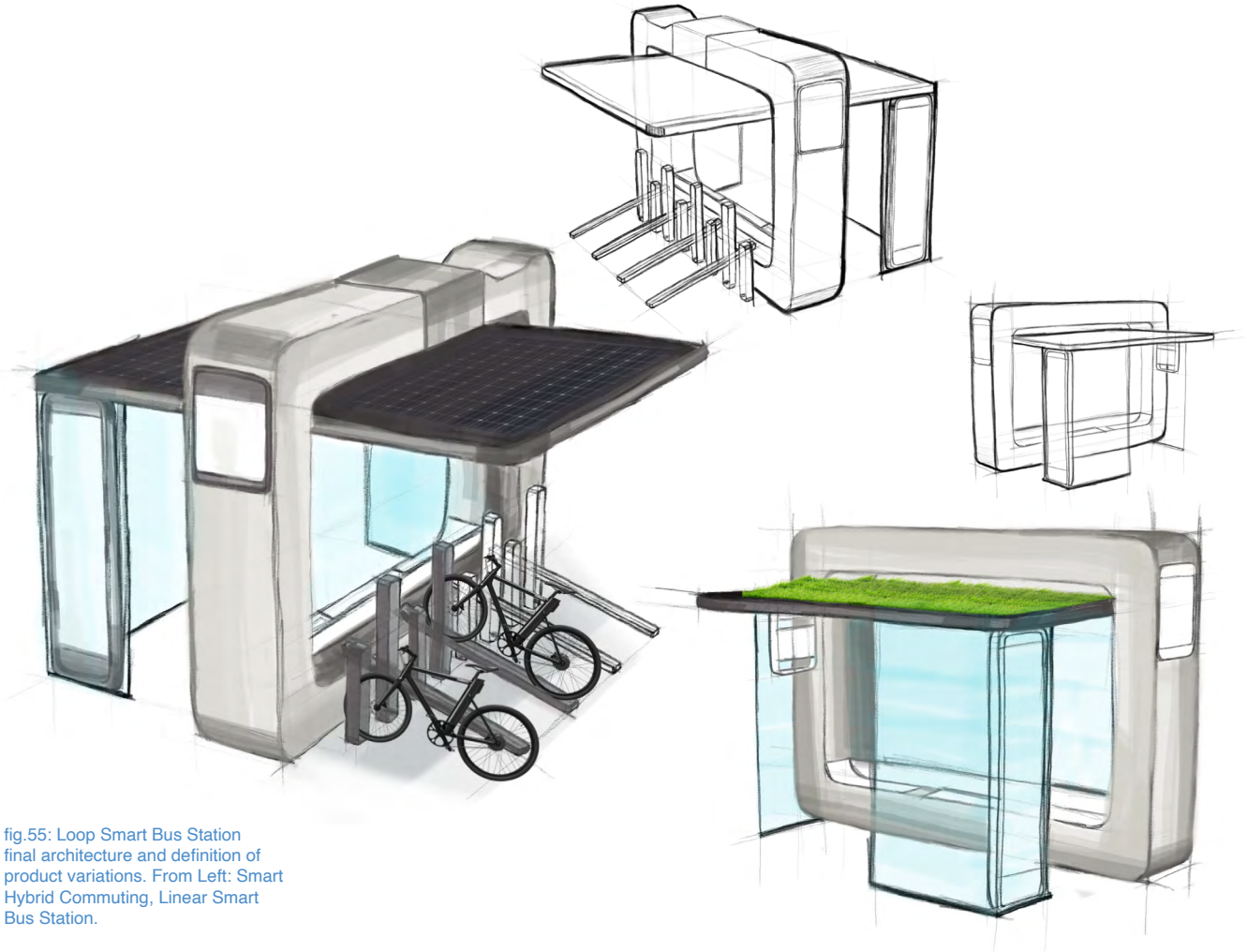


fig.55: Loop Smart Bus Station final architecture and definition of product variations. From Left: Smart Hybrid Commuting, Linear Smart Bus Station.

Smart Bus Station: product family.

This Loop product family has moved from formal exploration towards a final product architecture and then a final solution. In order to generate the final products, we have first dived into the cad development, where the product was refined. At this stage, we have used the same software as we did in the smart pole development, namely the Autodesk Fusion 360. We have used this tool to move towards the structural ring or motif, to the integration of technology and final product assembly. The figures 56, illustrate the smart bus station architecture process in the 3D model software.

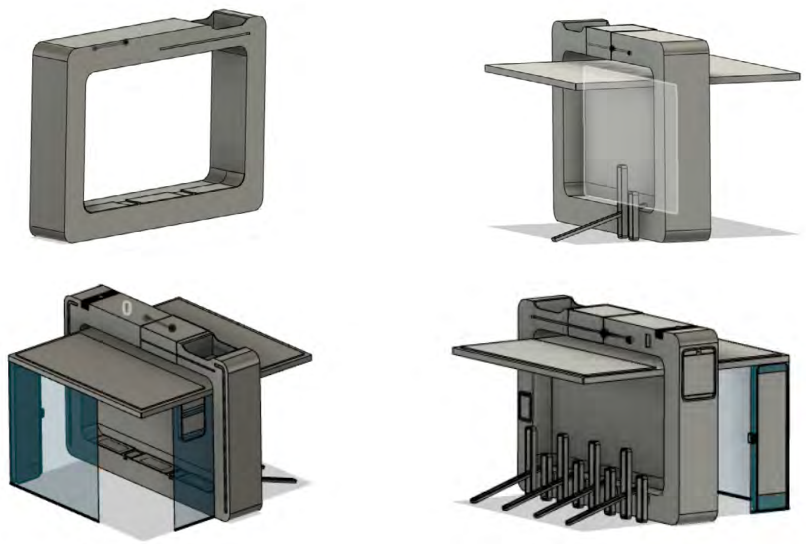


fig.56: Smart Bus Station CAD development.

We have generated two product variants that can integrate different services and easily fit into different urban contexts, namely:

- The Linear Smart Bus Station that can answer to a low-medium volume of traffic, and easily fits into restricted spaces.

- The Smart Hybrid Commuting Station, that can answer to a high-medium volume of traffic, which occupies more space providing green options for city-wide commuting.

Both products use the same motif of a modular ring, enabling most of the tech components to be integrated in this infrastructure. Therefore, it is possible to update a Linear Smart Bus Station into a Smart Hybrid Commuting Station if local traffic volume increases.These products can be customised by the city, and utilised in various manners; the roof can be used to harvest energy through solar panel modules, or to capture CO2 and increase biodiversity through the use of green roof modules. Therefore the city can select the service that is most useful based on local needs. Both products are equipped with charging services in the user seating area, which enhances the public transport experience. These charging services are both wireless and USB based in order to avoid the obsolesce of technology. Finally, we have also included a smart terminal, in other words an interactive interface, that enables the citizen to interact with the city platform and various other services.

In conclusion, the Loop Smart Bus Station family enhances the usability of bus stops, by transforming this infrastructure into vibrant multimodal hubs that enhance the sustainable and smooth navigation through the smart urban fabric.

Linear Smart Bus Station

Smart Hybrid Commuting Station

fig.57: Loop Collection
Smart Bus Station solutions.

4.2.2.2 Product technical considerations

General dimension definition

Defining the correct proportions, measures and forms, is highly relevant in the design process. Different requirements for those measures, such as the optimal dimensions, demanded sizes and existing restrictions, are often explored. There are two common approaches to defining general dimensions: firstly, choosing the dimensions based on existing artefacts, and identifying the most commonly used proportions, and secondly, recognising the most used dimensions from the target user's anthropometric properties.

Due to the nature of this project, which targets the conceptualisation without contemplating an advanced manufacturing phase, the definition of dimensions was not exhaustive. Therefore, the focus on the user's anthropometric properties was set aside due to our short and ambitious project deadline. Industrial design ergonomics drivers remain a space for further development. Nevertheless, we have defined the product measurements and form based on the best practices available in the market. Through this analysis we could consider the general form, a few function restrictions and, briefly, a review of materials, a topic that will be further explored later in this section.

We are aware that a process based on measurements used for existing artefacts was not the ideal approach for disruptive innovation, but, due to the short timeline, this seemed as the most adequate process to guarantee a minimal level of manufacturing and mass production considerations. Additionally, we have considered other drivers of the definition of the general dimensions, such as functional drivers and market drivers, since we have defined our product based on functional requirements and on the expectation of the end user. But, mostly, we have determined our product based on law & standard drivers, since each city has different requirements and applied standards for street furniture.Based on this approach we have first analysed different poles general dimensions, in order to define our own product dimensions. In Figures 58 and 59 there are two light pole families which are currently in use in different areas of the city of Espoo in Finland, due to the natural characteristic of each of those urban zones. Those pole families represent some of the artefacts upon which we have based our general dimensions. Figure 60, illustrates the standardised restrictions of poles heights and implementation rules in Helsinki, Finland. Those were also analysed in order to define the Loop Smart Pole heights and establish a clear understanding of the installation requirement in this urban context.

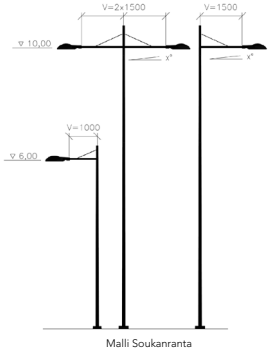


fig.58: Malli Soukanranta - City of Espoo street furniture dimensional reference.

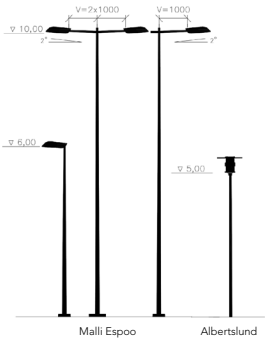
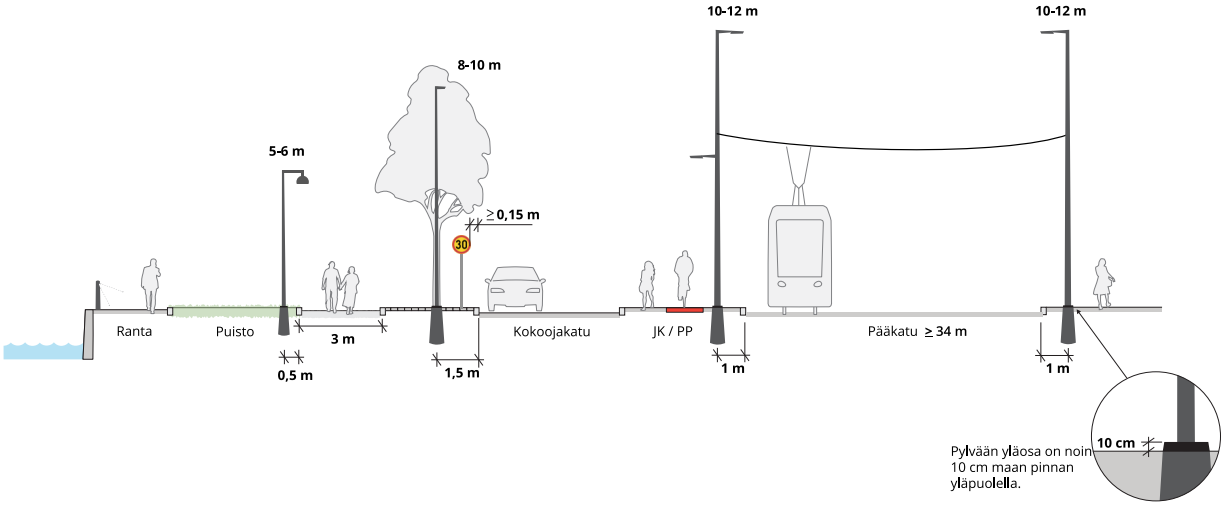


fig.59: Malli Espoo and Albertslund - City of Espoo street furniture dimensional reference.

fig.60: City of Helsinki public urban lightning, dimensions and implementation strategies references.



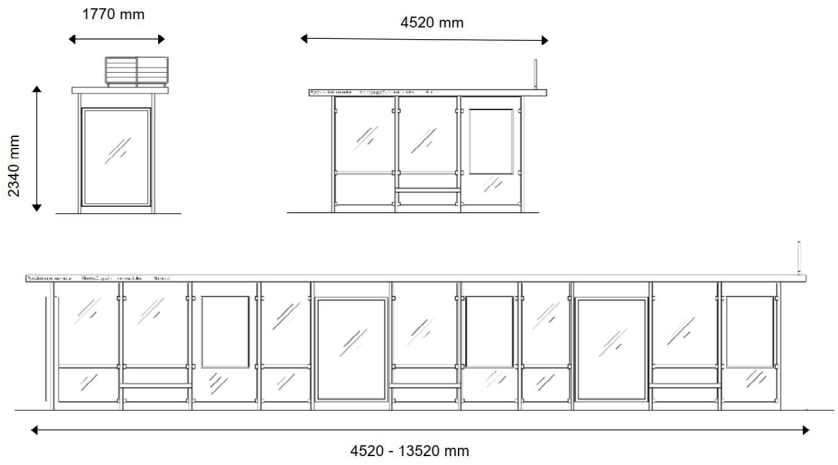


fig.61: City of Helsinki public bus stops dimensions and references.

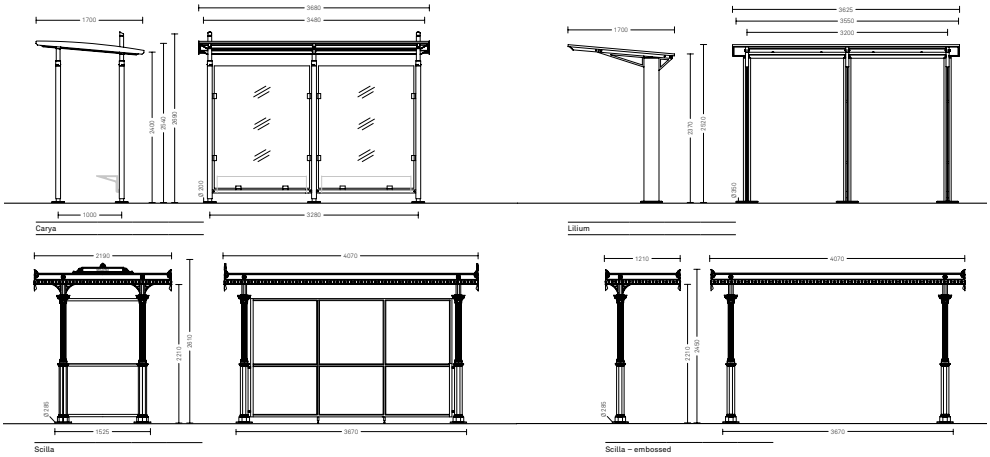


fig.62: Bus Station dimensional references from Neri's portfolio. From upper left: Carya, Lilium, Scilla, Scilla-embossed.

All the different products of the Loop collection have followed the same methodologies when establishing the measurements for the industrial design process. Therefore the definition of the bus station's form and dimensions was based on existing artefacts in the city of Helsinki, as illustrated in Figure 61. Moreover, we have analysed various bus stations artefacts. In Figure 62, four products are illustrated: Carya, Scilla, Lilium and Scilla-embossed. These artefacts are part of the portfolio of Neri, an Italian company that was founded in 1962 and has launched classic and contemporary pieces of street furniture for various contexts worldwide. This was one of the companies used as a reference to explore the proportions of existing products in the market.

We concluded that to better equip the smart cities of the future, city restrictions should be followed. Combining these with our own technological requirements, we obtained a set of dimensions, as illustrated in figure 63:

• The Loop smart pole family should offer four different heights, namely: 3000 mm, 5400mm, 7400mm and 10400mm. The luminaire should measure approximately 1400mm in length and was designed to fit the three highest pole versions proposed. The product architecture of the smaller pole differs in measurements due to the different nature of the requirements for this product. Namely it should house fewer technological components in order to prevent vandalism and minimise disruption in the urban spaces where it is to be placed, namely parks.

• In the Loop Smart Bus Station family, it was determined that the users' hut area should not be taller than 2600 mm. Nevertheless, it was assumed that this product would be taller than existing commonly used solutions, in order to be able to house different technologies with specific restrictions. We have also used

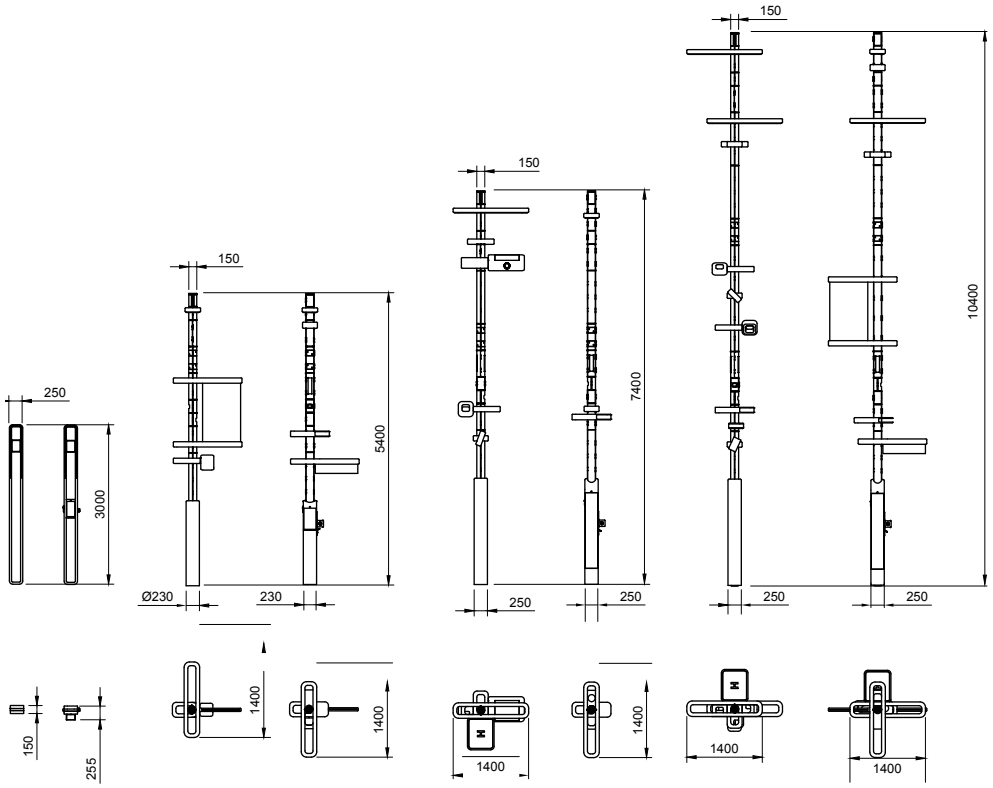
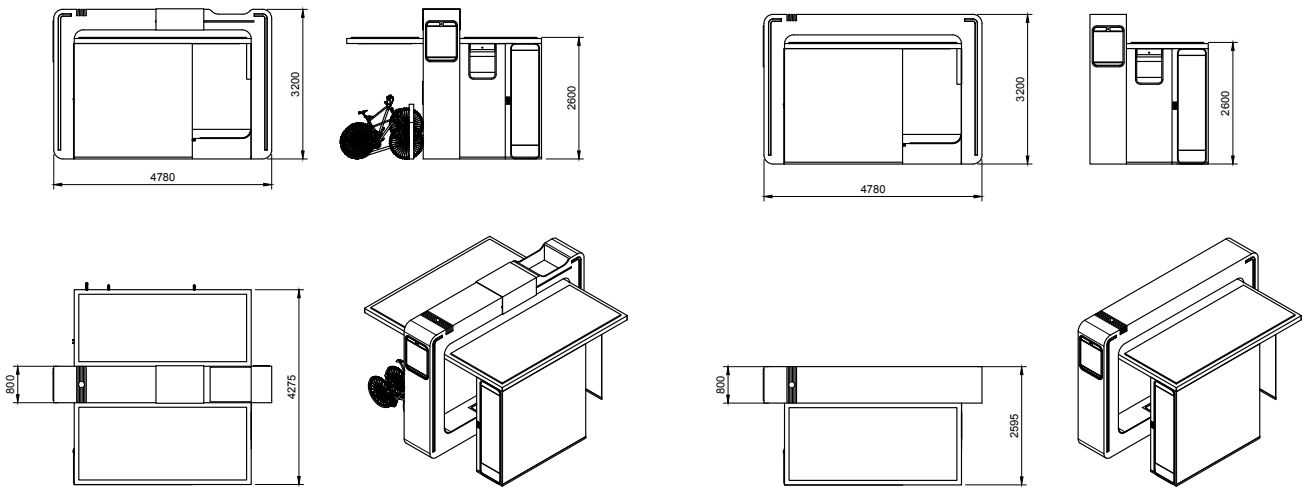


fig.63: Loop Smart Pole family, technical drawings.

the Loop arc to extend the space for that integration. For example, we have embedded the drone docking station into this structure. It should be emphasised that the characteristics of the bus station artefacts vary enormously in the urban context. However, it should be highlighted that the Loop bus station is relatively narrow: 2595mm (in the Linear Smart Bus Station). This dimension was defined after rethinking the flow of the exit and entrance of the infrastructure, based on its functionality and accessibility. With this proposal we have aimed to offer a better experience to its users. The length of the Smart Hybrid Commuting Station is 4275mm because it integrates a bike stand charging module on the back structure of the bus station.

In conclusion, the mission of industrial design has traditionally supported engineering and marketing by improving the look and feel of a product. Designers have always conveyed simplicity, or beauty into their products. Nevertheless, in this project we aimed to extend the parameters of design in terms of product's usability. The term "usability", in the design field, means to cover several dimensions of people's

fig.64: Loop Smart Bus Station family technical drawings.



interactions with products. On the other hand, in conventional design, usability largely concerns ergonomics. In the Loop collection we have employed user-centred design, going beyond that traditional definition to embrace the cognitive and emotional aspects of using and interacting with a product. Based on this user-centered design we try to understand those interactions and translate our understanding into a product's form in the Loop collection. To that end, we have observed and ideated how people use or could use the existing products, in order to propose a more comprehensive and user-friendly solution (March, 1994). These methodologies were applied in all the products of the Loop collection.

Product development and technology integration.

"How did we reach the point where our technology is more important than people? And most importantly, how can we reverse this trend in order to ensure that our technologies are designed with people in mind, more humane, more collaborative, and more beneficial to the needs of people, societies, and humanity. To me, these are some of the foremost issues facing the world" Norman (2018).

Professor Donald A Norman emphasises the necessity of keeping people at the core of any design, in order to answer to the needs of the real world. Therefore, the Smart Urban Furniture concept is designed to target human driven solutions that can be enhanced by the use of novel technologies. In other words, we are countering the technology-centred approach. Currently some technology entities offer solutions that require people to perform certain tasks. These tasks might force people to work on the technology's terms, often resulting in mistakes or error performance, often named as "Human error". From the Smart Urban Furniture perspective these are not considered human errors but, instead, inappropriate design (Norman, 2018).Therefore, we center the human as our priority and use technology to serve the user's needs.

Therefore, we center the human as our priority and use technology to serve the user's needs. This human-centric core of our concept calls for collaborative innovation in the technological and product development fields. This dual innovation approach produces new challenges, such as managing dependencies, and generates new opportunities, such as streamlining development. Therefore, this could inspire unprecedented solutions that would be based on transferring and sharing technology among different industrial sectors, which could create different partnerships. Cooperation between various companies and across industries will become the "new normal" in product design, in the Smart City context (Bitzer et al., 2014).

These product solutions should then equip the city with the right technology to provide city services. For that purpose we try to blend the physical and virtual worlds together, and provide the complete Smart City ecosystem, through the integration of technology in the Smart Urban Furniture collection. It is important to emphasise that technology keeps evolving at a fast-paced rhythm and therefore new infrastructure should be future-proof and able to be updated to profit from those advances.
The Loop collection integrates this technology in a minimum viable product (MVP) manner. The Loop products were ideated to provide the enough features that could be used in the urban context in order to be able to generate various services that integrate the smart city ecosystem.

The Loop collection integrates this technology in a minimum viable product (MVP) manner. The Loop products were designed to provide enough features that could be used in the urban context in order to be able to generate various services that generate the Smart City ecosystem. Technological integration was used to generate concepts, spark discussions and provide feedback from potential stakeholders that

could be considered for future product development. The selection of the technology was first based on the components used by the LuxTurrim 5G consortium, in the current Smart Poles pilot, and, secondly, on the expansion of services that our Smart City ecosystem proposes to contribute to the urban fabric. Therefore, the technology that was integrated in all the Loop collection products was divided into eight main clusters, namely: Environment, Navigation, Energy supply and management, Surveillance, Lightning, Safety, Communication and interaction. Each cluster lists some of the components that were considered in every artefact, which are listed in Figure 65, below:

fig.65: Technology clusters and components integrated in the Smart Urban Furniture

In conclusion, the technology integrated in the Loop collection products drives continuous product development and introduces new services that expand the impact of the Smart City network. Purpose drives technology. The Loop collection's purpose is to enhance citizens quality of life and equip the cities of the future with a novel service ecosystem.

Material definition.

The merging of creative industrial design and technical design results in successful products. The fusion of these two fields creates the character of the product, since it processes the way the material is used to provide functionality, usability and satisfaction. When these 3 layers of complexity are considered we generate more than a good design, we produce an excellent design that provides pleasure (Ashby et al., 2003). Pleasure derives from form, colour, texture, feel and the perceptions of haptic stimuli of the material selected. Therefore, the sensorial qualities of materials influence whether the product provides adequate functionality, usability or gives a pleasant emotional experience and promotes satisfaction.

We have embraced this approach in the Loop collection. Materials play an important role in these artefacts. On the one hand, functionality is highly dependent on the choices of material and manufacturing process to fulfil technical requirements of the design, economically and safely. On the other hand, usability is highly linked with the visual and tactile characteristics of materials. Therefore the aesthetics, associations, and perceptions of the product are strongly influenced by the choice of the material.

It should be emphasised that the scope of this project consisted of the conceptualisation of the Smart Urban Furniture artefacts, without contemplating an advanced manufacturing phase. Therefore, material definition was not exhaustive, and merely hypothetical. Nonetheless, we to incorporate some functional parameters from the outset of this conceptual study by considering some initial manufacturing criteria, namely:

- Basic performance requirements.
- Reliability, quality, and durability requirements
- Cost requirements
- Manufacturing and assembly requirements
- Government regulations
- Sustainability requirements

Additionally, designing for a collection of products required first the construction and definition of a basic material pallet that would also contribute to the cohesive language of the Loop collection. This material palette should be easily adjustable to different instances or contexts and applied in different product architectures. Additionally, this material selection should perform well in different urban contexts with different weather conditions. Besides this criteria, electrical materials were also reviewed in order to guarantee the functionalities of the integrated technologies. Therefore, the materials should minimally attenuate the electromagnetic signal received by antennas, and be transparent to radio waves. For this reason we have used radome components in some modules in the smart urban artefacts.

Figure 66 illustrates the core materials considered for all of the artefacts in the Loop collection. This visualisation also lists the benefits of each material selection, and some examples of where those materials were applied or implemented.

Galvanised steel with black or dark grey powder coating.

WHY?

The combination of this treatment and finishing guarantees a cost efficient solution, resilient to weather conditions, rust resistant, highly durable and aesthetically appealing.

WHERE?

- Smart Bus station roof
- Smart Pole core segment structure
- Smart Pole segment lids
- Bike stand charging module
- Smart Trash can deposit

Light weight concrete, reinforced with steel and varnish finishing.

Concrete mixed with Leca, an expanded clay aggregate.

WHY?

The combination of concrete with “Leca”, reinforced with steel, will provide a lightweight solution, resistant to various weather conditions, that is easy to manufacture, cost efficient and aesthetically appealing.

WHERE?

- Every Loop arc product (collection motif)

Solid surface (deep anthracite finishing) with a steel structure reinforcement.

WHY?

This material provides a high quality finish, good resistance to weather conditions and thermal variations, scratch-resistant, graffiti resistant, UV resilient, fireproof and aesthetically appealing. The inner steel structure provides a stable infrastructure for technology integration.

WHERE?

- Smart Bench seating
- Smart Hub outdoor structure

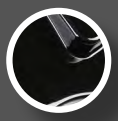
Laminated and tempered glass, frosted or transparent.

WHY?

Laminated glass provides: increased security and safety, since the glass does not shatter when broken, additionally it increases protection in natural disasters. The Loop collection includes frosted or transparent glass depending on the specific product architecture and component.

WHERE?

- Smart Bus Station windows
- Smart Hub windows
- Drone landing station (frost)



High density polyethylene, glossy black finishing (or other colour finishings)

WHY?

This material is highly resistant to corrosion and weather conditions and thermal variations, it is an insulator for electric components, recyclable and cost efficient.

WHERE?

- Tech surfaces (AC plugs, wireless chargers, etc)
- Modules and buttons

Opaque white oak, exterior varnish finishing.

Use of opaque white oak deck for floor solutions.

WHY?

Opaque White oak produces fine lumber and appealing aesthetics. It is a good outdoor wood, since its cellular structure is impermeable to liquids and resistant to decay.

WHERE?

- Smart Bus Station seating area
- Smart Hub Floor
- Green wall concept

fig.66: Loop collection material palette.

The previous illustration made it possible to visualise the general use of materials in the Loop collection. Some of the material uses and applications in the Smart Pole and Smart Bus Station, but also on other products that constitute the Loop collection will be further introduced in the coming section.

The Loop collection denotes a minimal approach in the selection of materials and in the adopted pallet of colours. In this project minimalism does not contribute to build a “clean or sterile” environment, but it contributes to nurture the citizen’s physical and emotional needs, by facilitating their interaction with the urban environment. Cities are becoming more cluttered, so the Loop collection aims to reduce the urban noise by promoting the use of smooth materials that balance their shapes and attributes. The fluid cool shape of the concrete Loop arc is balanced with organic and detailed use of wood in other components. The selection of materials contributes to balance the use of forms and textures, creating sensible aesthetics that can promote serenity and harmony in the urban context. In conclusion, the design challenge no longer lays in meeting the functional requirements alone, but in doing so in a way that also satisfies the aesthetic and emotional needs (Ashby et al., 2003).

4.3 Phase III: Product family expansion.

The Smart Urban Furniture concept, as demonstrated by Loop collection, integrates technology in the public realm. These artefacts contribute to the development of urban fabric. In other words, our aim is to bring novel solutions to furnish the future of smart cities.

The Loop collection integrates different products that better fit the cities’ various requirements, and support different services of the Smart City ecosystem. In Phase I of this chapter we have introduced the theme and motif of this collection that conveyed a minimalism based on clean aesthetics, but also on inherent values, aiming to reduce the urban clutter and enhance the user experience. Secondly, we have reviewed in Phase II the methodologies and design processes used to develop our urban solutions, more specifically the Smart Urban Pole, Smart Bus Station and respective product variants. In that section we also reviewed the design process from the formal exploration to the final solutions. We introduced the product architecture and dimension analysis based on existing products in the market. A materials and technology review was also carried out, which is not only applicable to the two products that were discussed but in all of the artefacts of the collection. All the products developed in the Loop collection have followed the same methodologies and design process. Due to the extension of this research work and deliverables, the design procedure documentation of the remaining products will not be as exhaustive as the previously introduced products. The introduction to the remaining three products will only target their conceptualisation and functionalities. The products that will be introduced in the coming pages are the following:

- Smart Bench
- Smart Hub
- Smart Trash can

fig.67: Loop Product Family.

4.3.1 Smart Bench

Benches are one of the most common elements that can be found in the urban landscape. These artefacts are often seen in central areas of urban settlements, such as green areas, major squares, and areas with significant pedestrian presence. These products are commonly provided by the local authorities and positioned by urban planners to serve as a resting place, or to support points of social interest such as playgrounds, historical references, or viewpoints.

After analysing the common uses of this product we quickly understood its potential to include features that could enhance the Smart City service ecosystem. Therefore the Loop Collection has embraced this idea and conceptualised the Smart Bench as a potential space for resting and recharging. The bench is also seen as a resting point or gathering area for social engagement, and mostly a link to education and communication. This product was designed to support citizens in different manners, specially by providing different infrastructures that can enlarge the offer of smart services and launch a new platform for interconnected systems.

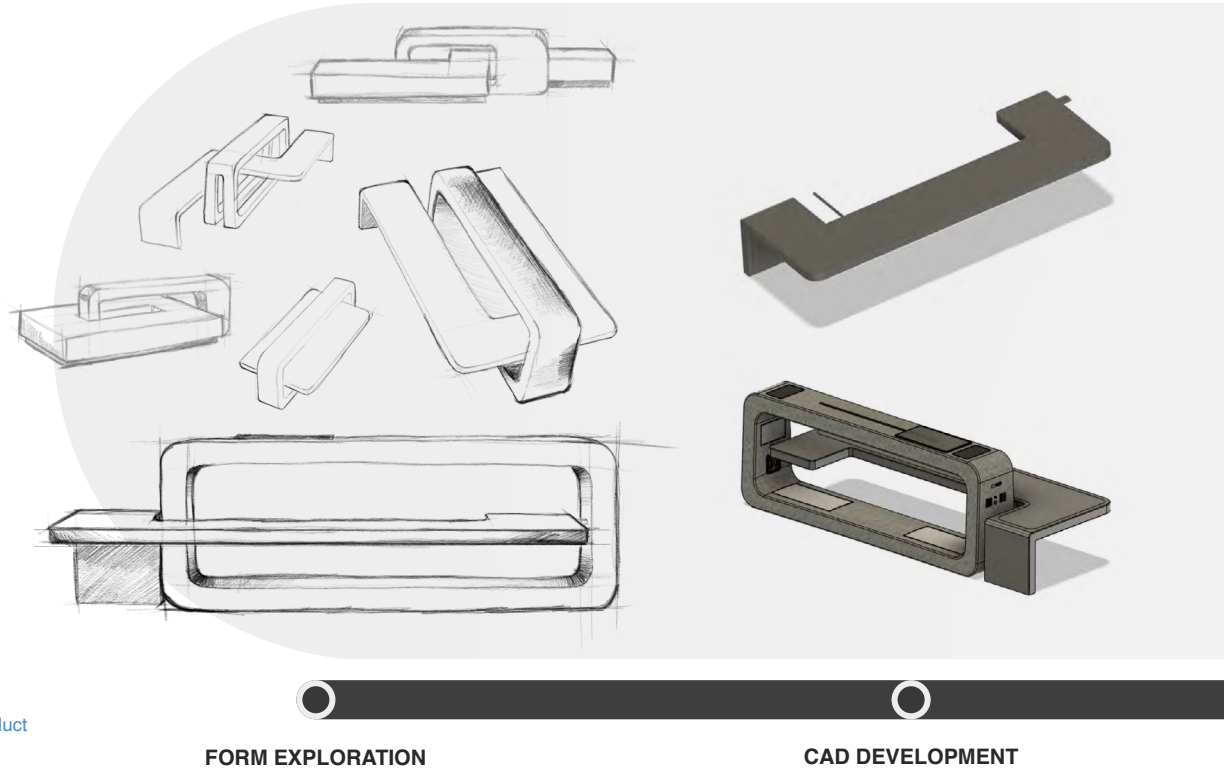


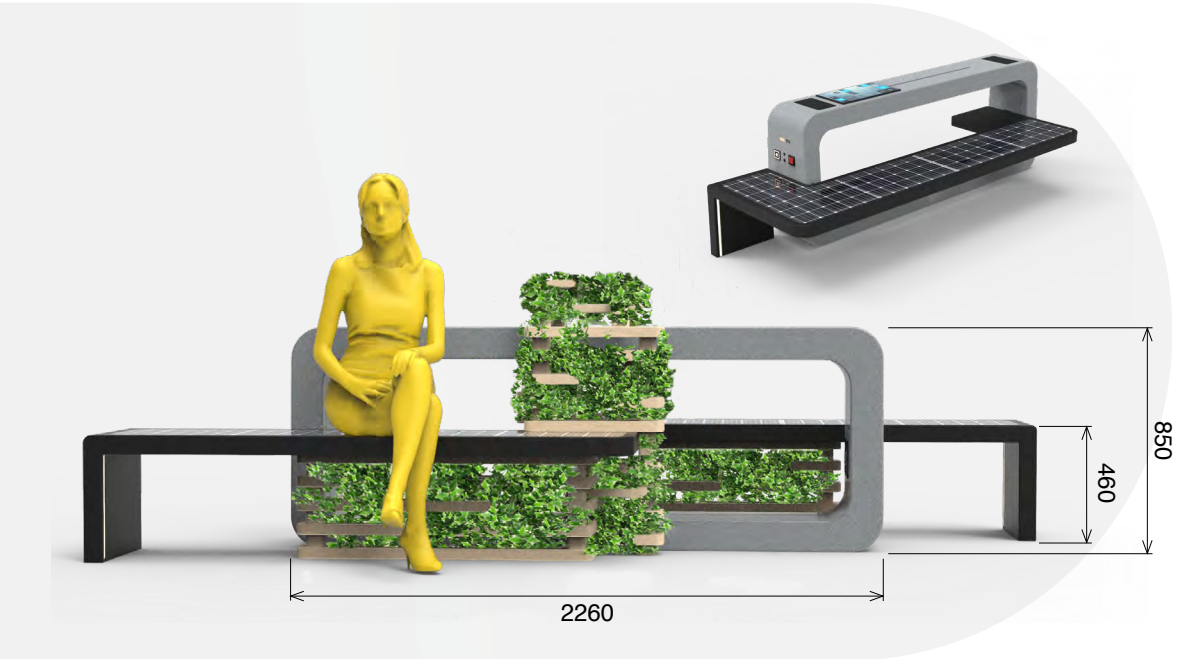
fig.68: Loop Smart Bench product development timeframe.

Figure 68 illustrates the smart bench development phase from the formal exploration towards final product architecture, including the 3D CAD development as an intermediate step of the design process. In the formal exploration various drafts and sketches were produced in order to enhance the product's aesthetics and functionality. The collection's motif was explored in this context as a seat backrest that can serve simultaneously as a working table. Therefore, this artefact merges two product concepts and can serve different scenarios of product usability, as bench or bench and table interactive space. Additionally the Loop motif follows the same usability pattern used in the Smart Bus Station, since it is used for the structural integrity of the product, with the seating area attached to the motif arc and seeming to hover in the air. Mostly, the Loop arc hosts the majority of technical components,

providing a space with protection against electromagnetic interference and allowing for easy cabling installation. The Loop collection Smart Bench is focused around a concrete loop that serves as a core structure that integrates technology modules.

The final architecture provides a versatile and coherent product line that can fit different city zones. This product can be customised on two levels: in its physical form, and in its service provision. In consequence, this product family conveys three variants of seat morphologies and three levels of technological products to support services. These nine options can be implemented depending on the characteristics of the urban area but also the influence of pedestrians in those public spaces.

Additionally, the product line can be customised based on the service requirements. From the services point of view, the Smart Bench family provides different levels of technological integration and therefore offers different levels of embedded smartness to the Smart City. Designing for a Smart City, and creating an urban fabric, does not simply mean to integrate IoT solutions and tech components in every object. That is why the Loop Collection seeks to prevent the cluttering of the fragile urban space,



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by offering modular features that are specifically required for the city, and not always the complete set of technological services and infrastructures.

The Smart Bench family final architecture is illustrated in Figure 69. Each row shows the bench final products and their variants, based on the seating options that can be attached to the Loop arc. Furthermore each row also contains three illustrations that represent not only infrastructural variants of the product, but also contemplate their service provision which can be a relevant part of the smart city ecosystem. The three categories of products offer different solutions based on the seating morphology:

• **Base Seat.** Targeted for narrow urban spaces and designed with conscious proportions, in order to fit in reduced space. It has been designed to replace the most conventional benches, nevertheless offering two functionalities: bench or bench and table.

• **2Side Seat.** Targeted for two sided roads, places with more pedestrian presence or social gathering points. It can enhance social engagement, since it provides the infrastructure for a traditional bench or table. The users can face each other, while interacting with the product.

• **4Table.** Targeted for large public spaces, such as green areas or main squares, places with more pedestrian presence. A two-sided bench with both sides oriented towards the central table, the bench format enhances social cohesion, and strengthens communal activities in the public space.

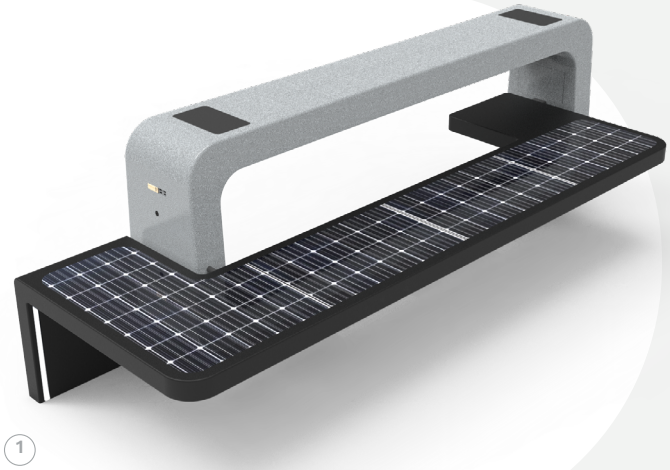
All of the products mentioned above can be used as traditional resting area furniture for social engagement and also as convenient small workstations. The Loop Smart Bench product line provides different packages of interlinked services that will be further detailed in this section. All these services include charging features, ensuring good usability not only for community outreach, but opening the possibility of “working on the go” and rethinking the borders of traditional offices. Moreover, these products can be used to enhance public participation and feature leisure and entertainment activities, among other services. With this approach the Loop collection has generated three variants targeted to provide different services, namely:

• **Linear (1).** Provides the city with a smart infrastructure that is not corrosive to the urban space and offers a balance between the analytical and digital content necessary to furnish the future of smart cities. The smart bench can be used as a hybrid reference, collecting relevant information for city services optimisation and providing just enough services such as charging, high-speed internet connectivity, environmental sensing and lightning.

• **Smart+ (2).** Sets a new boundary and reinterpretation of the bench as a concept. It should be applied in a cautious way to preserve the city’s identity and maintain a balanced level of digitalisation in public spaces. It proposes the bench as a major contributor for smart city services. Besides the services offered by the Linear bench, it can also be used for improving urban safety, as a quick response to emergencies and to increase cultural engagement. Through the use of a sliding screen mechanism, it can link citizens with the city’s service platform and promote cultural content and social activities.

• **Urban Green (3).** This is a product committed to environmental sustainability, that points towards a more eco-friendly urban environment, in order to enhance citizens’ quality of life and environmental impact. It offers modules that can be added to the benches, in order to purify the air, suppress dust, reduce noise and heat, and increase biodiversity. The product was designed to bring green to the core of urban spaces.

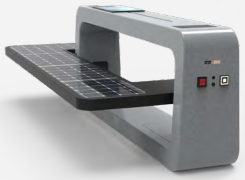
The Loop Smart Bench family described above provides the city with the possibility of updating the benches according to the city’s needs since all the products core tech components are embedded in the Loop motif. In other words, the city can place first Linear benches and update those to Smart+ or Urban Green according to the city and citizens’ needs. Therefore, our collection evolves organically with the city. The Loop Smart Bench product line aims to boost the interaction of citizens with public spaces.



1

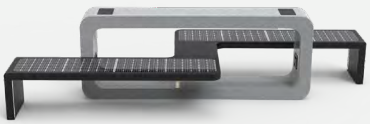
Base Seat

3



2

2



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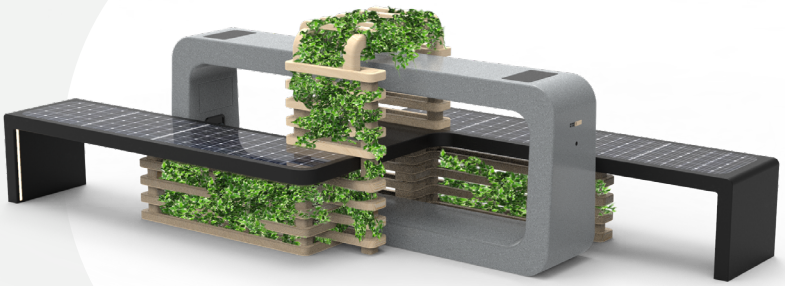


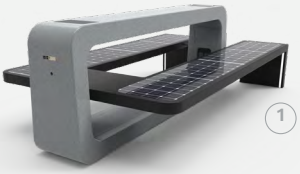
3

2Side Seat

2

4 Table

3



1

fig.69: Loop collection,
Smart Bench solutions.

4.3.2 Smart Hub

A Smart City is not only about the optimisation of resources and the enhancement of city service efficiency. Instead, the smart city is about citizen engagement and the improvement of services and experiences. Digitalisation can be seen as a tool to improve social participation and avoid social exclusion in various ways. Therefore, Smart Cities that place their citizens in the urban core can serve as a vehicle for social change and positive sustainable impact. The governance of those cities should address important social challenges and ensure digital inclusion in new forms of public participation. The role of physical “third places”, neither home nor work, can be used to promote knowledge exchange and new digital skill development.

Consequently, engagement needs to go beyond simply listening to citizens and implies co-constructing public policies with citizens (OECD, 2020g). In order to involve citizens in the process of digitalisation and making the cities smart, a space where citizens can experience the city smartness first hand and explore its

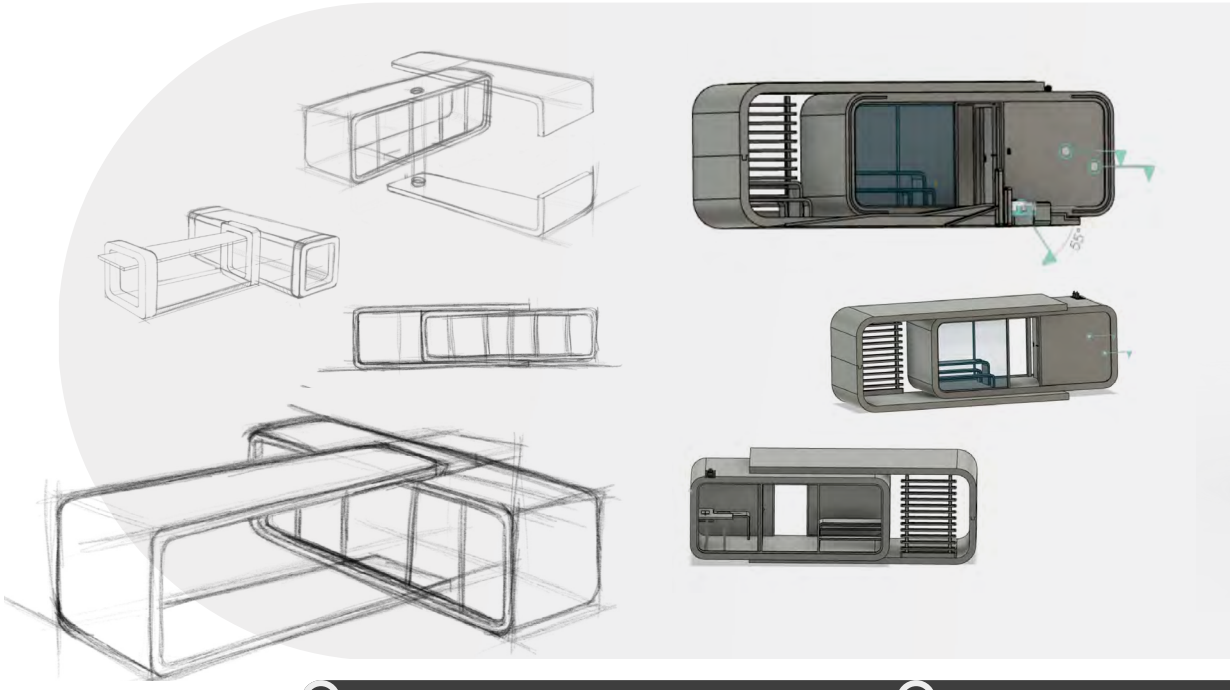


fig.70: Loop Smart Hub product development timeframe.

benefits should be created. With this approach citizens and cities can grow and flourish simultaneously, advancing side by side with the fast pace of technological development. The city is accountable for providing a public space or infrastructure that can be used to raise awareness and promote understanding of the benefits of novel, high-tech, solutions. Innovation, unfortunately, is not always visible to the city end-user and, for that purpose, we should enable experiences and opportunities for the citizen to get familiar with current digital reality and the importance of the Smart City cause.

In order to generate a “third space”, designed for people, the Smart Hub concept was included as one of the artefacts of the Smart Urban Furniture collection. The Smart Hub is a common area equipped with IoT and novel technologies available to be experienced. Figure 70 visualises the design process undertaken to achieve the final architecture of the Smart Hub product of the Loop collection. We recognised that this

public environment should be modular and easy to transport and assemble at an early stage. Therefore, it was designed with the premise that it should start by a base hub module with reduced dimensions from which more than one can be assembled in order to create larger areas. The base module should have the standard sizes of a shipping container (20ft) in order to guarantee a quick and efficient response for new deployment. With this strategy it would be possible to reduce manufacturing and transportation costs and, in consequence, the implementation price.

These products should be remarkably versatile in order to provide different concept-based services required by the city and its citizens. This concept was then expanded, giving rise to highly connected spaces and making it possible to identify four specific uses that could enhance social engagement and promote a new digital commitment, namely:

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• Community hub: a space designed for the local community as an engagement area, able to host various events promoted by the community and/or the city. It should encourage civic participation, workshops and exhibitions, thus being designed to be the “public living room” of various urban zones, integrating decentralised municipality services, such as small medical stations, to improve citizens’ urban experience. In this context the integration of embedded technology can be used for socially committed purposes.

• Urban green hub: a space to promote multi-faceted collaborative farming in the urban context. This concept contributes to “greening” the city, reducing air pollution and encouraging localised food production, an effective way to reduce the environmental impact of agriculture. Mostly, it contributes to social co-creation and engagement, therefore promoting healthy communities through urban farming and gardening activities.

• Workstation hub: a space that extends the borders of any traditional office, providing an efficient and smart workspace, where users can perform individual or collaborative work. It was designed to embed the opportunity of working in parks or outdoors in campus areas, in order to encourage the use of public spaces. This innovative workstation provides the user with sophisticated solutions and embedded technology to enhance the urban work experience. It extends the possibility of working on the go in the urban context.

• Commercial hub: a space designed for private or public businesses and entities to display products, exhibitions, and other possible services. This smart popup facility provides citizens with a chance to test new concepts and services that can in the future be implemented on a larger scale. On the other hand, it offers an opportunity to seek feedback from real end-users. The LuxTurrim5G consortium could use this concept to obtain citizens' assessment of the Smart Urban Furniture collection, and based on the results, plan the implementation of the product.

The Loop collection Smart Hub shown in this section's figures is the Smart Workstation Hub, but it could be easily adjusted to interpret any of the concepts above explored. The Workstation Hub provides two working areas, designed for collaborative work and featuring different services to enhance the work experience of users, including a hybrid meeting room (remote and on-site), recreational spaces, improved connectivity and other IoT based services.

fig.71: Smart Hub customisability.

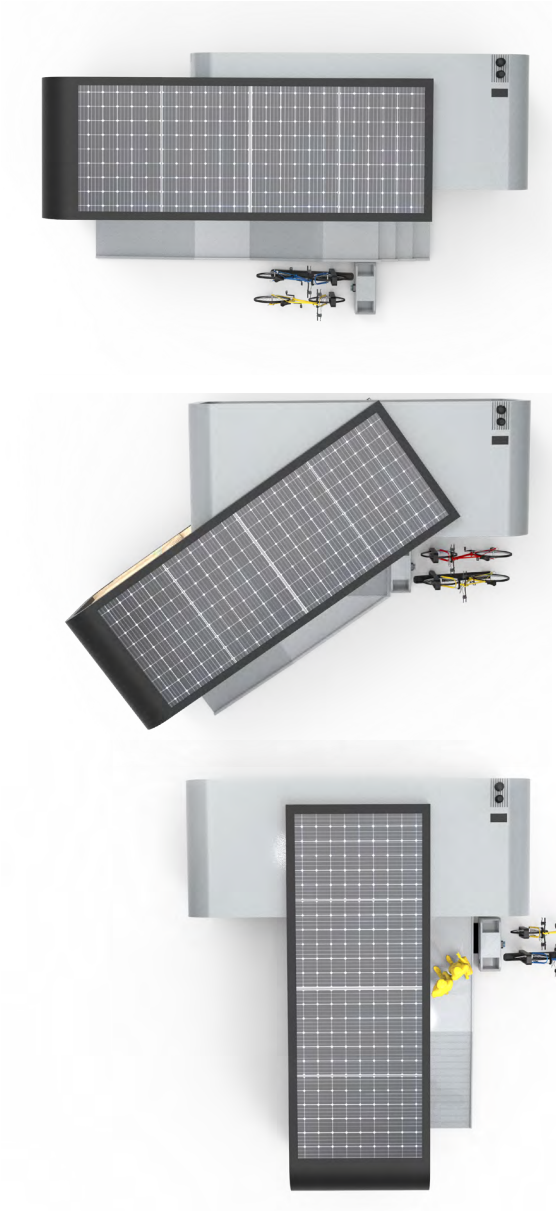


Figure 71 demonstrates the customisability of the product, since the Loop arc, used for the hub entrance and outdoor area, can be easily tailored to the specificities of the urban zone where it will be deployed. This versatility allows the product to be easily placed in any city area. Additionally, it is possible to assemble more than one hub module to enlarge this novel concept space. Those solutions are illustrated in Figure 72, and can also be customised to provide a rooftop area and/or an energy harvesting space.

The digital revolution in cities is providing new windows of unprecedented opportunities that can enhance the lives of citizens today and tomorrow. Nevertheless, there is no guarantee that the rapid diffusion of digitalisation will automatically benefit, or be perceived as benefiting, citizens across the urban fabric. Therefore, there is a clear need to guarantee that the use of these technologies will promote social inclusion and not the opposite. To do so the Loop collection offers the Smart Hub concept as the physical infrastructure and place that can enhance knowledge exchange of the Smart City transformation and drive improvements across the economic, social, cultural, and ecological dimensions, leveraging the social and cultural impact introduced by digitalisation as an intrinsic part of the urban fabric, ultimately enhancing citizens quality of life. (OECD, 2020g).

fig.72: Loop collection,
Smart Hub solutions.

2.3.1 Smart Trash Can

fig.73: Binology Trash Can.

fig.74: BigBelly Trash Can.

Appropriate waste management is essential to urban sustainability. Nonetheless, this operation is still not an easy task for most cities. Pekka Vikkula the project director from the Kera Area in Espoo, a Smart City pilot area in Finland, emphasised an interest in integrating a Smart Trash Can in the ecosystem of smart urban furniture, due to its impact on the city's efficiency. Vikkula highlighted that waste management can comprise significant costs. Therefore, the integration of this service system in our infrastructures could contribute to better operations of essential municipal services and spare numerous resources. Therefore, the integration of IoT technology in Smart Trash Cans can significantly contribute towards the optimisation of the general services provided in the Smart City platform and service collection, reducing operational costs. With this approach, we have designed the Smart Trash Can to replace outdated waste management infrastructure, integrating the new devices into data-driven collection processes.

fig.75: Loop Smart Trash Can product development timeframe.

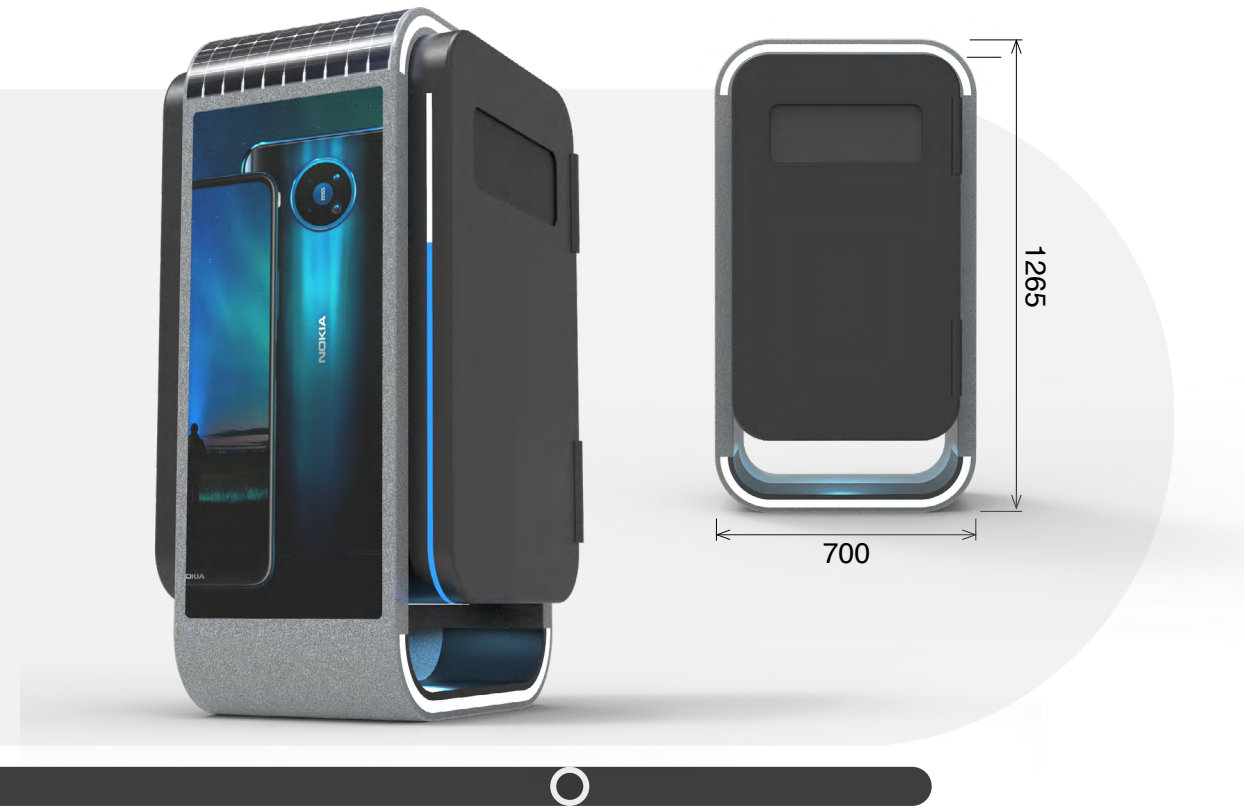
A Smart Trash Can is not a brand new concept, there are already good solutions in the market. Our team has identified best practices, namely Binology and Bigbelly, among many others. These are illustrated in Figures 73 and 74. The Smart Trash Can of the Smart Urban Furniture Loop collection has similar features to the existing products in the market but integrates these products in an interconnected platform and network of products and services. Therefore, it is not a standalone solution.

Figure 75 represents the design process from formal exploration to the final architecture. Starting by illustrating different ideations regarding this product and the final solution that embraces the Loop motif, we arrived at an element that portrays the essence of the Loop collection but also brings structural integrity to the product. The motif is also used for the integration of a side screen and a solar panel to harvest energy for the artefact's functioning. Our Smart Trash Can is divided into 2 variants that feature different levels of embedded technology and/or "smartness", providing customised solutions for the city's needs:

• Linear: features just enough services to effectively optimise the city waste management. It collects relevant data for city operation optimisation and provides services such as: energy harvesting, bin capacity tracing, lighting, and basic emergency detection (such as fire).

• Smart+: the most equipped variant, it provides a more complete set of services to the city's operational service. It equips the urban fabric and the city management entity with three more features than the Linear variant, namely: built-in compactor for higher capacity, enlarged safety features, interactive interfaces for advertisement or educational purposes.

fig.76: Smart Trash Can and human scale.



FINAL PRODUCT ARCHITECTURE

Besides the features provided, the Loop trash can was designed targeting human interaction. Therefore, both variants offer an intuitive capacity line on the side of the main trash can. With this detail the user is visually aware of how full the garbage container is, and can therefore act accordingly. In other words, the user is conscious of the bin status and can seek another trash can in case the closest one is already full. Nevertheless, it is important to emphasise that one of the product variants, without enlargement, offers additional capacity, thanks to its internal compactor. Figure 77 shows the internal structure of this bin with the frontal access door open. Another innovative feature came from the reinterpretation of a traditional pressure pedal, improving the user interaction. Under the trash can deposit a clean surface illuminated by a blue light is visible. This space is equipped with proximity and movement sensors that can detect when the user places a foot there. Upon detection, the light blinks in order to provide feedback and opens the lid for the deposit. With the Loop Trash Can we aim to keep the future efficient, sustainable, healthy and clean.

fig.77: Smart Trash Can internal structure

4.3 Smart bus station prototype

"If a picture is worth 1000 words, a prototype is worth 1000 meetings.—saying at @ ideo" Maeda (2014).

Apart from being a fantastic tool to motivate a team and convey efficient communication between various parties, the production of a prototype can be used to prove a product concept and some of its basic functionalities. Additionally, having physical access to a product prototype, materialising the idea, can be a beneficial tool to demonstrate and validate a preliminary level of user interaction. These methodologies also open a preliminary manufacturing phase, since this process gives the opportunity to have a detailed look into the core architecture of the products, and to define future improvements. Prototype development expands the level of experimentation and concept assessment, since it analyses basic user interactions and identifies architectural issues. Therefore, prototyping can be seen as an effective way to test the concept and define enhancements.

Our research team has embraced the prototyping phase in order to test our designs, introducing a preliminary manufacturing analysis and examining user interaction with the final concepts. The research team developed, collaboratively, three prototypes in real scale that refer to different smart urban furniture collections, namely:

- A Smart Pole
- A Smart Bench
- A Smart Bus Station

The Smart Bench and Smart Pole prototypes were extremely valuable to prove the concept and impact of the products. Furthermore those were used to demonstrate the interconnectivity of the Smart Urban furniture concept as an ecosystem of smart product solutions. Nevertheless, these two prototypes are out of the scope of this research and will not be further explored.

The Linear Bus Station is part of the Loop collection and was developed during a one year period. The correspondent prototype construction took approximately one month. It should be emphasised that the period of prototyping did overlap with the construction of the other products, and therefore it is difficult to allocate an exact duration estimate for the production of this specific prototype. In terms of resources we have spent approximately 9000 euros in all the materials, components and features used in the construction of this prototype. Having said that, it should be emphasised that this prototype is not a high fidelity model since it does not reflect the final manufacturing and production methods. Therefore, it does not use the final construction materials, due to the complexity of that construction and ambitious timeline of the project. So, this medium fidelity prototype was assembled based on a combination of wood work and metal work.

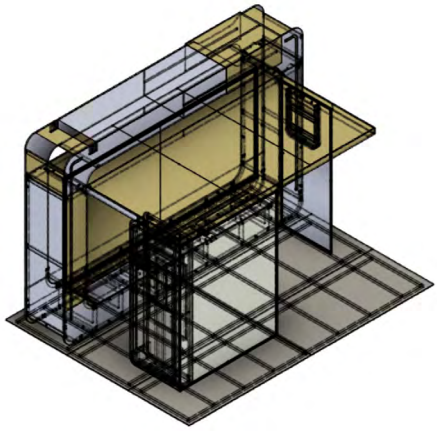


fig.78: Prototype CAD development.

The structure of the Loop Bus Station can be divided into these manufacturing blocks: 3 parts of the structural ring, 2 bases, 1 roof, 1 terminal and 2 window panels. In order to produce these blocks, and the final assembly of the prototype, we have divided the construction phase into six main sections, namely:

• **CAD Development.** This phase was extremely relevant since it defined all the processes and the manufacture line of the prototype. It was developed collaboratively and therefore it used two software applications for its exploration, namely Autodesk Fusion 360 and Solid-works. At this stage, all the restrictions of the final assembly were considered, including material behaviour, structural integrity and tech integration. It should be emphasised that this phase of the project was highly demanding and challenging, due to the

nature of the materials selected for prototyping and the complexity of the real scale product, resulting in an assembly with more than one hundred components. The CAD development phase is illustrated in Figure 78.

• **CNC machining**. This manufacturing process was used as the main tool to obtain the components of the final assembly (arc structure, terminal panels and other components used in the final assembly). This machining process was selected due to its high precision, high fidelity, uniform outcome, easy scalability for large components and fast production. We were supported by the workshop master in this machining process, which helped us in this domain. At this stage we encountered some technical difficulties, notably a broken machine. In the end we were able to produce some of the last components by hand and using a secondary machine at Aalto facilities. The CNC machining process is illustrated in the figure 79.

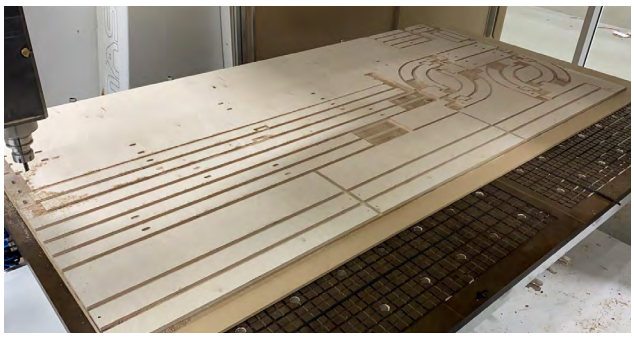


fig.79: CNC machining the prototype components.

• **Wood work and assembly.** At this stage we used the components machined by the CNC, and combined those with some parts produced manually. The material most used at this stage for the Loop structure was Birch Plywood 21 and MDF 25 (used for the terminal) or MDF 3.2 for other panels that integrate the general Loop arc and roof. Additionally, to guarantee the structural integrity of the core wood structure, we used domino joints to reinforce the connections. Finally, the main structure was assembled and glued, with a special emphasis on the core arc of the bus structure. It should be emphasised that this process was arduous and challenging due to the proportions of the components. The wood work process is illustrated in the Figures 80,81 and 82.

fig.80

fig.81

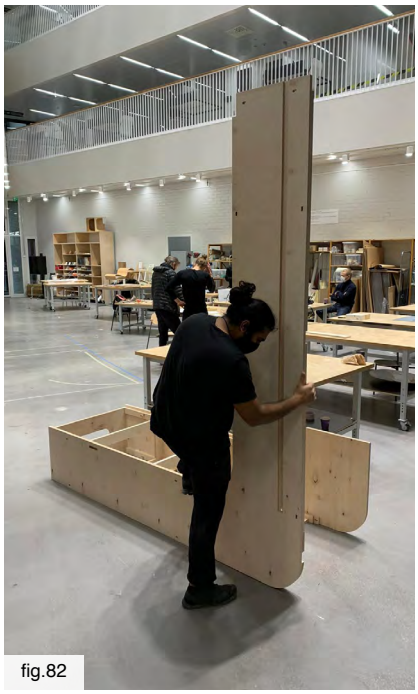


fig.82

fig.80: Wood work - gluing bench upper part and back rest.

fig.81: Wood work - assembly lower part (right side) of bus station Loop arc and bench upper part.

fig.82: Wood work - assembly Loop arc, “L” structure (right side).

• **Metal work and welding.** In this phase of the project we have produced the structure that holds the bus station terminal and roof. For this purpose we have used square steel profiles of 40x40 mm. Additionally, the Bus Station base was developed simultaneously. Both components required metal cutting and MIG/MAG welding work. This work resulted in the essential structural components of the bus station. The metal work process is illustrated in the figure 83 and 84.

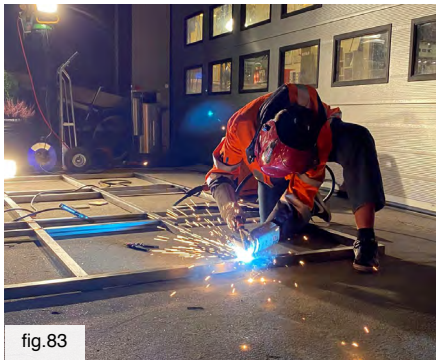


fig.83

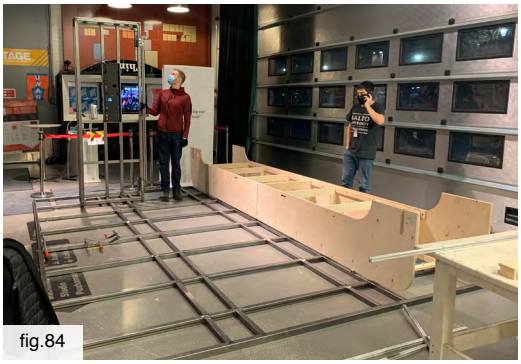


fig.84

fig.83: Bus Station base welding work.

fig.84. fig.84. Bus Station test assembly (base + terminal structure + wooden bench modules).

• **Final assembly and finishing.** At this final stage we have merged all the components, namely the 3 parts of the structural Loop ring, the two bases, the roof, the terminal and the outsourced windows. During this process we have painted and polished the main structure in order to guarantee its appealing aesthetics and to follow the identity of the Loop collection. Vigorous support from the Aalto Design Factory community helped our team in assembling the final product. The final assembly was remarkably complex and difficult due to the proportions of the components. The final assembly is illustrated from Figure 85 to 90.

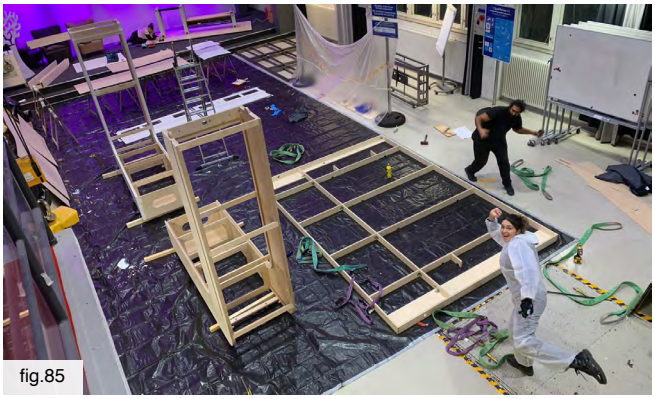


fig.85


fig.86

fig.85: Roof assembly and panels integration on the Loop arc segment.

fig.86: Painting three main sections of the Loop arcs.

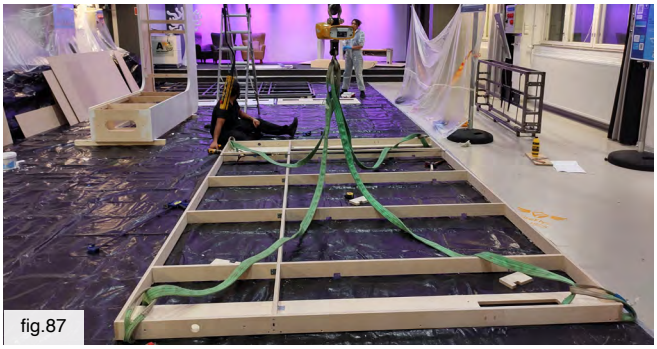


fig.87


fig.88

fig.87: Testing roof structure integrity.

fig.88: Preparation of Loop arc final assembly.

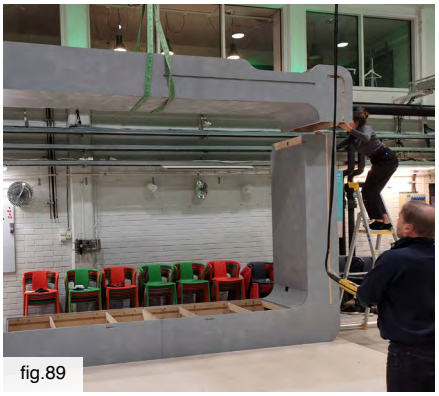


fig.89


fig.90

fig.89: Final assembly of the Bus Station Loop Arc.

fig.90: Final assembly and integration of the roof in the main bus station structure.

• **Electronics integration.** Lastly in this section we have integrated all the electronics in order to guarantee some of the functionalities that this product could offer. Namely, charging features such as USB and wireless chargers; the terminal display that includes the touchscreen that provides the HMI (Human Machine) interface to access the city platform with a very simple illustrative version of the UI; an SOS button that can notify the authorities about existing emergencies and therefore activate emergency lightning; as well as some basic lighting features in the station's hut room. It must be underlined, once more, the remarkable support at this stage of the prototype's development of the Aalto Design Factory community and the people of its Electroshop. With their support we were able to deploy our bus station functionalities.

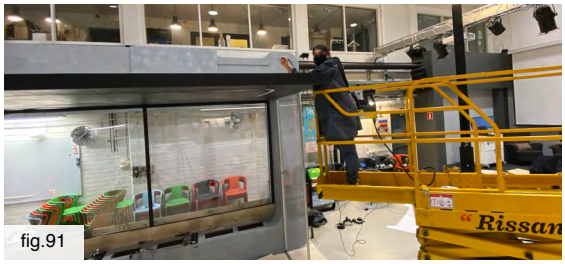


fig.91

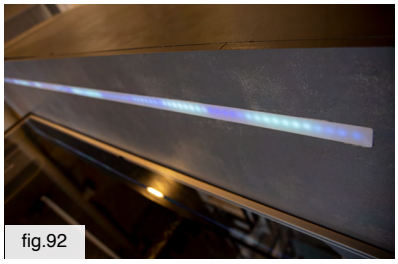


fig.92

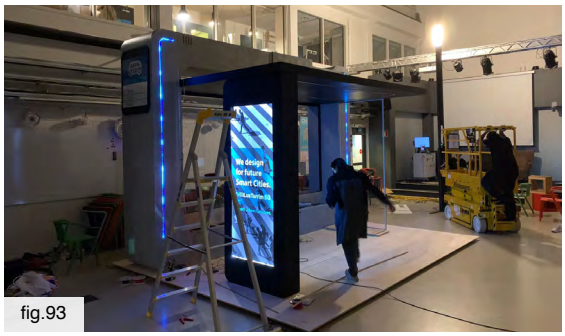


fig.93


fig.94

fig.91: Soldering electronics and LED in the bus station roof.

fig.92: Testing bus station lighting with programmed colour coding.

fig.93: Integration of terminal advertisement panel.

fig.94: Integration of wireless charger and USB chargers.

3D printing was used throughout to quickly obtain the small pieces required for internal supports, buttons, connections and similar.

Overall, the prototype construction and development was extremely challenging, due to the short timeline, the full scale proportions of the product, and the integration of low fidelity electronics that could enhance some of the functionalities of our product. Nevertheless, in the end, the final prototype had a massive impact that helped to convey the Smart Urban Furniture concept and value. The development of the Bus Station full scale prototype also helped the research team to define future works and required improvements to facilitate the manufacturing process. One of the main achievements was to see user interaction with the product that seemed intuitive and empathic and was highly valued by the consortium representatives.

fig.95: General view of final Loop Bus Station prototype.

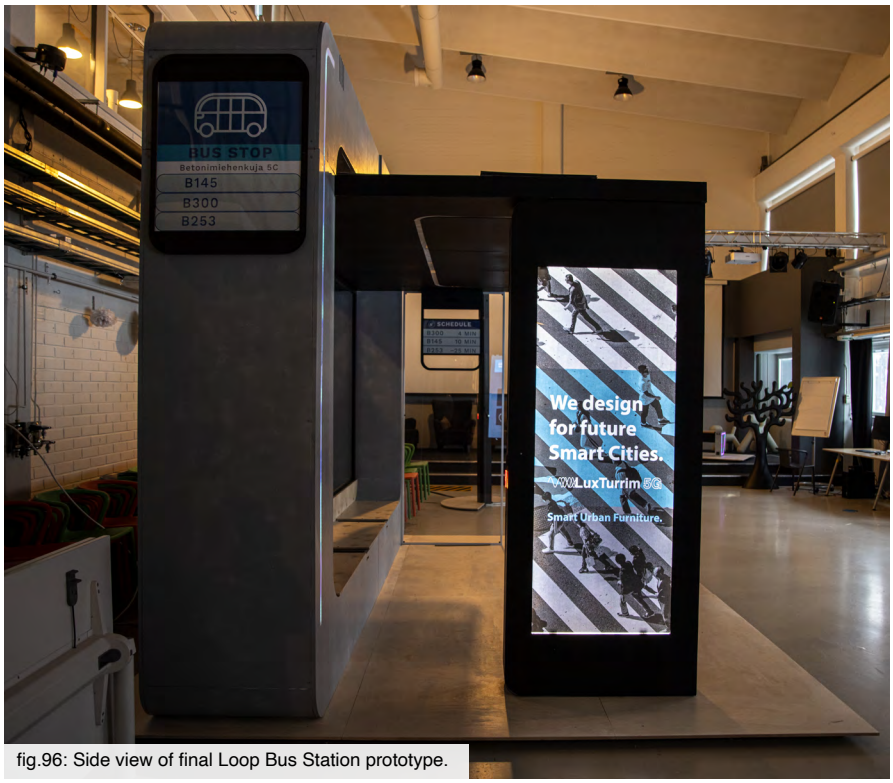


fig.96: Side view of final Loop Bus Station prototype.

fig.97: Wireless and USB chargers detailed view.

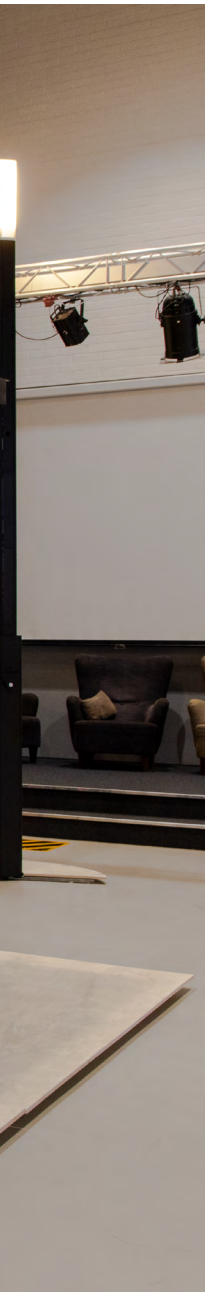


fig.98: Internal view of final Loop Bus Station prototype.

Technology, Services-Product Ecosystem

5.1 Systemic overview of Loop products.

5.1.1 Smart Pole

5.1.2 Smart Bus Station

5.1.3 Smart Bench

5.1.4 Smart Hub

5.1.5 Smart Trash Can

5.2. Impact of the Smart Urban Furniture in the urban environment

5.1 Systemic overview of Loop products.

“Superstar designers might garner the acclaim for iconic products, but much of the value they create lies in the systems that support and enable them. Products are often just the front door to these systems” Leadbeater (2013).

The fast-paced advance of technology opens the door for unprecedented innovation and for the creation of new product-platforms, and therefore systems. As noted by the author Charlie Leadbeater, designing a great product is not a guarantee of success, unless it is possible to gather around it the complementary services, software, and channels that allow consumers to use it effortlessly and effectively. Therefore, the Smart Urban Furniture concept requires a systemic understanding of city areas and urban needs as parts of local and global systems, in order to identify what services should be provided by our products. This concept urbanises technology as a process that unfolds and affects multiple levels of human behaviour, ranging from the sustainable use of resources to wellbeing outcomes. With this approach, we aim to develop a product-service system that targets social and ecological sustainability, and, ultimately, helps plan better cities. To accomplish this, we have merged material and immaterial, product and service and therefore open the door for systemic innovation. A good example of systemic innovation is Apple. This company started as a product focused company, by making computers to sit on desktops. It has since become one of the most valuable companies in the world by doing something different, namely: creating products that are entry points to systems. (Leadbeater, 2013).

Currently, various opportunities for systems innovators are being opened up by the inclusion of 5G technology in the cities. This will change the way some urban services operate and support citizens. This technology enables real-time, consistent, and reliable data with near-zero latency for wireless devices, opening a new window of opportunity to support new product-services in the urban context. Smart Urban Furniture is embracing this technological turning point to interlink the use of technology in order to answer to the growing needs of cities.

In this section we will analyse the systemic impact of the Loop collection, by briefly reviewing the service ecosystem initially introduced in this research, and the products that facilitate specific service provisions. In other words, some technologies that are integrated in the various products will be interlinked and bond with the sub-services that the infrastructure is providing to the urban environment, and/or end users. Therefore, products facilitate, and technology enhances, services. It should be emphasised that the product-service, and technological integration stressed in this concept answers to present urban needs, and those could be revised according to the fast-paced development of technology and evolving city needs.

Additionally, later in this chapter, two user scenarios that envision the impact of the smart urban furniture artefacts in the city will be analysed, targeting user interactions with the products and representing how the user might benefit from the service provided, along with the urban fabric. These short stories describe what different citizens (personas) need in different contexts, and why. These scenarios analyse the interaction of the user with the product-service and build a narrative within user-centric episodes.

5.1.1 Smart Pole.

fig.99: 3m Smart Pole services.

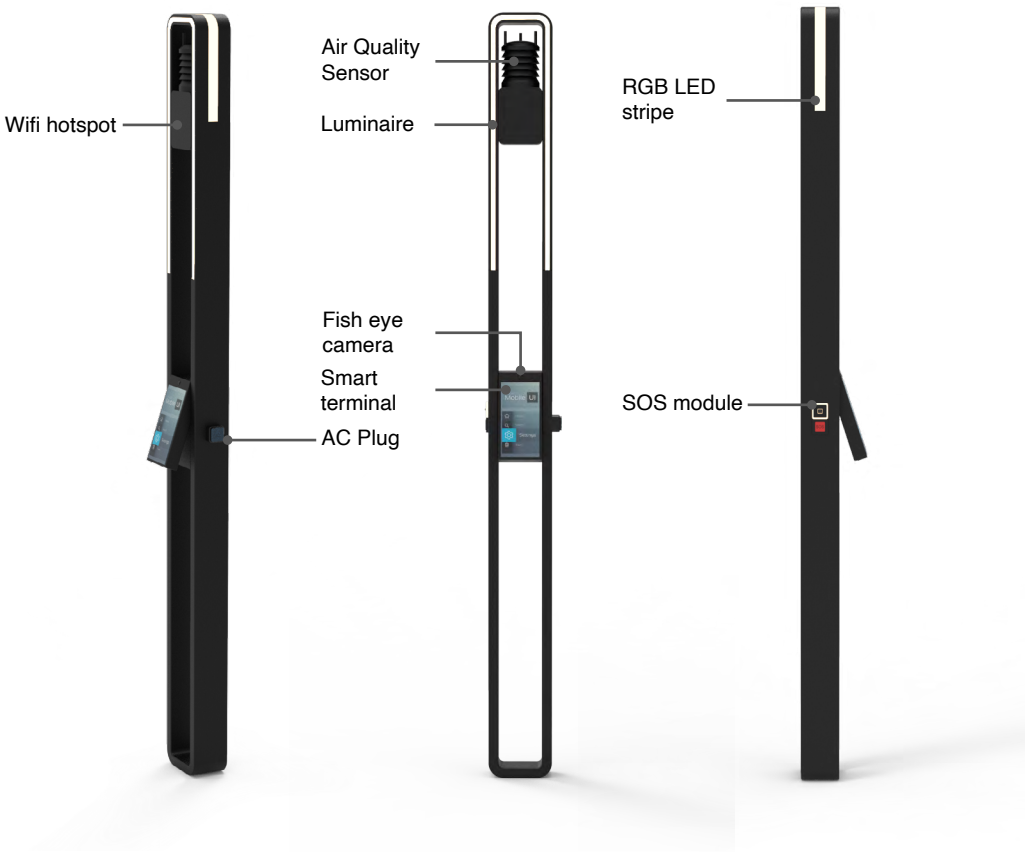


fig.100: 3m Smart Pole and technology integration.

3m Loop product is equipped with the traditional luminaire, for its main function of lighting, and RGB LED stripes can be used to alert the citizens in case of an emergency, recurring to colour codes. Additionally this same system can be used to guide urban evacuations, under extremely hazardous conditions.

The 3m pole uses an air quality sensor to feed data to a hazardous emergency recognition system. An excess of pollutants into the air is detrimental to health conditions, and can be classified as health hazards. With air quality monitoring the city can better support citizens' health and wellbeing.

This same infrastructure also integrates a wifi hotspot that provides reliable connectivity to the urban fabric. Moreover, it provides basic charging features throughout an AC plug that can be used to charge personal devices or e-scooters. Thus, it supports diverse means of green commuting that do not rely on fuel burning.

Last but not least, the illustrated device represents the most equipped variant of the 3m Loop smart pole. This variant integrates a smart terminal that can be interlinked with the smart city portal, and therefore used for the most varied proposes, such as the integration of a feedback platform to inquire with citizens about various topics, possibly related to the urban area where the product is implemented. This service promotes civic action and participatory governance, since it makes it possible to collect citizen testimony. With this approach we aim to design the cities of the future starting from the inside, by understanding the citizens' thoughts and providing them the opportunity to shape the place where they live.

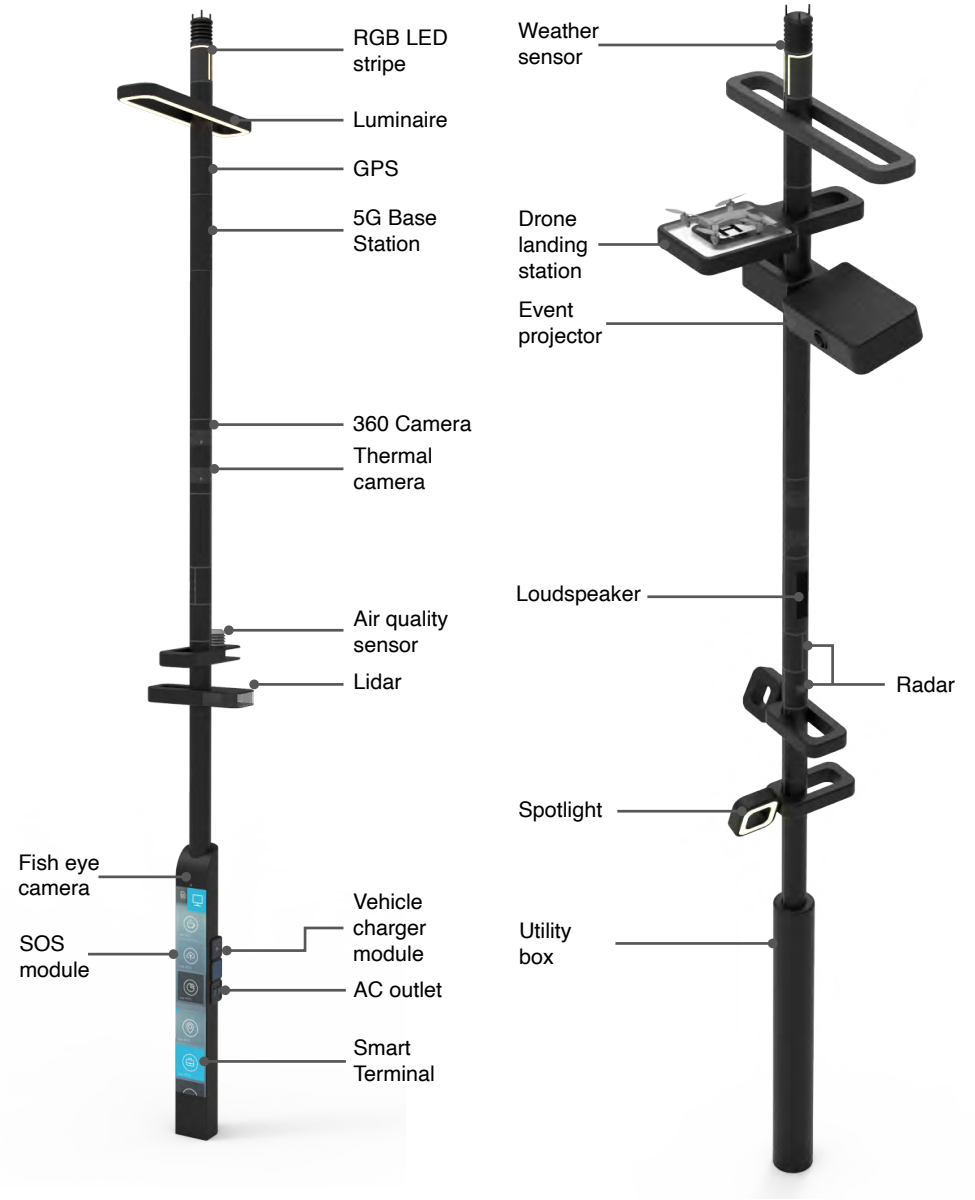


fig.102: 7m Smart Pole and technology integration.

7m Loop. The 7m Smart Pole architecture provides modular and customisable solutions for the integration of various services. It should be emphasised that the visualisation represented in Figures 101 and 102, illustrates just a few of those features and interlinked services. This product ensures and enhances security in the urban environment, since it provides city wide surveillance in real time. For that purpose, the Smart Pole combines features such as 360° thermal cameras and drones. Modern surveillance technologies can greatly benefit the public, if used in a transparent and responsible way. This contemporary safety system analyses possible hazardous events and uses the smart pole infrastructure to emit an alert in case of emergency, or to prevent accidents. Additionally, this infrastructure also provides the ideal space for the integration of the 5G Base stations, and offers the right spacing range between them, which is approximately 500m. Furthermore this product can integrate various relevant components for the development of future services and infrastructures, such as a Lidar, a crucial sensor that provides an accurate infrastructure for autonomous vehicles. This concept is currently being tested by the LuxTurrim5G consortium. Lastly, this product merges different sensors and IT components (such as cameras, air quality sensors, weather sensors, data processing and other) to support a smooth commuting flow and crowd management, enhancing quality of life and use of resources.

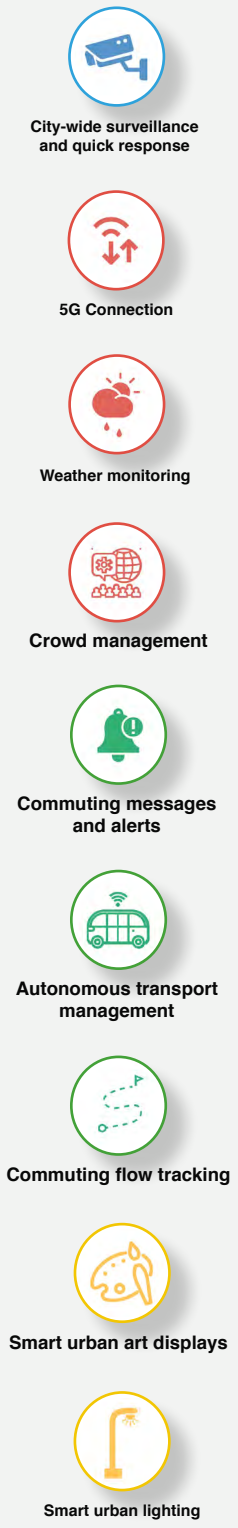


fig.101: 7m Smart Pole services.

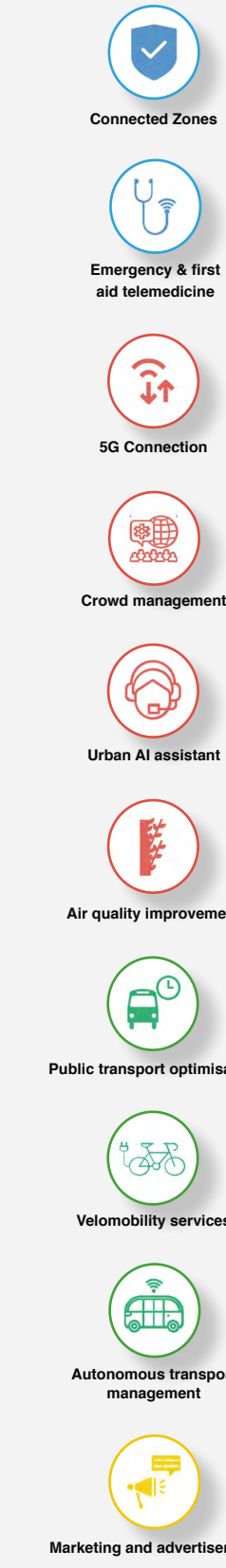


fig.103: Smart Bus Station services.

5.1.2 Smart Bus Station

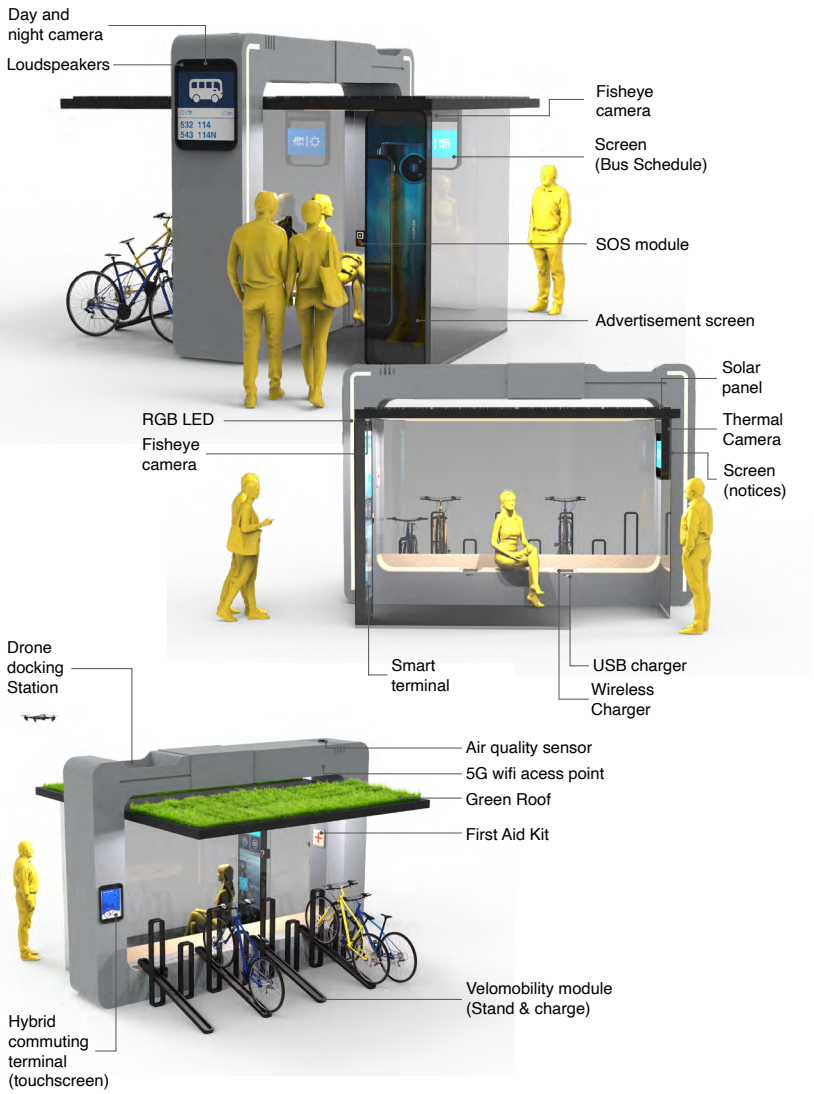


fig.104: Smart Bus Station and technology integration.

The Loop Bus station expands the service boundaries of the traditional public transport stop. This infrastructure should be perceived as a hybrid commuting hub that integrates conventional public transports, velomobility services, other means of transportation, private vehicles and autonomous vehicles. Additionally, it can be used to harvest energy through the roof modules with solar panels or increase air quality through the use of green roofs. This product also provides a drone docking station, a relevant facility for city wide surveillance, that can perform various emergency services or medical support. Moreover, this infrastructure can be used as a high safety shelter in case of hazards or criminality. Through the use of various cameras it can identify “at risk” citizens close to an incident in real-time . This product ensures safety and a highly surveilled space during an ongoing hazard. This enables monitoring by the authorities as soon as the emergency is detected. This concept is already being prototyped by the LuxTurrim5G consortium and Teleste company and is commonly called “Connected Zones”. This infrastructure also provides the integration of telemedicine in case of medical emergencies, using a service deployed by the smart terminal. Additionally this product uses the smart terminal to display the real time location of the commuting vehicles, and offers the possibility to optimise the routes of busses based on the exact location of the citizens. This terminal can be also used for marketing and advertisement and to provide an interface to the citizens with the city platform and an Urban AI assistant which can support them in using the city.

5.1.3 Smart Bench

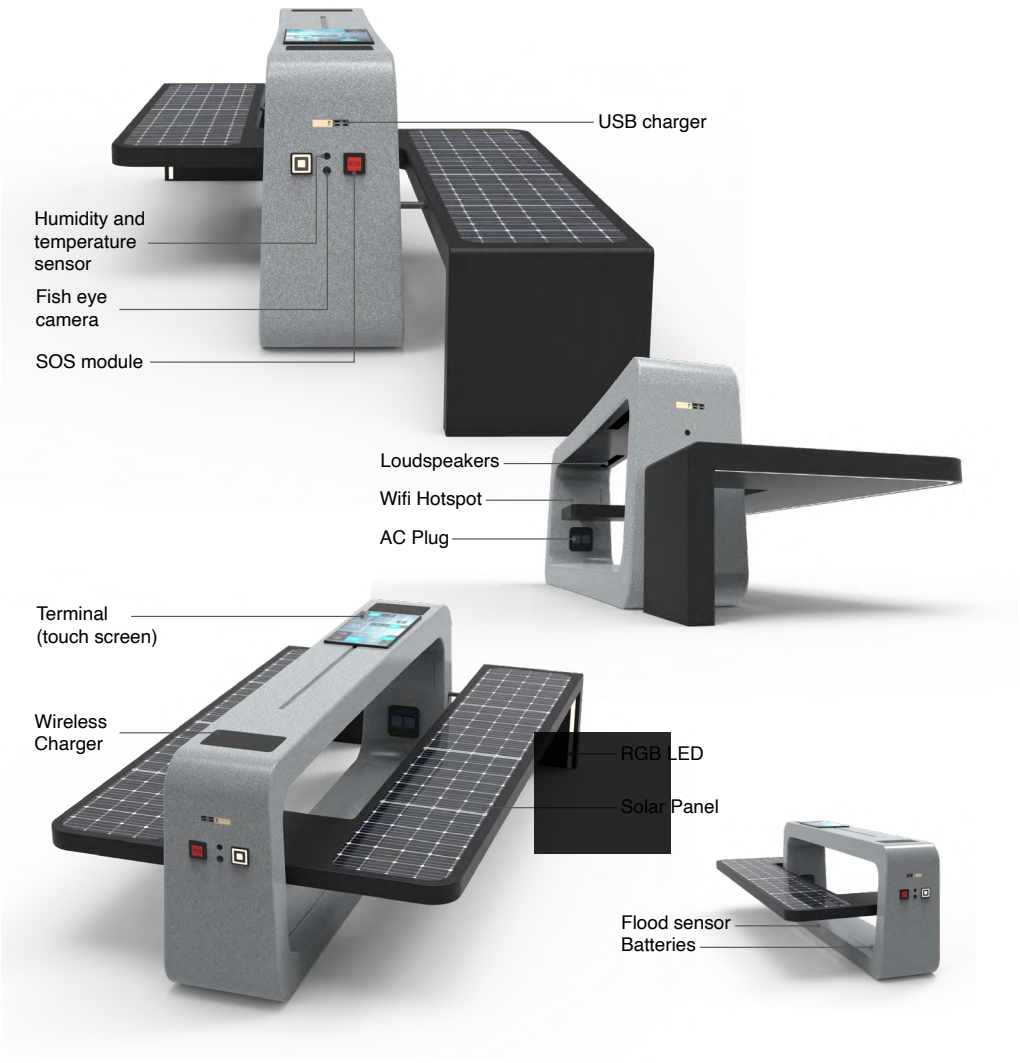


fig.106: Smart+ Bench and technology integration.

The Smart + bench integrates different features that can be used for various purposes and can be adapted depending on the modularity and customisability required by the urban context. Being a bench this element is available all along the city, in parks, squares and other public spaces. Besides the resting function, it expands security services in various ways. Firstly, it seeks to optimise light usage, promoting a better use of energy resources. Secondly, it extends the city wide surveillance services by integrating SOS modules, a camera, and a loudspeaker, that can be activated by citizens in case of emergency. By delivering safety information instructions, it can provide a quick response in case of any incident. It also offers high-speed internet connectivity through the use of wifi hotspots embedded in the infrastructure which can improve the general city operations and the wireless connectivity. The inclusion of a smart terminal creates the opportunity to embrace cultural and educational activities, connecting to the Smart City platform and integrating services such as participatory feedback access, that enhances the citizens' civic action. It can also integrate general entertainment, designed to enhance the interaction of the citizens with the public space. Lastly this product uses various components such as flooding, humidity and weather sensors that can monitor the environmental status and inform the authorities to act accordingly. It can also offer charging services through wireless chargers, USB ports and AC plugs.

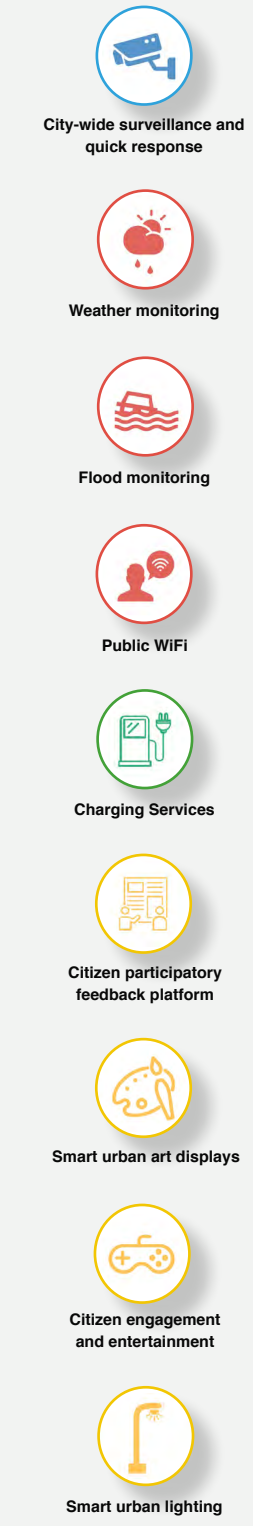


fig.105: Smart+ Bench services.

Emergency alerts & guidance.

Weather monitoring

Air quality improvement

Flood monitoring

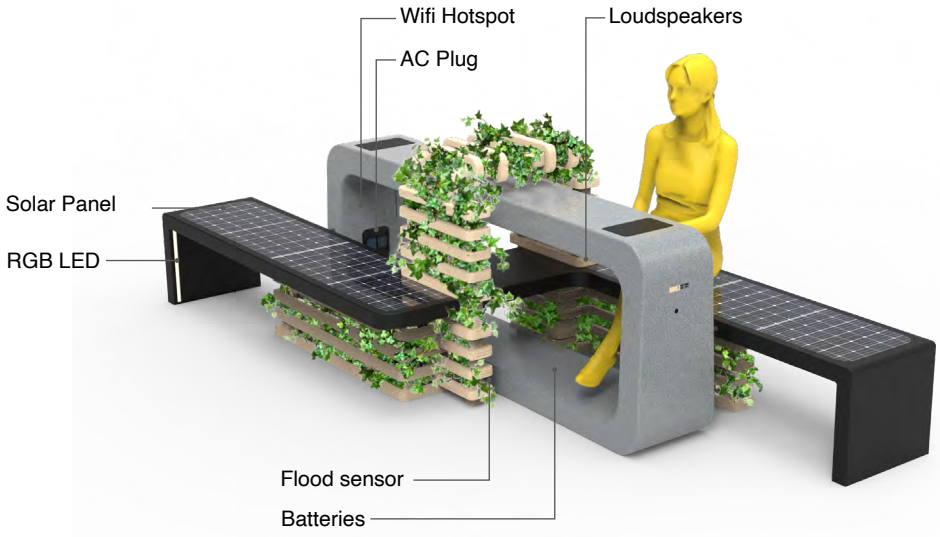
Public WiFi

Charging Services.

Smart event lighting, audio and video mapping.

Smart urban lighting

fig.107: Urban Green Bench services.



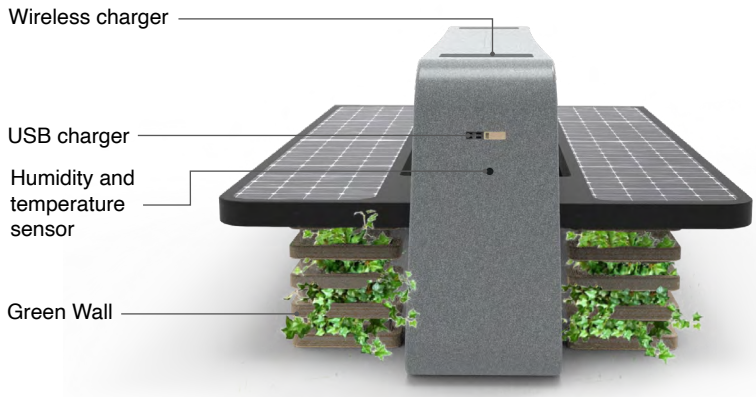


fig.108: Urban Green Bench and technology integration.

The Urban Green integrates less features and services than the Smart+ variation. Nevertheless it can be updated for a more equipped solution in case the urban fabric demands it. The Urban Green bench provides, as the previous version, the infrastructure to communicate general alerts through the use of lights, to collect general environment status through the combination of multiple sensors and to offer the possibility for basic charging features. These service-features were already introduced in the previous discussion of the Smart+ bench. The most remarkable feature and service enabler of this product is the modular smart green wall that can purify the air, reduce the ambient temperature and create a sense of well-being.

5.1.4 Smart Trash Can

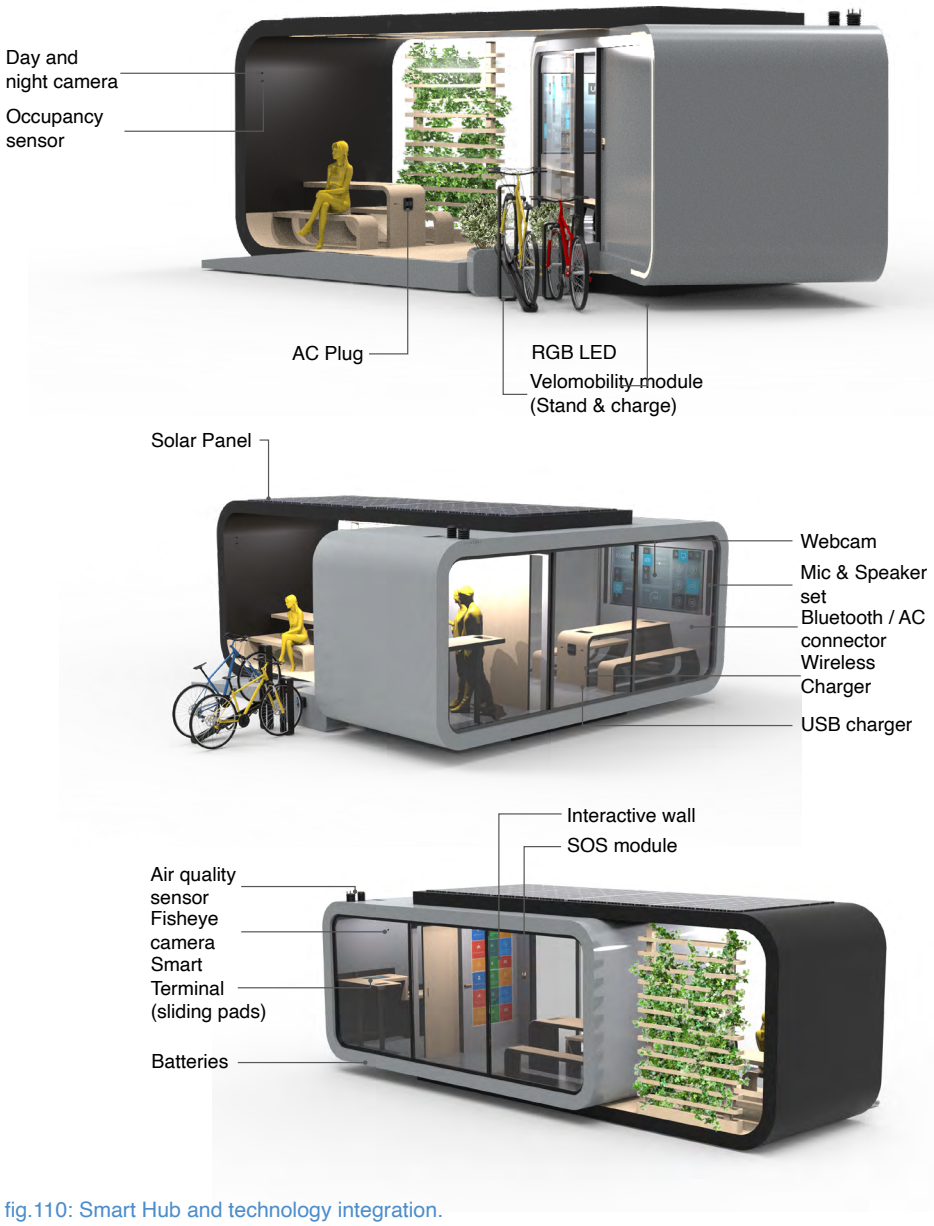


fig.110: Smart Hub and technology integration.

The Smart Hub integrates almost the full set of smart technologies available in the other products, promoting their dissemination and inclusiveness. With this in mind the product was designed to promote citizen engagement. This product maintains the features for city wide surveillance and offers the connected zones shelter with the services introduced in the bus stop. It also keeps the infrastructures to enhance air quality, and offer high-speed internet connectivity and 5G connection, thus being able to support various services targeted for social engagement. It is unique because it not only uses resources efficiently, such as energy that can be harvested by the infrastructure, but also emphasises the user interaction with the public space and with advanced technologies. In fact, it is designed to be a comfortable and highly usable community platform, and, for this purpose, it uses various features such as interactive walls, a highly equipped meeting and workshop room, smart sliding pads that can be used individually and linked with personal phones, charging services, among others. This space can then be used to facilitate participatory governance and host various workshops or even community engagement activities or exhibitions that can be displayed in the interactive screens and walls. This product uses technology to serve citizens, social cohesion and culture.

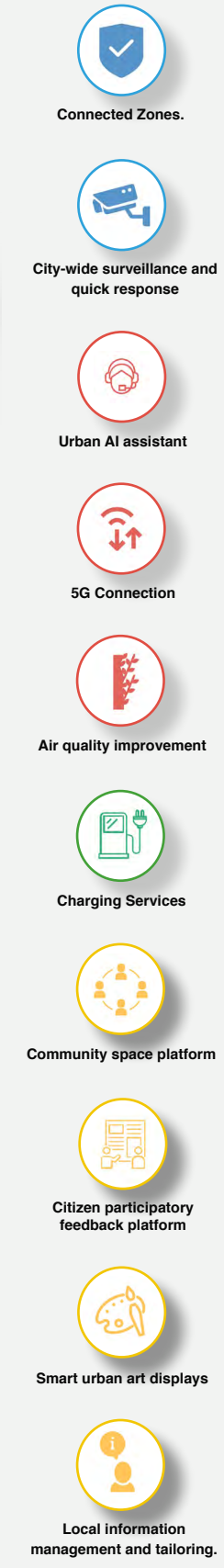


fig.109: Smart Hub services.

Emergency alerts & guidance.

Hazard detection system.

Marketing and advertisement.

Local information management and tailoring.

Garbage fleet management

5.1.5 Smart Trash Can

fig.112: Smart Trash Can and technology integration.

The Smart Trash can integrate various features and therefore promote various services. It mostly integrates beacons and trash level sensors in order to track the capacity of the garbage cans. Through access point modems and/or Bluetooth, it is able to communicate with the garbage fleet in order to optimise their routes and thus minimise fuel consumption and collecting time. Additionally it includes a fire detection sensor that can be used to prevent hazardous episodes and promote citizens safety and security. Furthermore this artefact can be used to display local information using the side screens. Those can also display educational content, for example helping the citizens to select the right trash can according to the trash they are disposing. These same screens can also be used for advertisement or other commercial purposes. Lastly, the light integrated in the Smart trash can also be used to alert citizens about ongoing emergencies or unconventional circumstances. This future-service based product promotes a better use of resources, a clean city and citizens' wellbeing.

fig.111: Smart Trash Can services.

USE case scenarios

5.2. Impact of the Smart Urban Furniture in the urban environment

- Hybrid smart commuting
- Urban crowd optimisation

5.2 Impact of the Smart Urban Furniture in the urban environment.

This section will illustrate two user scenarios that were envisioned to demonstrate the impact of the Loop artefacts and of the Smart Urban Furniture concept in the city context. Such user scenarios demonstrate how the citizen might act to achieve a goal in the urban environment. The scenarios were illustrated to identify citizens motivations, needs or blockers when interacting with the Loop products. These were valuable tools to convey and visualise the Smart Urban Furniture concept within the LuxTurrim5G consortium. Additionally, they were used to promote the discussion of the proposed solutions. They were also used to visualise the service-product system and understand what users might appreciate in their contexts of use.

Hybrid smart commuting

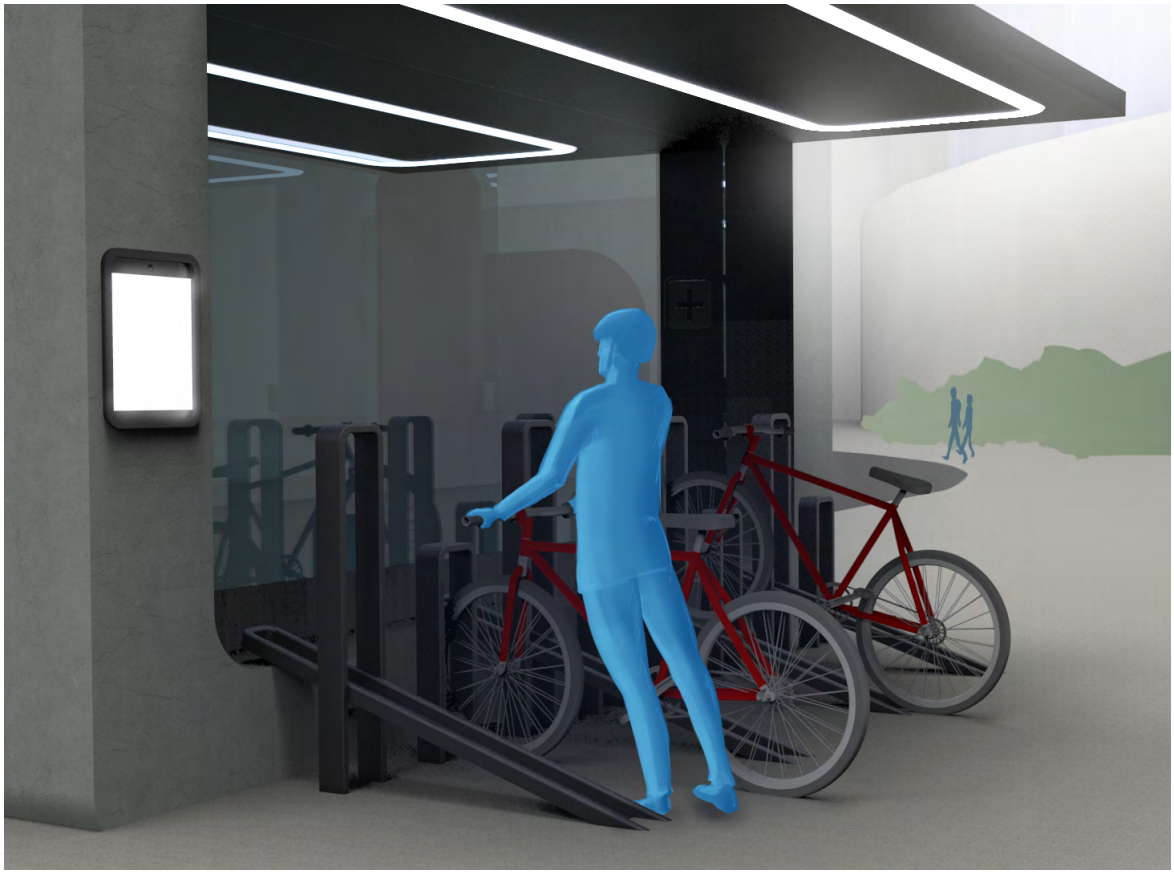


fig.113: Hybrid smart commuting, scene one.

John starts the day by taking a city e-bike, which he rides for 3.5km, until the most convenient bus stop on the way to his place of work. He could use other available public transports, but this bike path will optimise his morning route. It reduces the time of commuting, provides him the opportunity to enjoy the green features of the smart city, while allowing him to avoid traffic congestion and areas with reduced air quality. He is aware of the air condition through the Smart City platform that visualises and compares the data that is collected by the sensors integrated in the Smart Urban Furniture artefacts. When John arrives at the Smart Bus Stop, he can check the real-time positioning of the available vehicles, and the prediction of the next bus arrival. Additionally, he can interact with the smart terminal and notify the public transport management that he is waiting for the N122 bus. With this information the public transportation routes can be optimised and avoid the bus from stopping when they are not being used at the moment. While briefly waiting for the bus, John enjoys the fresh air provided by the green roof and additionally charges his mobile device in the wireless chargers.

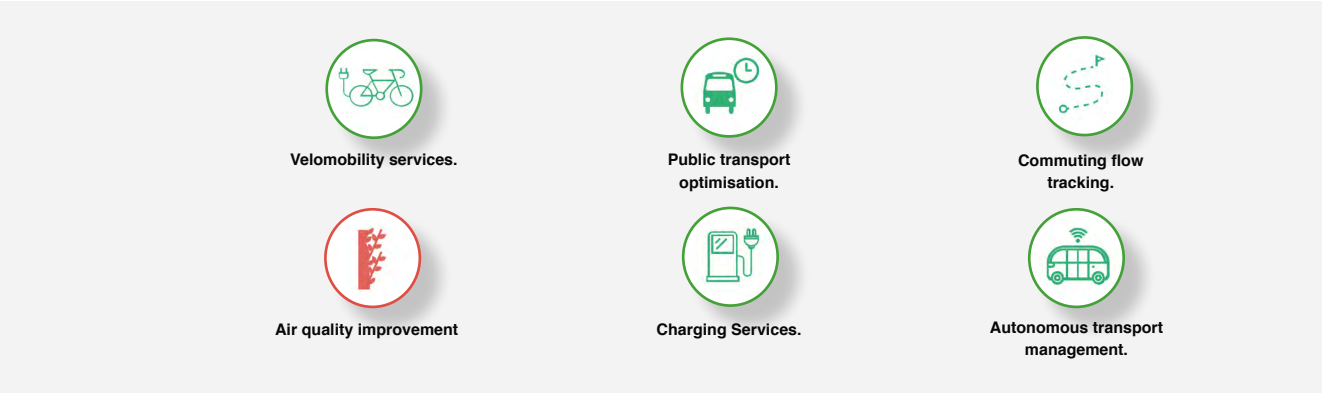


fig.115: Services used in the hybrid smart commuting user scenario.

fig.114: Hybrid smart commuting, scene two.

After a long day of work, on the way back, John was feeling tired and not willing to ride a bike or take a bus back home. He was aiming to get home as soon as possible. Therefore, he walked for 2 minutes to the nearest bus stop and requested an autonomous vehicle that could drive him home from the smart terminal. The Loop Bus Stop is no longer a traditional public transport infrastructure. This product is seen as a smart mobility hub that can interlink various services and provide the best experience to its citizens. Throughout the day the infrastructure has adjusted its service offer to real user needs, first by providing smart velomoblity services, secondly by offering optimised bus routes and thirdly by integrating private vehicles in the commuting network. This service provision has granted a smoother experience of the urban context to John, and he has arrived peacefully home after a long day of work.

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Urban crowd optimisation

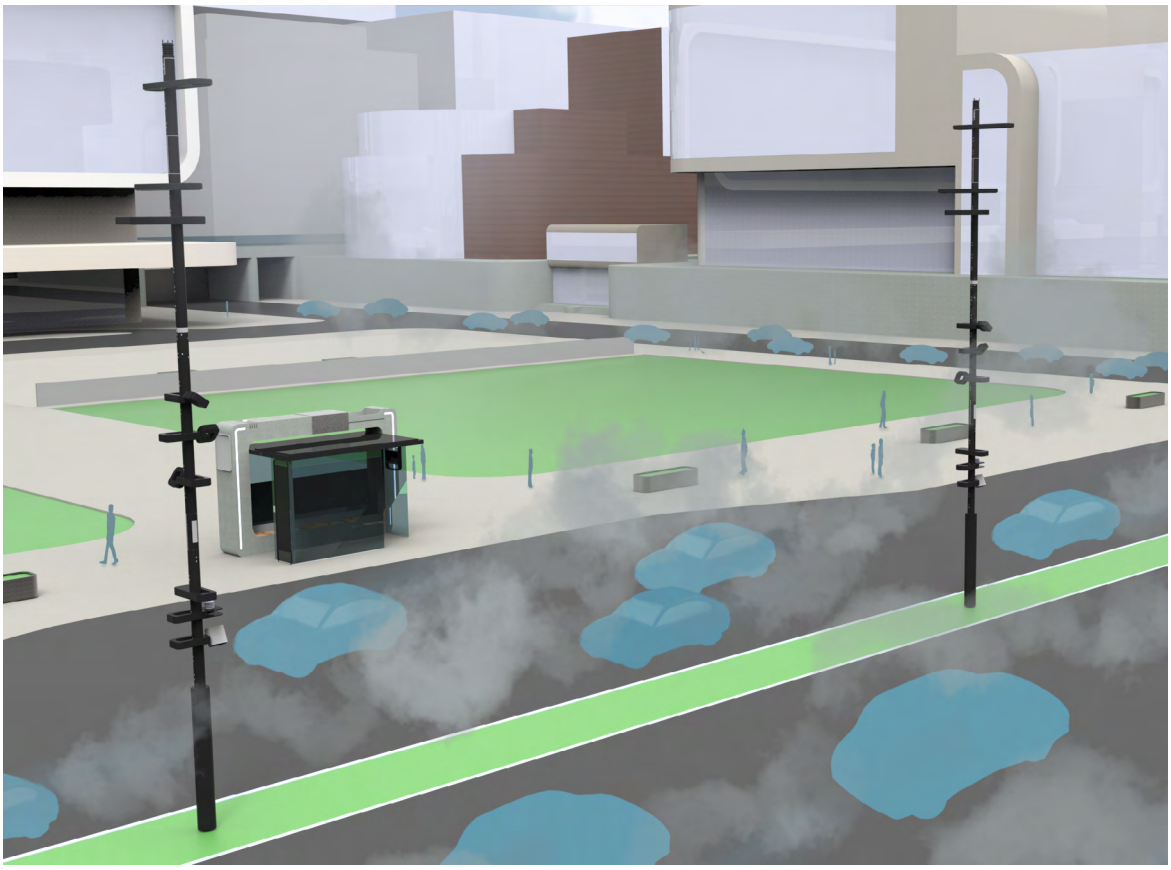

fig. 116: Urban crowd optimisation, scene one.

It is Monday morning (08:00 am), and the majority of the citizens are commuting towards work. Unfortunately, there was an accident in the nearest intersection. For this reason, the main avenue is forming a traffic bottleneck. The commuters have received a notification about the incident in real-time and are already avoiding the congested areas. While the remaining vehicles avoided the traffic, the weather and air quality sensors placed on the smart pole network detected air quality anomalies due to the high level of the existing traffic in the main downtown avenue. The authorities verify the alert and initiate the crowd optimisation service in order to redirect traffic, and protect their citizens from the excessive concentration of pollutants into the air, which are detrimental to health (and additionally to the environment).

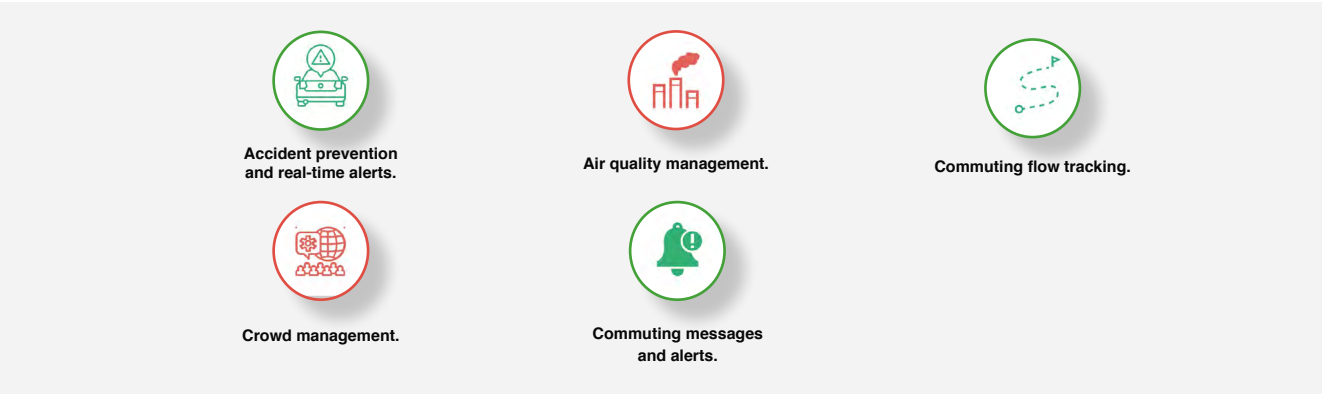

fig.118: Services used in the urban crowd optimisation user scenario.

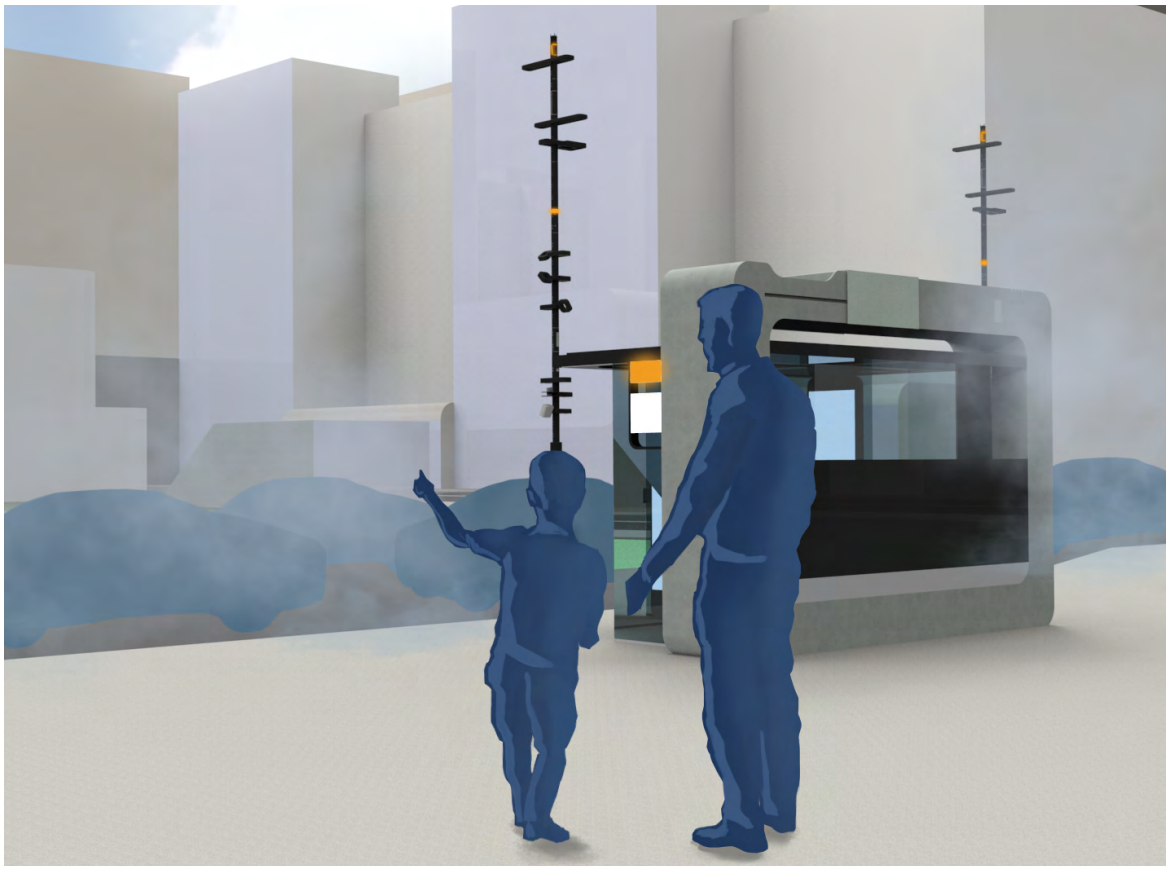

fig.117: Urban crowd optimisation, scene two.

In order to directly communicate with the citizens and to support the crowd optimisation operation the colour-coded lights and displays are activated on the Smart Poles to inform car drivers, and, on the bus stations, to inform pedestrians about current circumstances. The Smart Urban Furniture uses different colour-coded lights to effectively alert citizens about different hazardous situations. Mathew and his father saw these alerts. Even though he is young, Mathew can recognise the colour code, and knows to avoid this urban area in order to prevent the contact with the unusual rise of CO2 levels due to the heavily trafficked roads. Mathew has kindly suggested to his father that they should take another route. Both father and son walked to the nearest bus stop. Mathew's father checked the available recommendation to avoid areas with reduced air quality and selected one of the paths suggested by the Smart City platform. The Smart City air quality and crowd management have supported Mathew and his father to arrive safely to school. This service provision enchances the citizen safety and wellbeing.

6

Discussion

6.1 Main achievements
6.2 Contents of master thesis
6.3 Evaluation of the results
6.4 Conclusions
6.5 Future works

6.1 Main achievements.

This dissertation results from work carried on at Aalto Design Factory that led to several contributions for the LuxTurrim5G project. This project, developed by a consortium of companies led by Nokia in Finland, has established a first generation smart street pole that incorporates street lighting, various sensors and the electronics for small 5G cells.

The main contributions of this work from a macroscopic point of view are related with the expansion of the Smart Pole context to the Smart Urban Furniture collection concept. This concept integrates new technologies and rethinks the usability and urban impact of street furniture. Consequently, the core of the work is focused in urban renovation and sustainable development of our cities' future.
This enlargement of the concept was highly valued by the LuxTurrim5G project consortium as it led to a more holistic view of the city infrastructure. In this view, urban furniture, besides supporting technology, is designed to fit citizens' needs and desires while offering adequate support to install the required technological systems. Besides facilitating technology installation, urban furniture offers an enlarged set of services to the citizens, improving wellbeing and health, contributing to make better the usual more aggressive city environment.
Besides this more conceptual achievement, the work led to significant material results as it resulted in the design of four urban furniture collections, each with its own specific characteristics. This diversity of characteristics was intentional and was intended to fit the urban furniture to the specificities of the city where it should be installed, taking into consideration several aspects such as architecture, culture, civilisation, climate and others.
Within this endeavour of designing urban furniture it should be emphasised that the work developed in this dissertation, besides coordination work of all the Urban Furniture collections, led to the conception of one of them, the Loop Collection. The design of each collection and, in consequence, of the Loop Collection included 5 types of urban artefacts: a Smart Pole, a Smart Bus Station, a Smart Bench, a Smart Hub and a Smart Trash Can.

The Loop collection denotes a minimal approach, taking into consideration that cities are becoming more complex, increasingly crowded, and mostly cluttered. It embraces minimalism in order to bring neutrality and tranquility to the citizens in the urban context. With this minimal approach it is possible not only to engage and enhance the identity of the city and its heritage, but also to provide citizens with the opportunity to focus on the right things. The design of this contemporary collection has also followed the lines of emotional design in order to create a relationship between the users and the artefacts to facilitate early adoption by the citizens and to promote the adequate mood in experiencing the city services available.

It should be noted that the five Loop Collection elements offer a high degree of modularity that enable adaptation to the city itself and to the location within the city where they are installed. The number of elements and the number of modular alternatives led to an explosion of pieces that was difficult to handle due to the correspondent work load. However, from the material point of view, this is the most significant achievement within this dissertation. Going back to an immaterial plan it should be emphasised that a significant part of the work related to the urban furniture design was beyond the physical infrastructures. In fact, the work also analysed and proposed an enlarged set of services, either for the citizen or for the municipality, that should be installed in the different artefacts to cope with the needs and expectations of citizens and municipality managers. In other words, we have generated a Smart City Service-Product Ecosystem.

6.2 Contents of the dissertation

In order to report the work made in this dissertation, a general review of the LuxTurrim5G project was presented, by presenting its background, context, the consortium, its partners and respective role and the collaborative project goals and challenges. The idea currently disseminated by Nokia of an “innovation ecosystem” which resulted in the enlargement of the project horizons, and of “how to build fast a 5G network” was also introduced.
The link between the original concept of the Smart Pole from the LuxTurrim5G consortium and the Smart Urban Furniture concept that resulted from the project evolution should also be emphasised. A brief introduction to the Aalto Design Factory collaborative research and team member roles, together with the project path, goals, deliverables and main outcomes has also been provided. The project coordination strategy and the holistic perspective on the research work, as well as all the methodologies that drove the work, haven been highlighted.
The dissertation document also contains a more theoretical part resulting from desk research, analysing the Status Quo of the Smart City topic from different angles and perspectives. The initiative of transforming cities into Smart Cities and the re-use of public spaces were reviewed. Our work has been supported by an extensive analysis that visualised the complex city structure, based on different perspectives of urban environments, looking at the city as a complex organic abstraction, and defining the concept of Smart City from the citizen-centric perspective. The role and point of view of citizens was based on the outcomes of a user workshop organised to collect citizen feedback under the scope of the LuxTurrim5G project. The topic of this workshop was the urbanisation of technology and the notion of Smart Cities, based on citizens’ needs and concerns. This part of the work also revolved around mart City service provision and underlined the main service clusters present in the city environment, emphasising its core principles.

The report has also discussed the links between the service and holistic realm with the product ecosystem necessary to implement Smart City service provision. A list of the values and needs of the required infrastructure to deploy Smart City services was also provided. At the same time the collections of products required in the Smart City context and their aesthetic values were introduced. Each city’s cultural heritages is unique and therefore it is necessary to build product collections that can easily adapt to specific city requirements.

After this more general part of the work, the Loop collection of Smart Urban Furniture was not only introduced but also detailed, demonstrating options for adopting a minimal and neutral design and their consequent impact on the city. We also touched on the design analysis, which was driven from an emotional perspective, and the prospective effect of a minimal method in contemporary cities.
The most physical part of the work was presented by illustrating the product development path from the initial conceptual sketches to the final visualisations of the collection products. We added a more technical perspective on the products’ development, which demonstrated the conceptual singularities of each product, technical drawings, material selection and technology integration. Our intention was for the industrial outlook to be based on generating a good interaction between the user and the product. With regards to material selection, we based our decisions on environmental impact and durability and tried to combine efforts to meet the sustainable development goals (SDG) set by the UN.

In order to cope with the initial core technological character of the LuxTurrim5G project, we had to describe each product according to the modular sensors and devices that are to be integrated in the product design. It should be noted that we were able to integrate technological elements into modular and customisable bases in order to prevent obsolescence. We had then to emphasise the integration and interconnectivity of the product development and service provision. Cities are

complex and divided into several layers of infrastructure based systems. To deal with this issue, we had to define the comprehensive product-service ecosystem that the Smart Urban Furniture concept provides in urban environments. This definition takes into consideration specific service reviews per product and case scenario visualisations.

6.3 Evaluation of the results.

This project's goals were ambitious and the deliverables complex. Not enough time has passed to enable an evaluation of the products (and, consequently, of the concept) since their deployment in the city environment. However, there have been other types of evaluation steps that make us confident about the effectiveness and quality of the work produced.

We started by listening to prospective users through a workshop with citizens to enable us to discover and validate a new set of city services and urban opportunities that could be provided in the scope of the project. We avoided the trap of tunnel vision within the design team.

Afterwards, a refined definition of the products and services was performed with the aid of specialists from the city of Espoo through several sequential interviews. The development of the the specifications for, and design of, the final urban furniture elements, and the prototyping of the most relevant of them, namely the Smart Pole, the Smart Bus Station, and the Smart Bench, were validated by the steering group of the consortium partners in a series of meetings with the design team.

The prototypes were useful to test user interactions in real scale models. This was done in a final workshop/presentation where the prototypes were revealed, inspected, used, and briefly tested. This event was organised in a hybrid fashion with some onsite participation and a significant amount of remote attendees that contributed with feedback and suggestions.

A virtual reality application to create a model of the urban environment populated by the products conceived was also developed in the scope of the LuxTurrim5G project. This app enabled us to test user interactions without having to build all the product variants, and additionally, to showcase to stakeholders, such as cities, how these products can impact the real urban landscape, optimise certain operations and benefit the citizens.

6.4 Conclusions.

Cities have always been the major centres of human and economic activity. They create the space for building synergies, advancing progress in various fields and generating diverse opportunities to their citizens. Nonetheless, while cities grow in size and complexity, they face a wide range of challenges, such as growing populations. In order to support and design the solutions for the future, a comprehensive and holistic overview of the city infrastructure is required, in order to consider the governance initiatives and citizens' needs and embrace technological driven solutions. There is an urgency in merging these different layers and relating them to the specific city challenges in order to generate innovative services and solutions for the urban space.

For these reasons, cities need to integrate a holistic approach to address urban challenges through digital innovation for the sake of innovative civic governance, planning, infrastructure investment, wellbeing and quality of life.

Our work tries to contribute to this holistic view by expanding urban artefacts, from a set of individual infrastructures with just a traditional physical presence, to a coherent ecosystem of technology enabled elements that not only offer traditional functionalities but also support a significant set of services for the citizens and for the city authorities. Additionally, we expanded this holistic approach to the often-overlooked installation of the technological elements so that they are able to function better and can be easily deployed, maintained, and expanded. This objective goes back to one of the main initial goals of the LuxTurrim5G project that is the support of a dense network of 5G stations, an important requirement to deploy this technology.

This work also explored a minimalist line, based in emotional design, and the values of modularity, customisability and interconnectivity. We tried to integrate those values in the Loop Collection. We believe this collection, due to its adaptive character, will fit in well in cities with different genetic codes and cultural heritages. We are hoping to have the opportunity to further develop this work and see the installation of these artefacts after so much effort, passion and enthusiasm in developing them. Personally, I would like to emphasise that taking part in this project was a fantastic opportunity, challenging and fulfilling in various ways. The complexity of the project allowed us to expand our design approach to comprehensive, holistic and systemic methodologies. Most of all, this project allowed us to focus on enhancing citizens' experience of the city, and positioned them in the core of the city's complexity. This novel perspective on the city expanded our human-centred design and connected our products to a deeper human layer.

Additionally, I would like to underline that this work journey gave me the opportunity to grow both personally and professionally. I was given the chance to mix and match design and project management, which could sometimes be seen as overwhelming. But mostly, it expanded my personal strategic design methodologies in order to deal with the inevitable uncertainties that crop up along the project path, to organise information, and to communicate effectively about it. Defining the strategy and managing the project, while complying with the work requirements, made me realise how important it is to understand design methodologies and identify the minutiae of all team members' design processes, in order to set goals, purposes and objectives. Being a designer and project coordinator allowed me to better understand the design process and embrace a multidisciplinary approach towards drafting a concept that endorses the transition of cities towards smart cities

6.5 Future Works.

Some tests and experiments have been left for future opportunities due to the short and ambitious timeline of the project. Future work could consist of deeper analysis of practical technicalities, validations, manufacturing analyses, and product implementation strategies.

This master thesis has been mainly focused on the conceptualisation of possible product-services opportunity in the Smart City context. Therefore, we have created a comprehensive ecosystem of services that can be facilitated by a collection of products and enhanced by the integration of technology. This approach has been validated, approved and defined by the LuxTurrim5G consortium. However, it leaves space for some considerations that could be regarded as future works and notes, which are described below.

• In terms of materials it should be emphasised that there is a wide path that could be largely improved by a multidisciplinary engineering team (mechanical, electronic and material engineers). A new set of material requirements for each component, based on the components functionality and performance, and also a life cycle assessment, could be pursued in order to guarantee a sustainable product.

• In what concerns manufacturing, different partners that could produce and contribute for the manufacturing of the products should be identified. An architectural redesign might require a new study based on the mechanical assemblies of the components. A manufacturing plan should also be drawn, and prepared for the necessary production tools to standardise the production line. The architecture should not only facilitate the final assembly but also integrate electronics and cabling in the infrastructure. This would require a straight collaboration between a mechanical engineer and electronic engineer in order to guarantee the most efficient manufacturing process.

• For manufacture and testing, subsequent validations are required to further develop the project. Therefore, prototyping tests will be required to improve the product performance and efficiency. These tests and validation will take place with a view to refine the manufacturing methodologies and reach beta prototypes.

• Further work is needed to validate user interactions and the usability of the products after the preliminary evaluation in the final workshop of the project. This will guarantee that those solutions meet the end user requirements and needs in the context of public places.

• Also, we intend to validate the collection with different city councils or local authorities, and to consider their inputs in future design iterations and adjustments.

• Future work to promote educational awareness when testing or implementing the products would also be desirable. Incentives for local authorities to trigger public awareness of the Smart Urban Furniture should be created. These agents could support citizens in the discovery phase of Smart Urban Furniture. This would also guarantee social cohesion when implementing and/or testing these products. Therefore, the work would lead to the promotion of educational strategies and to gathering a wider understanding of data collection practices and protections.

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ANNEXE

Annexe 01

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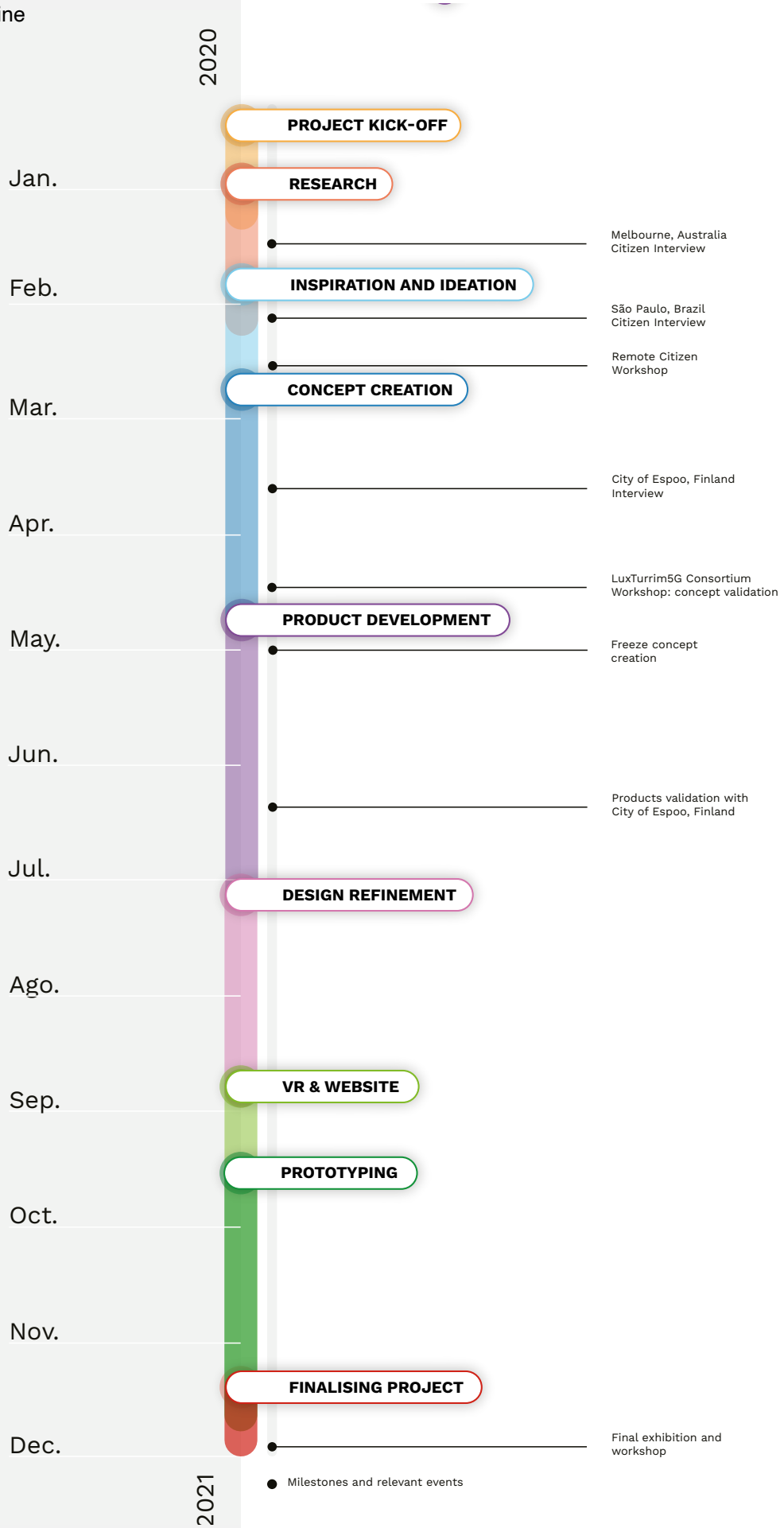
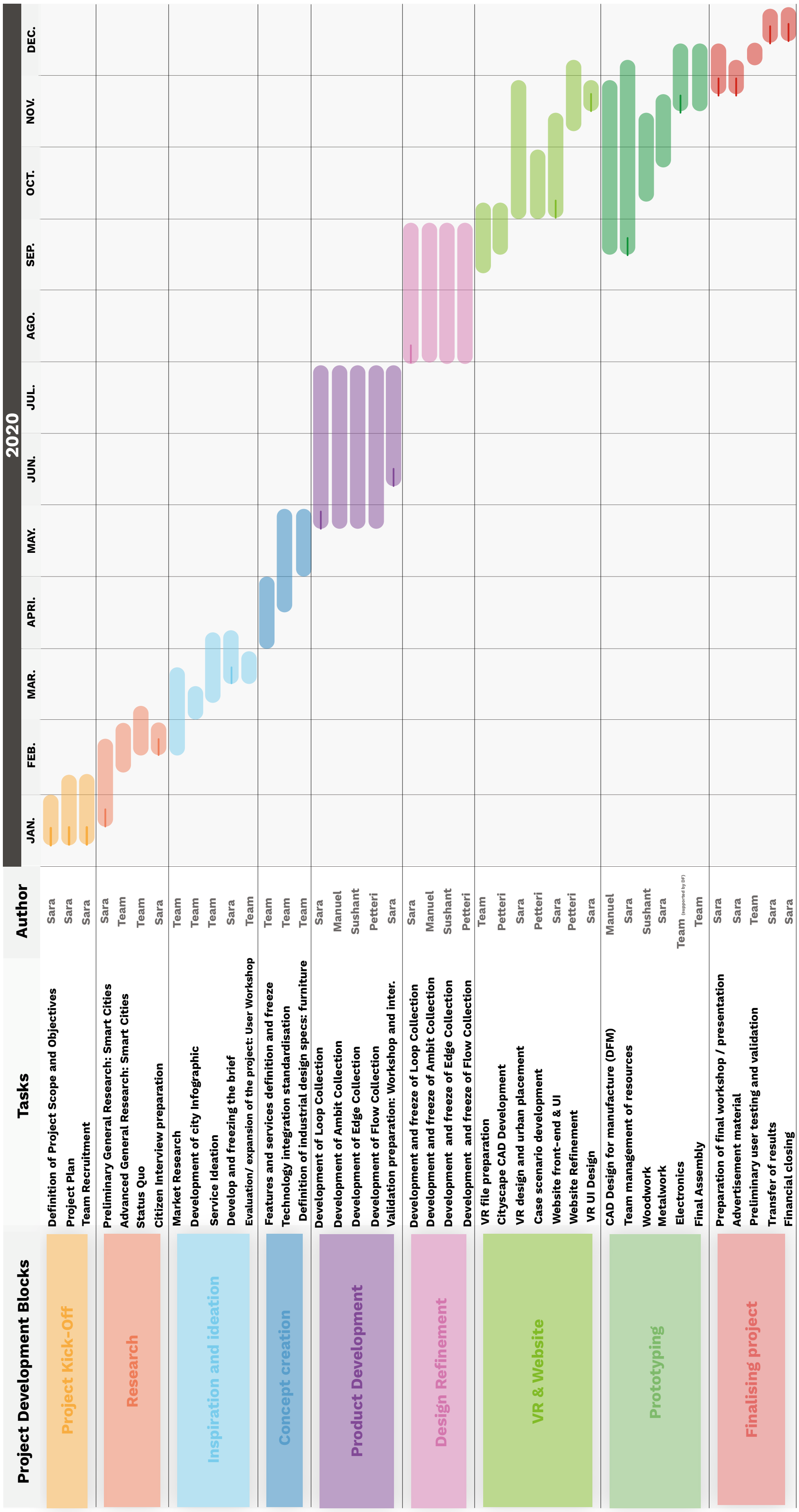


Annexe 02

Detailed timeline and activities: Gantt chart.



VIII

Annexe