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Towards e-cities. An Atlas to enhance the public realm through interactive urban cyber-physical devices

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Lab4U &Spaces
Living Lab of Interactive Urban Space Solutions

1. INTRODUCTION

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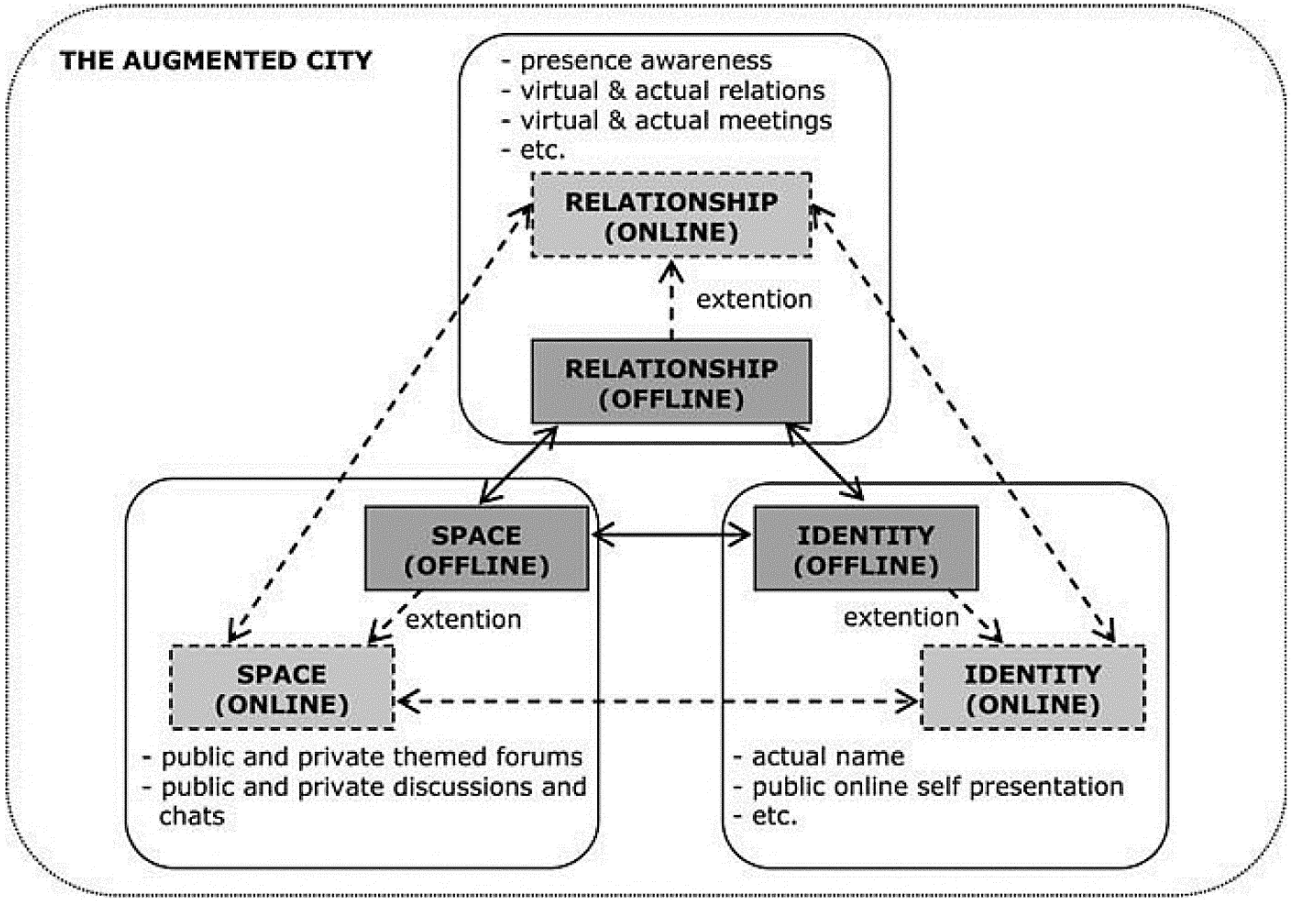
A new digitally mediated public realm.

The Augmented City: Relationships Between Actual and Online Dimension

In (Cindio, 2008)



1.1 Public space and ICT, key factor for the SDGs

Sustainable Development Goals (2015)

[UN Resolution 70/1 - Transforming our world: the 2030 Agenda for Sustainable Development (2015)]

17 Goals
169 Targets

"shared blueprint for peace and prosperity for people and the planet, now and into the future“. In (UN, 2015)

1.1 Public space and ICT, key factor for the SDGs

Benefits of Public Space for Achieving the Sustainability Development Goals. In (Daniel, 2016)

+ SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable

1.1 Public space and ICT, key factor for the SDGs

The UN World Summit on Information Societies

"a people centred, inclusive and development-oriented information society" (WSIS, 2003 and 2005)

11 WSIS Action lines (Cn)

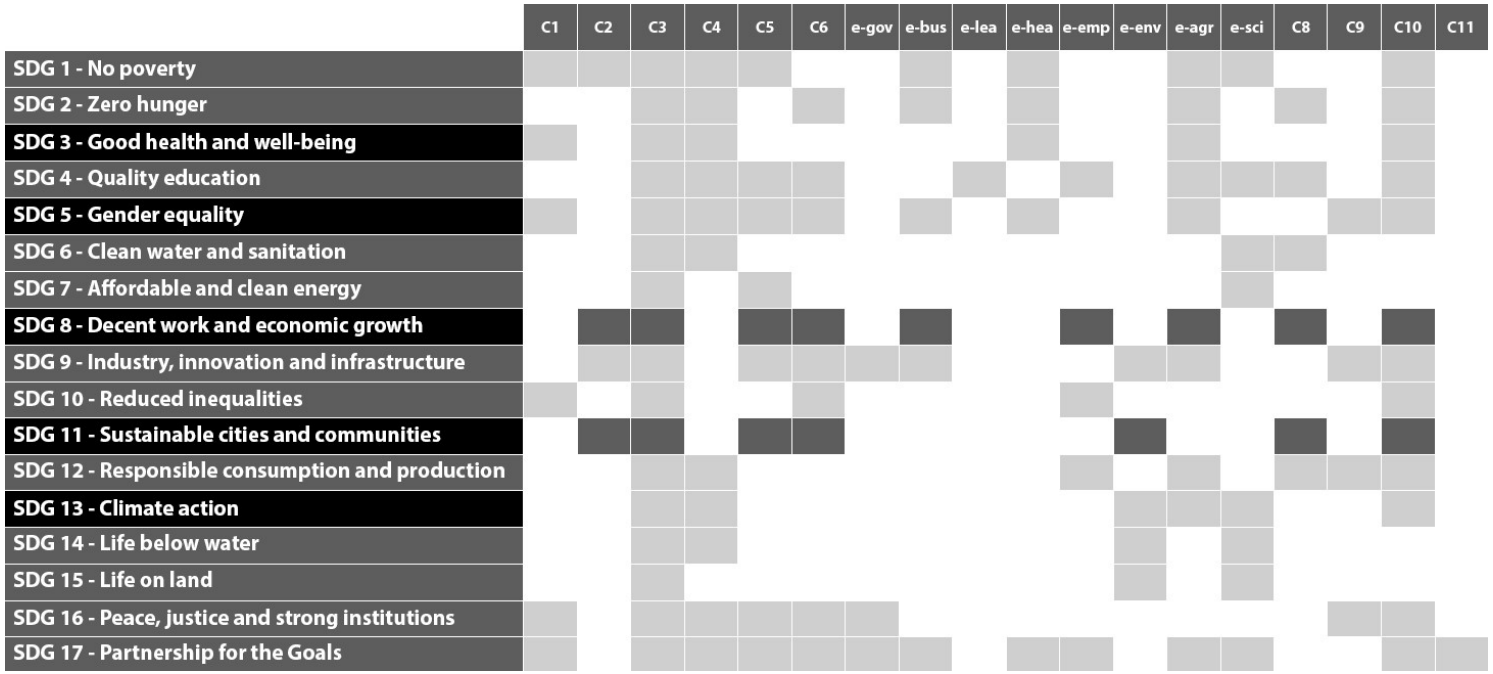
for ICT driven sustainable development

WSIS Action Lines	SDGs
C1: The role of governments and all stakeholders in the promotion of ICTs for development	Goal 1, 3.8, 3.d, Goal 5, 10.c, 16.5, 16.6, 16.10, 17.18
C2: Information and communication infrastructure: an essential foundation for the Information Society	1.4, 8.2, 9.1, 9.a, 9.c, 11.5, 11.b
C3: Access to information knowledge	Goal 1, Goal 2, Goal 3, Goal 4, Goal 5, Goal 6, Goal 7, Goal 8, Goal 9, Goal 10, Goal 11, Goal 12, Goal 13, Goal 14, Goal 15, Goal 16, Goal 17
C4: Capacity building	1.b, 2., 3.7, 3.b, 3.d, 4.4, 4.7, 5.5, 5.b, 6.a, 12.7, 12.8, 12.a, 12.b, 13.2, 13.3, 13.b, 14.a, 16.a, 17.9, 17.18
C5: Building confidence and security in the use of ICTs	1.4, 4.1, 4.3, **4.5**, 5.b, 7.1, 7.a, 7.b, 8.1, 9.1, 9.c, 11.3, 11.b, 16.2, 17.8
C6: Enabling environment	2.a, 4.4, 5.b, 8.2, 8.3, 9.1, 9.c, 10.3, 11.3, 11.b, 16.3, 16.6, 16.7, 16.10, 16.b, 17.6, 17.14, 17.16
C7 ICT Applications: i. e-government	9.c, 16.6, 16.7, 16.10, 17.8
C7 ICT Applications: ii. e-business	1.4, 2.3,5.b, 8.3, 8.9, 8.10, 9.3, 17.11
C7 ICT Applications: iii. e-learning	Goal 4
C7 ICT Applications: iv. e-health	1.3, 1.4, 1.5, 2.1,2.2,Goal 3, 3.3, 3.8, 5.6, 5.b, 17.8, 17.19
C7 ICT Applications: v. e-employment	**4.5**, 8.5, 10.2, 12.6, 17.9
C7 ICT Applications: vi. e-environment	9.4, 11.6, 11.b, 13.1, 13.3, 13.b, Goal 14, Goal 15
C7 ICT Applications: vii. e-agriculture	1.5, 2.3,2.4,2.a, 3.d, Goal 4, 5.5, 8.2, 9.1, 9.c, 12.8, 13.1, 13.3, 17.16, 17.17
C7 ICT Applications: viii. e-science	1.5, 4.7, 6.1, 6.a, 7.a, 13.1, 13.2, 13.3, 14.a, 15.9, 17.6, 17.7
C8: Cultural diversity and identity, linguistic diversity and local content	2., 4.7, 6.b, 8.3, 8.9, 11.4, 12.b
C9: Media	5.b, 9.c, 12.8, 16.10
C10: Ethical dimensions of the Information Society	1.5, 2.3,3.8, 4.7, 5.1, 8.36, 9.1, 10.2, 10.3, 11.3, 12.8, 13.3, 16.7, 16.10, 17.6, 17.7, 17.8, 17.18, 17.19
C11: International and regional cooperation	17.9, 17.16, 17.17

1.1 Public space and ICT, key factor for the SDGs

SDGs AND WSIS ACTION LINES MATRIX

UN Action Line facilitators have produced a WSIS-SDG matrix linking WSIS Action lines with SDGs (www.wsis.org/sdg)



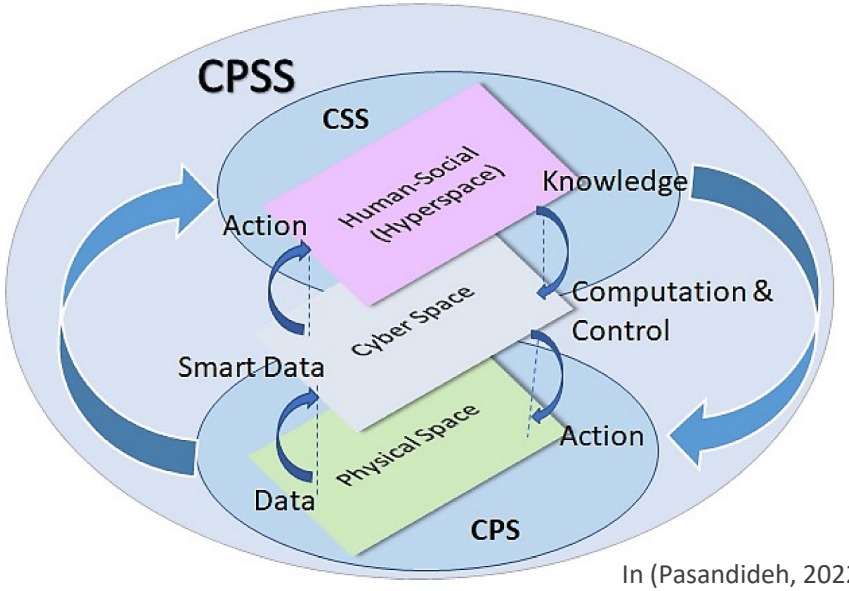
WSIS Action lines - SDGs matrix highlighting SDGs related to public space and Action lines related to SDGs 8 and 11 (adapted from https://www.itu.int/net4/wsis/sdg/).

1.2 The role of Urban Cyber-Physical Devices for Sustainable Smart Cities

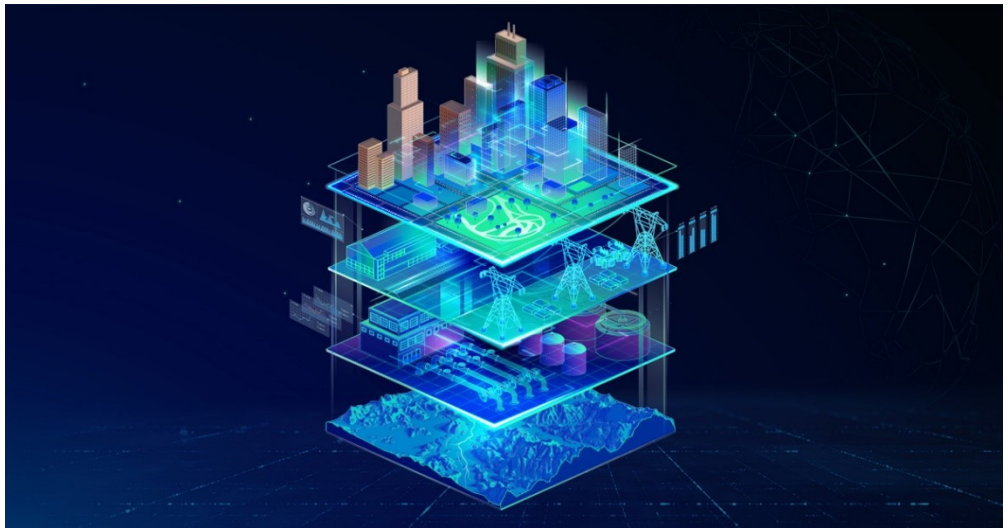
- A Cyber-Physical Device (CPD) is a device in which physical components and software are deeply intertwined.
  - Cyber-Physical Device (CPD) and
  - Cyber-Physical System (CPS)

- Our approach to CPDs departs from the architecture and urban design disciplines (assist urban life in public spaces or manage city infrastructures):
  - **Urban Cyber-Physical Devices** (UCPD) and
  - **Urban Cyber-Physical Systems** (UCPS).
  - Device physicality and impact on site are most important
  - (as a class of Cyber-Physical-Social Systems (CPSSs))

- UCPDs are the technologic backbone of the Smart City.
- UCPDs are:
  - **sensible hubs**, collecting and broadcasting urban information;
  - **interactive interfaces** between city, individuals and communities, raising awareness and engagement;
  - **gateway devices**, bridging cyber, physical and social spaces;
  - **adaptable devices**, pushing for design and governance solutions that address both large-scale long-term societal emergences, and small-scale short-term daily life individuals concerns.



In (Pasandideh, 2022)



1.3 The Research Project

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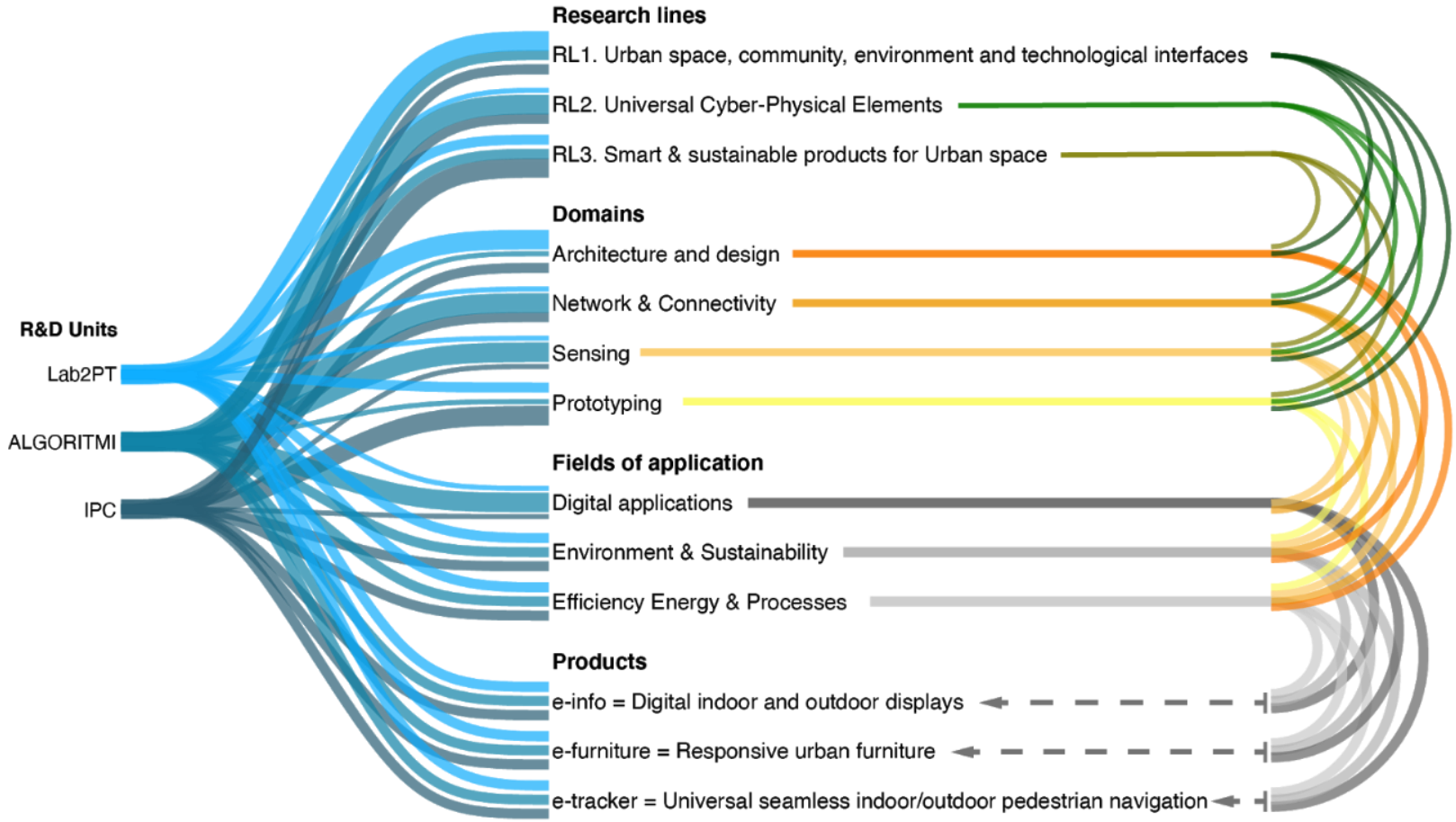
Living Lab of Interactive Urban Space Solutions



R&D Units:

- Lab2PT: Arts, Social Sciences, and Humanities
- ALGORITMI: Information Communications Technology and Electronics (ICT&E)
- IPC: Institute for Polymers and Composites

1.3 The Research Project

Atlas for the design of future e-cities

The initial architecture R&D unit review on the relations between:

Public space – Community – Environment - Digital interfaces

Materialized in an academic publication named *Atlas for the design of future e-cities* that collects, labels, relates and critiques a corpus of heterogeneous UCPDs case study projects deployed in public space around the world.

The scientific importance of this Atlas is trifold:

(i) for the Research Project the lessons learned from the Atlas fed the design guidelines for a Demonstrator of a new breed of environmentally sensible interactive urban devices, which integrates all the project's research lines;

(ii) for the scientific community: an updated state of the art in the subject, extending related work (e.g., *Pool of Examples of the CyberParks 2014-2018* (CyberParks, 2014) and Active Public Space publications (Markoupoulou et al., 2017);

(iii) for the non-experts: a theoretical and monographic introduction to the subject, with an ample set of fully illustrated applied cases.

2. MATERIALS AND METHODS

THE ATLAS STRUCTURE

Lab4U &Spaces

ATLAS
for the design of future e-cities

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(https://tinyurl.com/mrm5mnws)

2.1 Case Studies

Case studies selection rationale:

i. Innovative UCPDs;

ii. To portrait the diversity of:

- contexts and scales
- design and deployment strategies

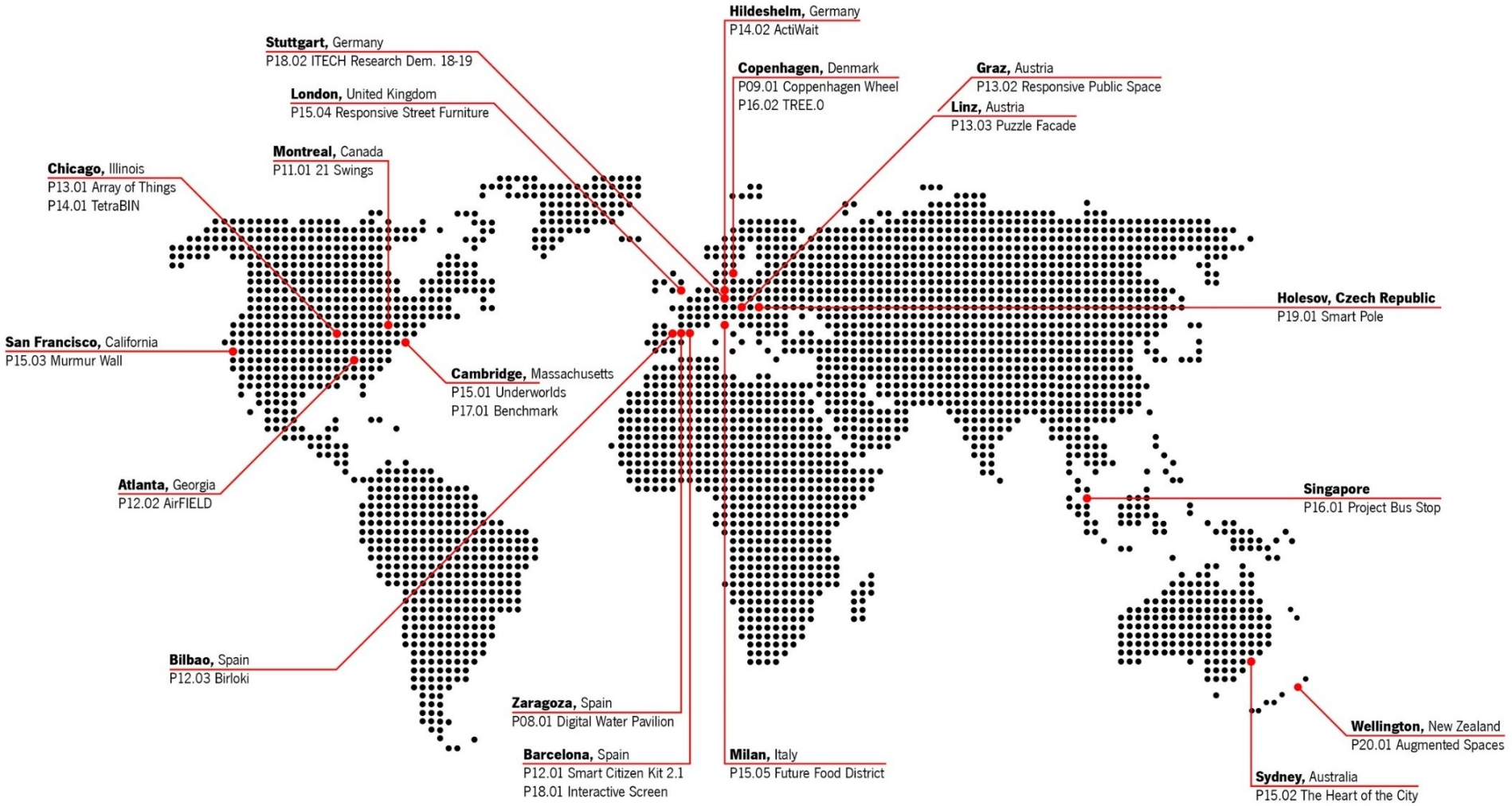
iii. Priority was given to:

- functional objects with a physical existence
- Implemented or prototyped design objects (over untested concepts, purely artistic interventions or digital-only initiatives)
- Possess some sort of sensing, communication, interactivity or adaptability capacity (augmented physical performance and digital twin)

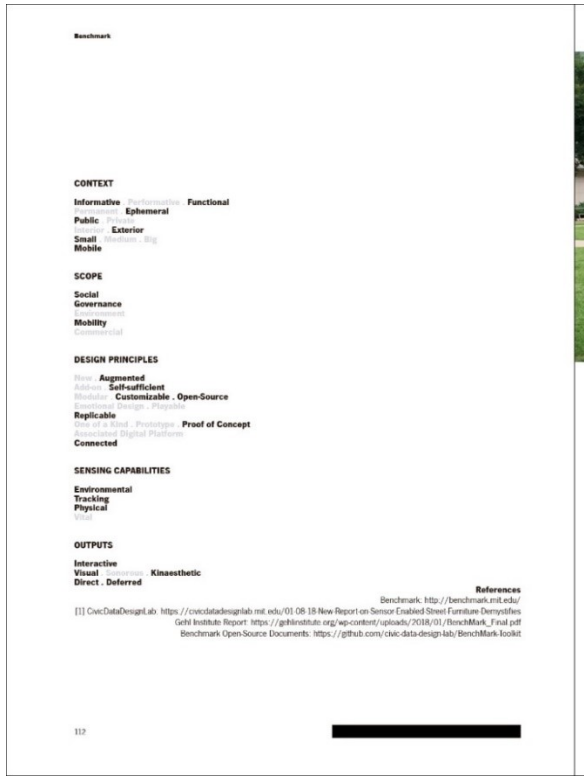
The Atlas currently comprises 24 case studies

Code	Name	Year	Location	Development Team
P08.01	DIGITAL WATER PAVILION [1]	2008	Zaragoza, Spain	Carlo Ratti Associati and MIT
P09.01	COPENHAGEN WHEEL [2]	2009	Copenhagen, Denmark	MIT Senseable City Lab
P11.01	21 SWINGS [3]	2011	Montreal, Canada	Daily Tous les Jours
P12.01	SMART CITIZEN KIT 2.1 [4]	2012	Barcelona, Spain	Fab Lab Barcelona
P12.02	AIRFIELD [5]	2012	Atlanta, Georgia	Ueberall
P12.03	BIRLOKI [6]	2012	Bilbao, Spain	Nerei Emotional Intelligent SL
P13.01	ARRAY OF THINGS [7]	2013	Chicago, USA	Urban Center for Computation and Data
P13.02	RESPONSIVE PUBLIC SPACE [8]	2013	Graz, Austria	ORTLOS Space Engineering
P13.03	PUZZLE FAÇADE [9]	2013	Linz, Austria	Javier Lloret
P13.04	BEACONS [10]	2013	USA	Estimate (Apple)
P14.01	TETRABIN [11]	2014	Chicago, USA	Sencity
P14.02	ACTIWAIT [12]	2014	Hildesheim, Germany	Urban Invention
P15.01	UNDERWORLDS [13]	2015	Cambridge, USA	MIT Senseable City Lab
P15.02	THE HEART OF THE CITY [14]	2015	Sidney, Australia	Anaisa Franco Studio
P15.03	MURMUR WALL [15]	2015	San Francisco, USA	Future Cities Lab
P15.04	RESPONSIVE STREET FURNITURE [16]	2015	London, UK	Ross Atkin Associates
P15.05	FUTURE FOOD DISTRICT [17]	2015	Milan, Italy	Carlo Ratti Associati
P16.01	PROJECT BUS STOP [18]	2016	Singapore	DP Architects
P16.02	TREE.0 [19]	2016	Copenhagen, Denmark	Interactive Spaces Urban Studio
P17.01	BENCHMARK [20]	2017	Cambridge, USA	Civic Data Design Lab
P18.01	INTERACTIVE SCREEN [21]	2018	Barcelona, Spain	Trison
P18.02	ITECH DEMONSTRATOR [22]	2018	Stuttgart, Germany	University of Stuttgart (ICD, ITKE, ITFT)
P19.01	SMART POLE [23]	2019	Holesov, Czech Republic	INELS (ELKO EP)
P20.01	AUGMENTED SPACES [24]	2020	Wellington, New Zealand	Holly Chan, Victoria University of Wellington

2.1 Case Studies



2.2 The records structure



Benchmark

CONTEXT

Informative · Functional
Ephemeral
Public · Exterior
Small
Mobile

SCOPE

Social
Governance
Mobility

DESIGN PRINCIPLES

Augmented
Self-sufficient
Customizable . Open-Source
Replicable
Proof of Concept
Connected

SENSING CAPABILITIES

Environmental
Tracking
Physical

OUTPUTS

Interactive
Visual
Kinaesthetic
Direct . Deferred

References

Benchmark: http://benchmark.mit.edu/

[1] CivicDataDesignLab. https://civicdatadesignlab.mit.edu/01.08.18-New-Report-on-Sensor-Enabled-Street-Furniture-Demystifies

Gehl Institute Report: https://gehlinstitute.org/wp-content/uploads/2018/01/BenchMark_Final.pdf

Benchmark Open-Source Documents: https://github.com/civic-data-design-lab/BenchMark-toolkit

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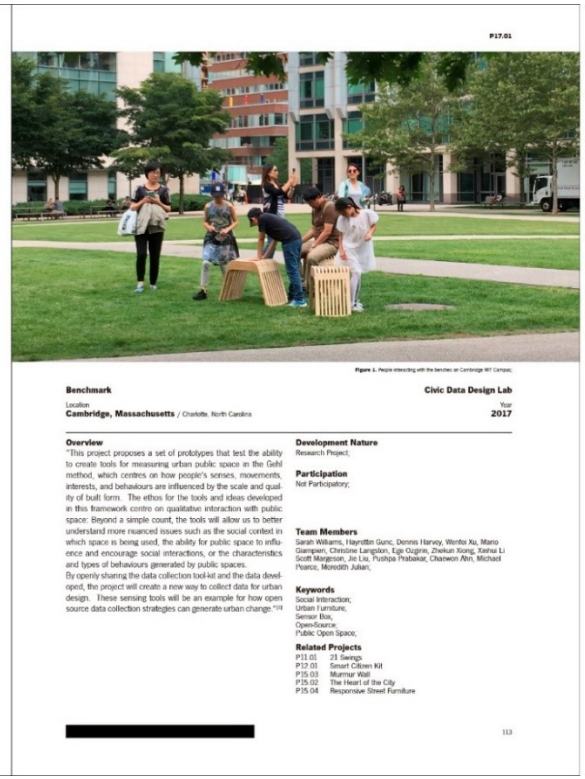

P17.01

Benchmark

Civic Data Design Lab

Location
Cambridge, Massachusetts / Charlotte, North Carolina

Year
2017

Overview

"This project proposes a set of prototypes that test the ability to create tools for measuring urban public space in the Gehl method, which centres on how people's senses, movements, interests, and behaviours are influenced by the scale and quality of built form. The ethos for the tools and ideas developed in this framework centre on qualitative interaction with public space: Beyond a simple count, the tools will allow us to better understand more nuanced issues such as the social context in which space is being used, the ability for public space to influence and encourage social interactions, or the characteristics and types of behaviours generated by public spaces.
By openly sharing the data collection tool-kit and the data developed, the project will create a new way to collect data for urban design. These sensing tools will be an example for how open source data collection strategies can generate urban change."[1]

Development Nature

Research Project;

Participation

Not Participatory;

Team Members

Sarah Williams, Hayrettin Gunc, Dennis Harvey, Wenfei Xu, Mario Giampieri, Christine Langston, Ege Ozgirin, Zhekun Xiong, Xinhai Li, Scott Mangrove, Jie Liu, Pushpa Prabakar, Chaewon Ahn, Michael Pearce, Meredith Julian;

Keywords

Social Interaction;
Urban Furniture;
Sensor Box;
Open-Source;
Public Open Space;

Related Projects

P11.01 21 Swings
P12.01 Smart Citizen Kit
P15.03 Murmur Wall
P15.02 The Heart of the City
P15.04 Responsive Street Furniture

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Benchmark

Design Principles

Remediated Typology: Benchmark benches are common benches with added sensing technologies;
Open-Source: both object designs and electronic plans are made open-source within open-data cultures;
Data Visualization: a data analysis and visualization toolkit was produced and made publicly available;
Customizable: both objects and electronics can be adapted to new situation as it arms to be a DIY project;
Ephemeral Installation: the prototypes have been deployed in three test places for restricted periods of time;
Replicable: the objective of Benchmark is to be replicated as a tool to study urban life.

Shape and Material

Benchmark project was materialized in a set of six individual benches and a small A-frame information board. The team sought a playful yet minimal aesthetic, a lightweight and practical design ensuring simple fabrication and assembly. These objects were made throw a set of CNC milled plywood sections held together by threaded metal rods. Magnets on each side of the benches allowed to connect and align them into bigger units. The A-frame board carried an information sign and housed a Gopro camera. The benches housed a weatherproof sensor box, containing all electronics on an Arduino like board. This box was made of transparent plastic ensuring the safety and visibility of all the components and light to reach in.

Sensors (Data) and Connectivity Infrastructure Technologies

Sensors: benches include a GPS device, a load/pressure cell sensor, an accelerometer and a gyroscope, a decibel and a luminosity levels sensor. The information board houses a Go-pro camera;
Connectivity: GPRS communication with central server. No near range or mobile devices communication, although BLE positioning and tracking is advocated.

Specific Functioning

The information board and benches were deployed following a daily protocol. The benches are used and manipulated by users and their sensors, and camera time-lapse images, communicate their location, whether they are being used, and the ambient sound and light levels to the project's servers through integrated SIM cards. A set of colour-changing LEDs visualized the data in real-time and stimulate interaction. Data analytics and computer vision trained algorithms were used specifically to identify patterns of stationary activities and pedestrian interactions. Some data and a data analysis toolkit is publicly available, as well a fabrication toolkit and a how-to guide to replicate Benchmark public space surveying process.

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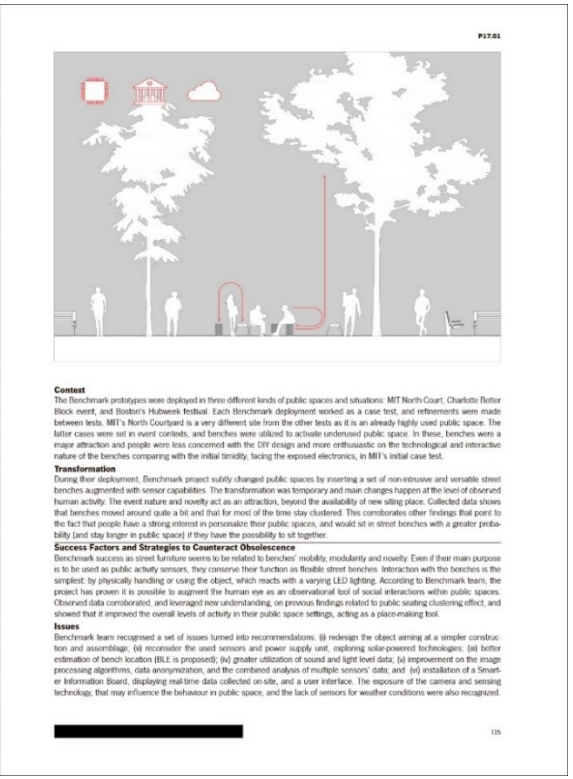

P17.01

Context

The Benchmark prototypes were deployed in three different kinds of public spaces and situations: MIT North Court, Charlotte Better Block event, and Boston's Hubweek festival. Each Benchmark deployment worked as a case test, and refinements were made between tests. MIT's North Courtyard is a very different site from the other tests as it is an already highly used public space. The latter cases were set in event contexts, and benches were utilized to activate underused public space. In these, benches were a major attraction and people were less concerned with the DIY design and more enthusiastic on the technological and interactive nature of the benches comparing with the initial timidity, facing the exposed electronics, in MIT's initial case test.

Transformation

During their deployment, Benchmark project subtly changed public spaces by inserting a set of non-intrusive and versatile street benches augmented with sensor capabilities. The transformation was temporary and main changes happen at the level of observed human activity. The event nature and novelty act as an attraction, beyond the availability of new sitting place. Collected data shows that benches moved around quite a bit and that for most of the time stay clustered. This corroborates other findings that point to the fact that people have a strong interest in personalize their public spaces, and would sit in street benches with a greater probability (and stay longer in public space) if they have the possibility to sit together.

Success Factors and Strategies to Counteract Obsolescence

Benchmark success as street furniture seems to be related to benches' mobility, modularity and novelty. Even if their main purpose is to be used as public activity sensors, they conserve their function as flexible street benches. Interaction with the benches is the simplest: by physically handling or using the object, which reacts with a varying LED lighting. According to Benchmark team, the project has proven it is possible to augment the human eye as an observational tool of social interactions within public spaces. Observed data corroborated, and leveraged new understanding, on previous findings related to public seating clustering effect, and showed that it improved the overall levels of activity in their public space settings, acting as a place-making tool.

Issues

Benchmark team recognised a set of issues turned into recommendations: (i) redesign the object aiming at a simpler construction and assemblage; (ii) reconsider the used sensors and power supply unit, exploring solar-powered technologies; (iii) better estimation of bench location (BLE is proposed); (iv) greater utilization of sound and light level data; (v) improvement on the image processing algorithms, data anonymization, and the combined analysis of multiple sensors' data; and (vi) installation of a Smarter Information Board, displaying real-time data collected on-site, and a user interface. The exposure of the camera and sensing technology, that may influence the behaviour in public space, and the lack of sensors for weather conditions were also recognized.

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- Development team
- Development nature
- Related projects, references, keywords
- Overview description

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- Sensors and ICTs
- Specific Functioning (interface)

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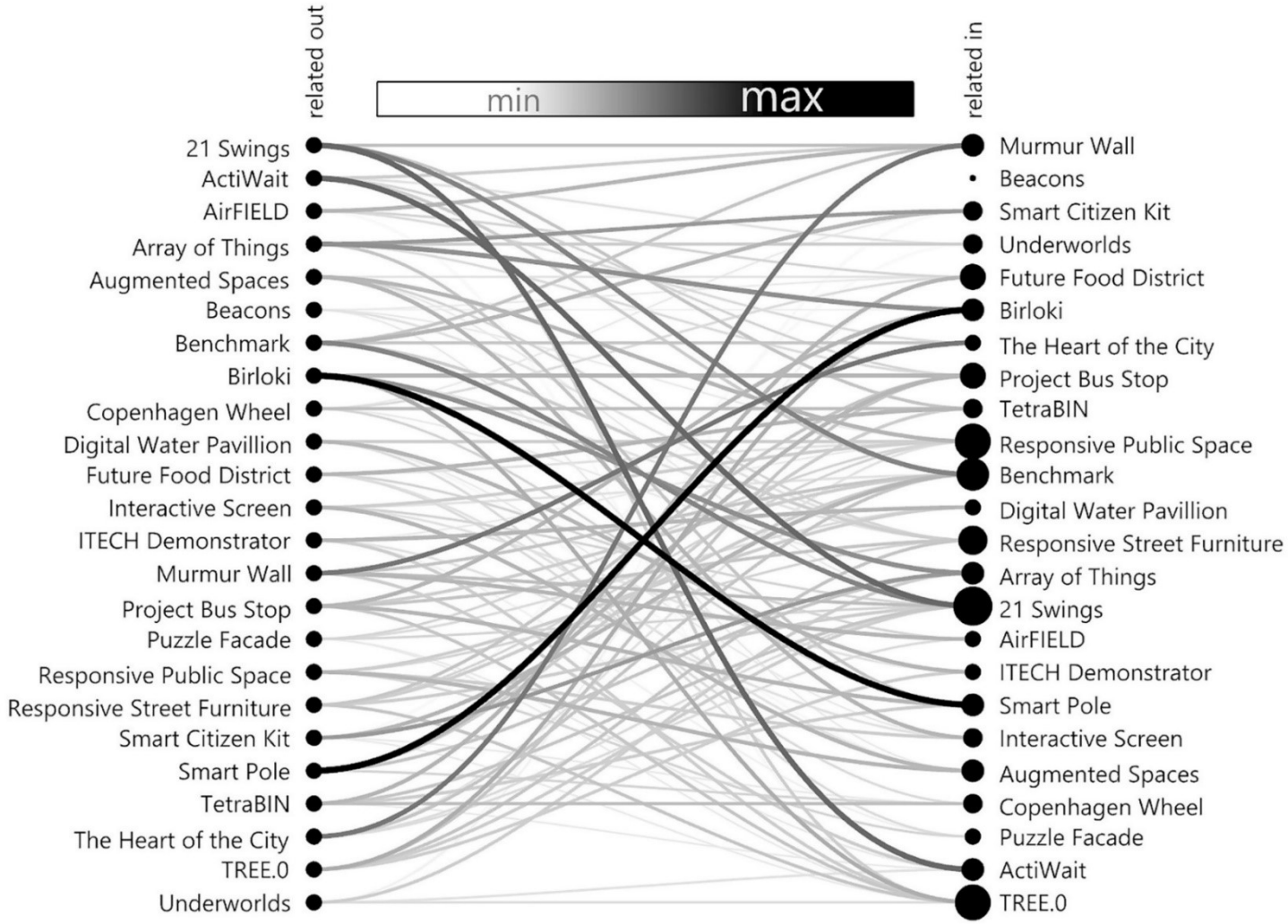
- Context (Place)
- Induced Transformation

(v) Review (bottom)
- Success Factors and Strategies Counteract Obsolescence
- Issues

3. RESULTS. MAPPING THE RELATIONS BETWEEN CASE STUDIES

- The stronger links:
  - **#1 *SMART POLE – BIRLOKI***
  - #2 21 SWINGS – ACTIWAIT
  - #3 MURMUR WALL - THE HEART OF THE CITY
- The most referred projects:
  - **#1 *21 SWINGS***
  - #2 *RESPONSIVE PUBLIC SPACE*
  - #3 *TREE.0*
  - #4 *BENCHMARK*
- The project ***BEACON*** has no incoming links (related project)
- The most used keywords:
  - **#1 Urban Furniture**
  - #2 Public Open Space
  - #3 Human Tracking
  - #4 Social Interaction
- The keywords more often ranked on top:
  - **#1 Smart City**
  - #2 Sensor Box
  - #3 Big Screen
  - #4 Art Installation



3.1 Results from cross readings

CONTEXT

Informative Performative Functional
Permanent Ephemeral
Public Private
Interior Exterior
Small Medium Big
Mobile

SCOPE

Social
Governance
Environment
Mobility
Commercial

DESIGN PRINCIPLES

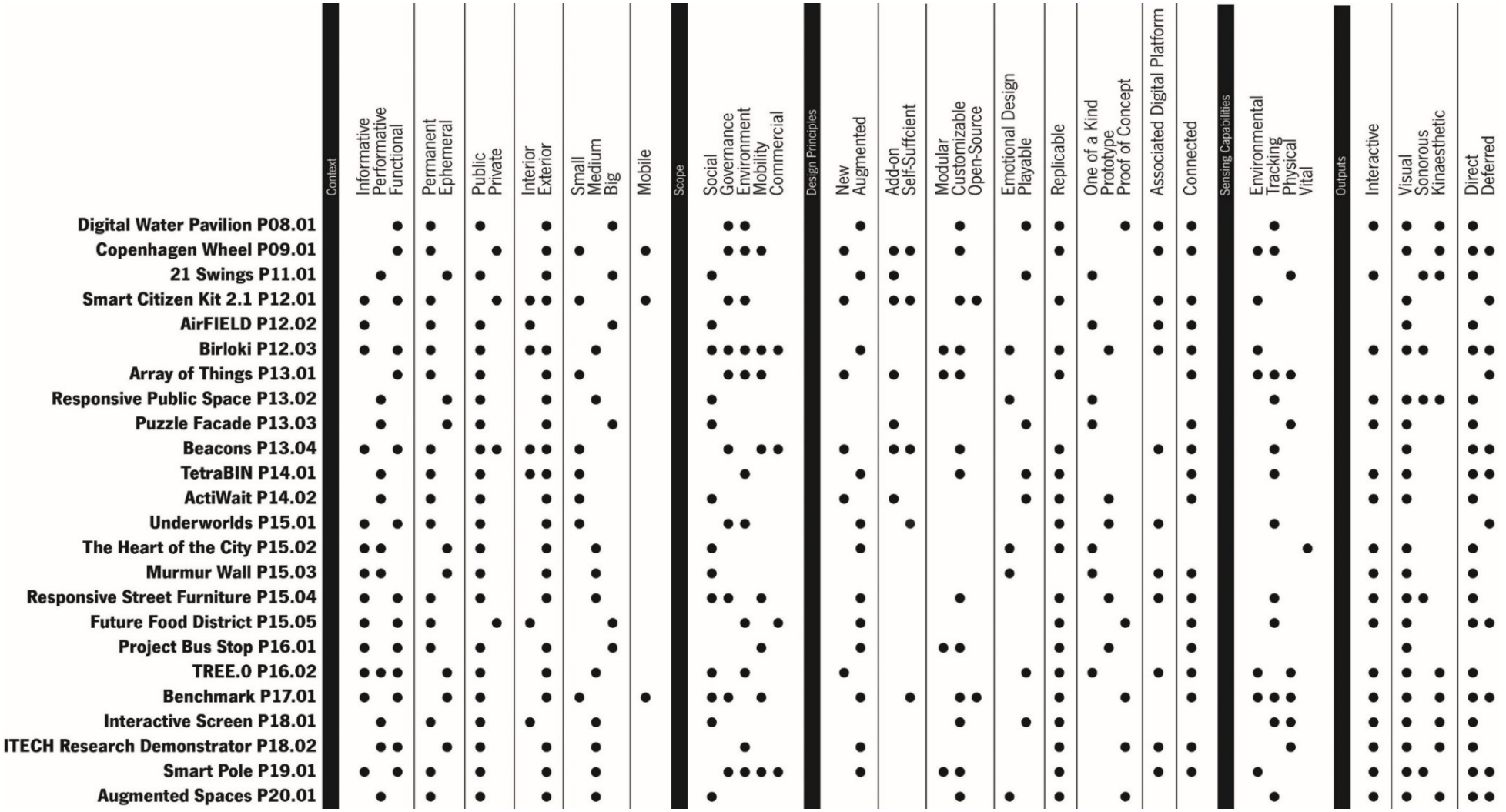
New Augmented
Add-on Self-sufficient
Modular Customizable Open-Source
Emotional Design Playable
Replicable
One of a Kind Prototype Proof of Concept
Associated Digital Platform
Connected

SENSING CAPABILITIES

Environmental
Tracking
Physical
Vital

OUTPUTS

Interactive
Visual Sonorous Kinaesthetic
Direct Deferred



3.1 Results from cross readings

[Object]

Design principles

- Multidisciplinary and codesign approaches;
- Playfulness, Gamification and Emotional Design (shape, interface and media content);
- Adaptability: modular design and/or mass customization (shape and ICT infrastructure);
- Open-source, open-data and data visualization.

Shape and material

- No typical size, scale or deployment strategy;
- User interaction mostly happens at human scale;
- Many interfaces are designed for urban scale (being seen from far, turning public the interaction);
- Simple and rectilinear shapes (industrial materials and fabrication methods;
- Some organic and metaphorical shapes (e.g., trees, hearts or animal).


©Birloki


©Smart Citizen Kit

3.1 Results from cross readings

[Object]

Sensors and connectivity

- Mostly environmental, interface and tracking sensors;
- Most collect real-time data (or simulate it by harvesting online data);
- Most used interface is the (touch) screen, from small tablet like to big floor screens;
- Sensor data can be used locally and discarded, or stored in a server;
- UCPDs connectivity with personal devices is mainly Bluetooth/BLE.

Specific functioning (interface)

- Interaction with UCPDs via soundscapes, lightscapes and personal device wireless linkage (QR codes, Beacons, Bluetooth);
- Interfaces escapes the common PC experience with gamification of common activities in public space;
- Synesthetic experiences (body as interface);
- Alternative ways of displaying information;
- Data handling manages: Personal and site sensitive data security (legal issues); Communication network and data storage; Energy consumption of systems' maintenance.

3.1 Results from cross readings

[Context]

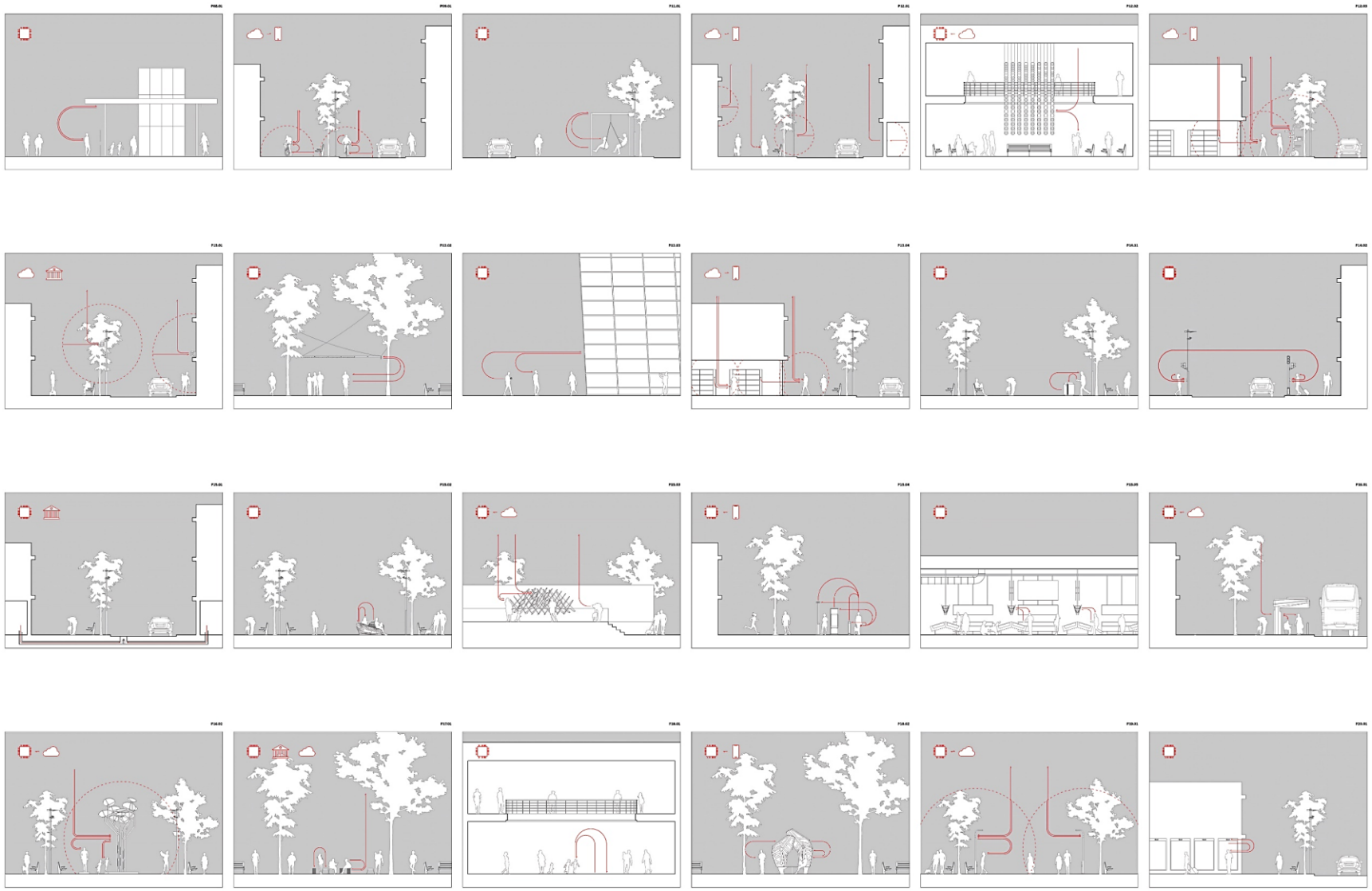
Context (Place)

- Issues addressed: environmental sustainability, public participation and recreation, community resilience and security;
- Installed in public open spaces seeking for high activity or pedestrian flow (e.g., squares, boulevards or important street intersections);
- Few are installed in segregated spaces, aiming at their activation;
- Others are connected to indoor activities and entertainment, or are mobile (not site specific);
- Most devices are designed to interact directly with pedestrians (instead of cars or traffic);
- A fruitful trend targets disabled people and assisted living in public space;
- Cyber contexts (network scale) vary from direct physical interfacing, or in-place mobile device pairing, to global internet connectivity;
- The deployment time frame of research or artistic based interventions is short. Functional and industrialized products are designed to endure harsh outdoor conditions for long periods.

3.1 Results from cross readings

[Context]

Context (Place)



3.1 Results from cross readings

[Context]

Induced transformation

- Physical presence is the only tangible direct transformation in the public space perception;
- Data collection is the base of governance informed decision-making (that leads to other tangible and intangible transformations);
- Behavioural change, namely sustainability awareness, is an indirect transformation;
- Social inclusion, encouraging rupture of bias and prejudice;
- Urban setting activation (foments social interaction and permanence);
- Facilitation of quotidian tasks;
- Enhancement of city infrastructures that can improve safety and impaired inclusion.

3.1 Results from cross readings

[Review]

Success factors and strategies to counteract obsolescence

- Opportune timing and placement (where interaction is welcomed);
- Design quality and physical affordances (fall-back against digital obsolescence);
- Enjoyable experiences and discovery through emotional design;
- Perceived utility of the device, inclusive goals and intuitive interface;
- Open-source design strategies.

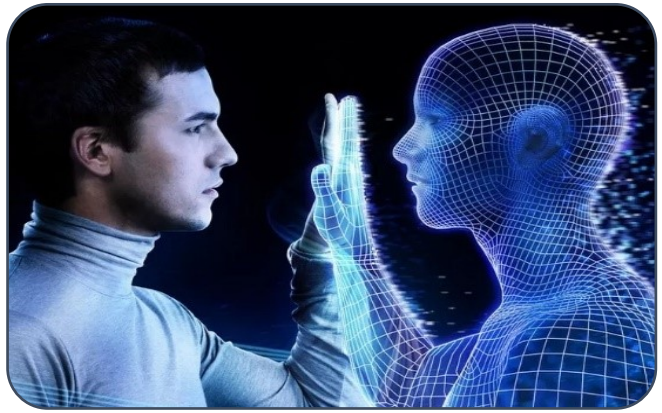
Issues

- Cost effectiveness and counterproductive dependencies;
- Inequality of access, digital illiteracy or the users bodily condition;
- User safety, both user's physical and personal data security;
- Ecological impact of UCPDs fabrication and energetic consumption.

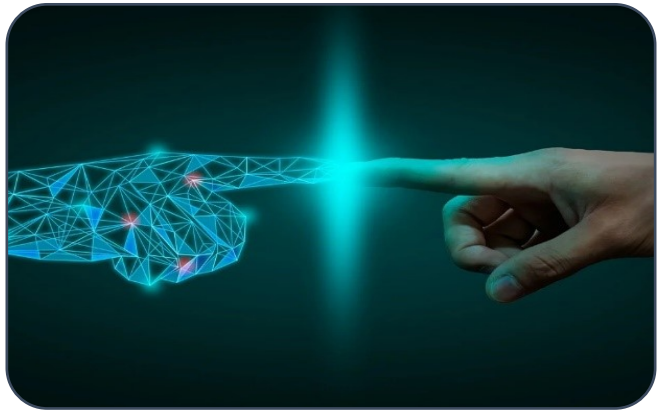
©Responsive Street Furniture

©Digital Water Pavilion

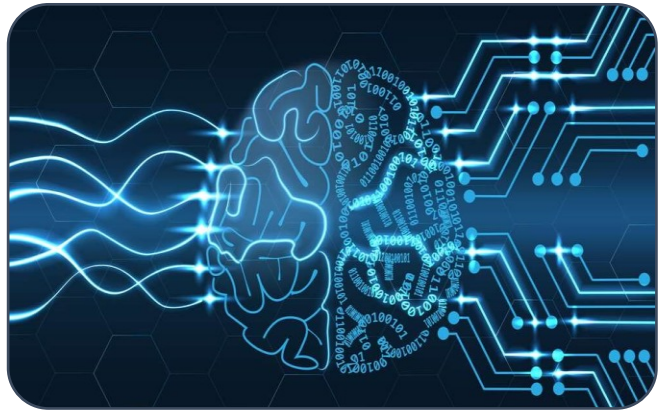
4. THREE CYBER-PHYSICAL META CONCEPTS



Digital twin

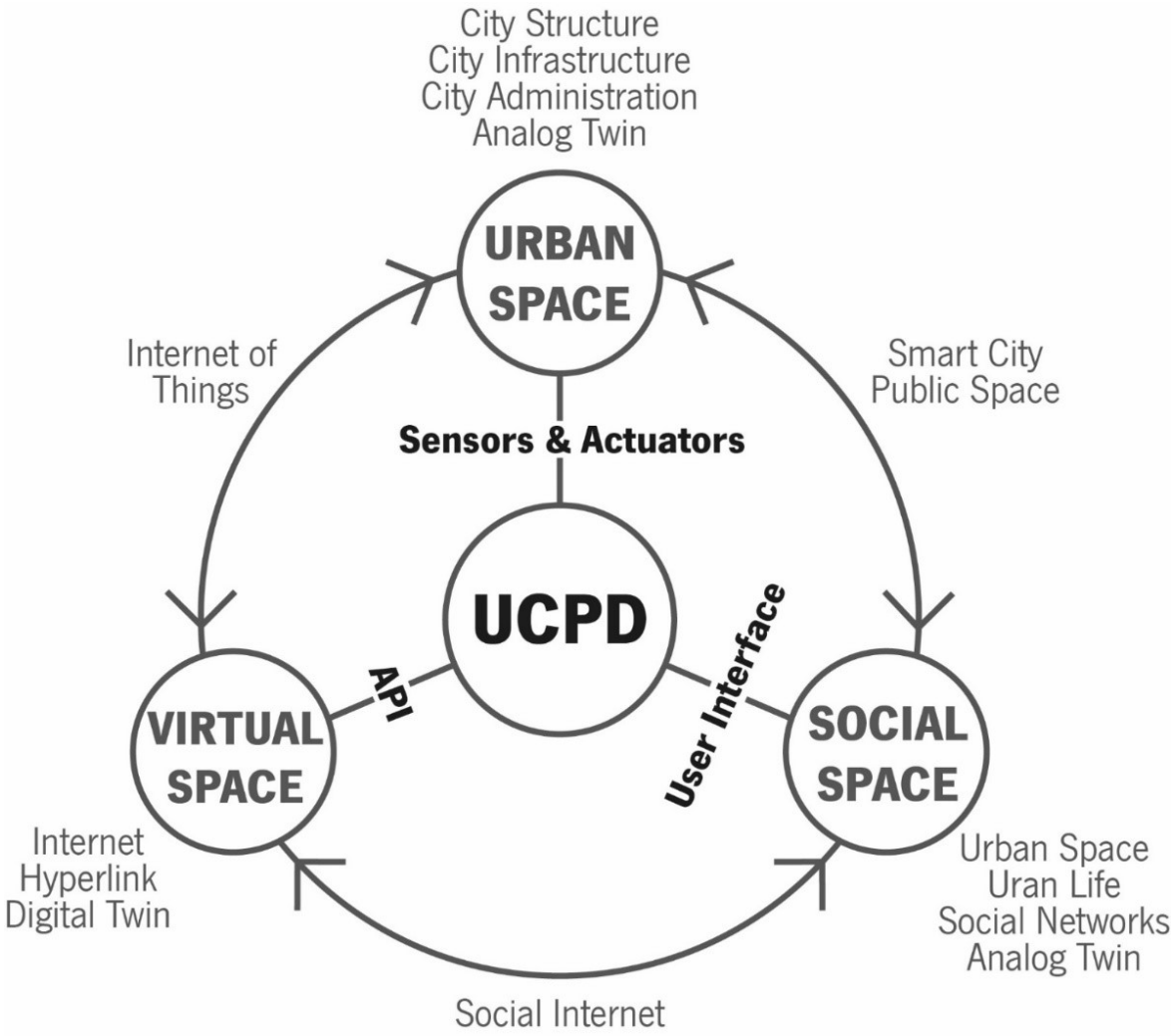


Interface



Awareness

4. THREE CYBER-PHYSICAL META CONCEPTS



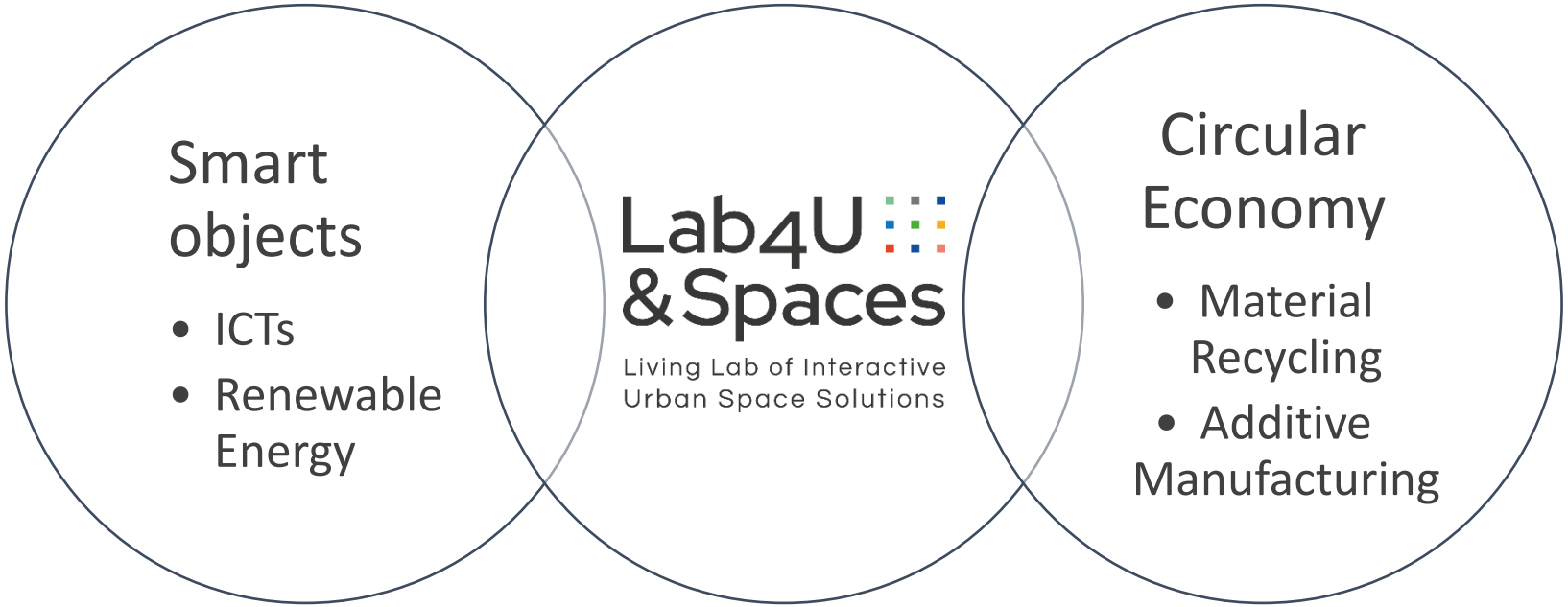
4.1 The rising of new (and remediated) types of urban devices

Sensor Boxes

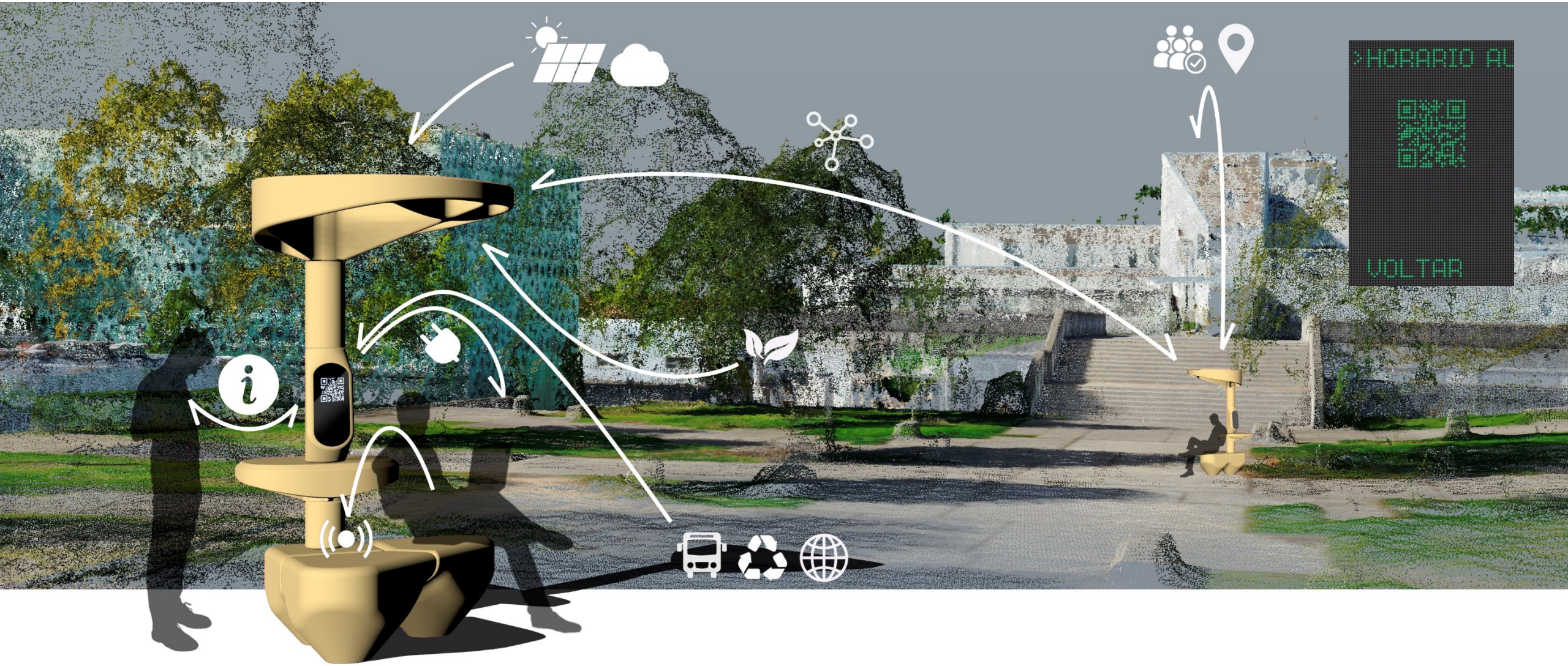
Smart Trees

Public Chargers

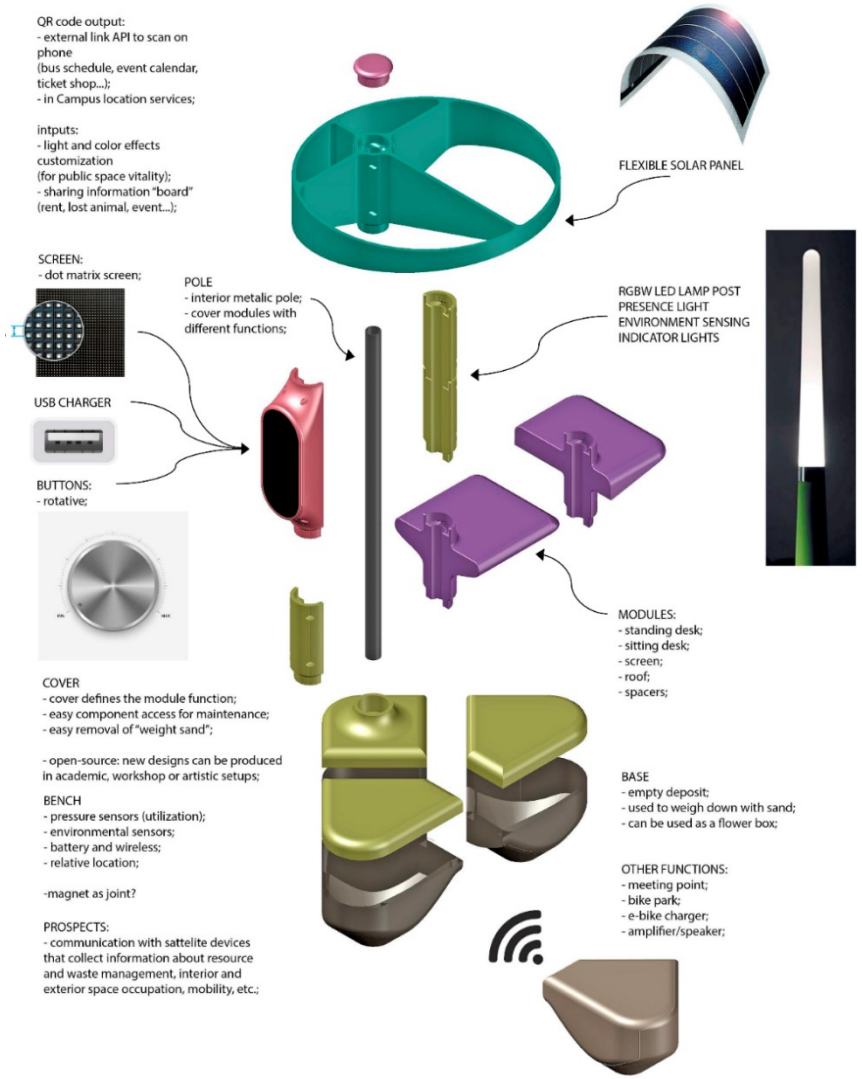
5. The Research Project Demonstrator

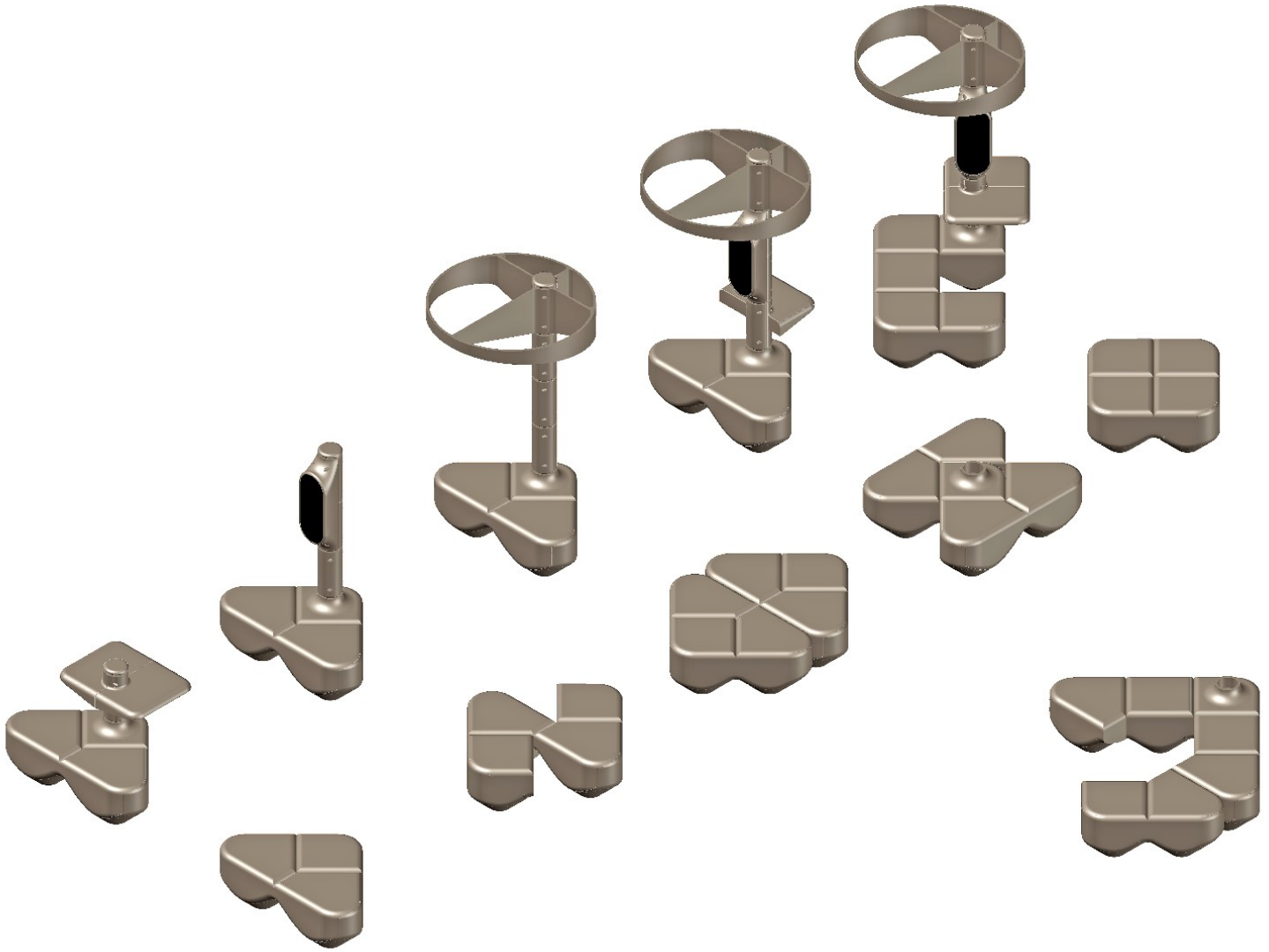


5. The Research Project Demonstrator

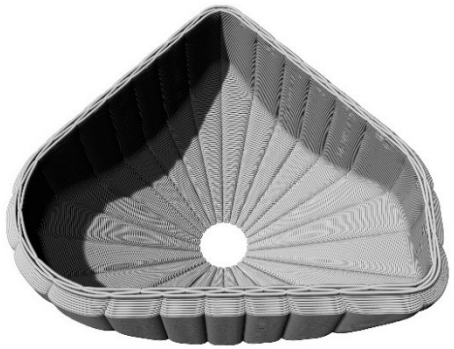


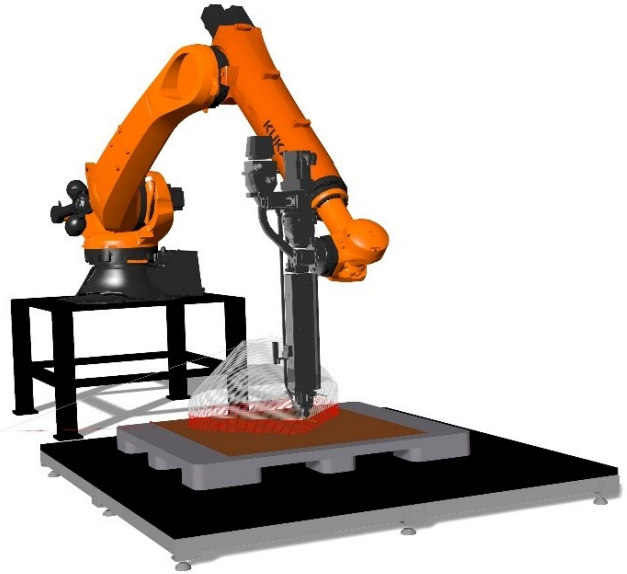
5. The Research Project Demonstrator

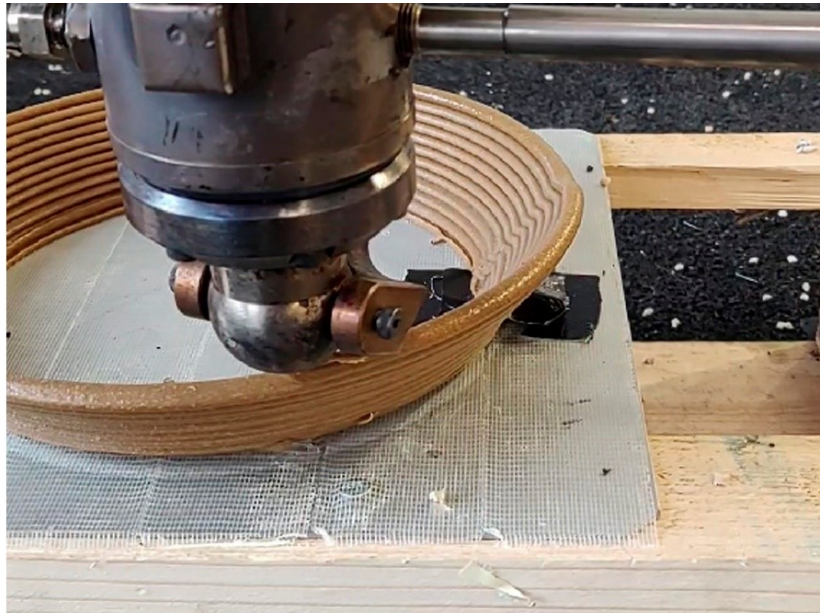




5. The Research Project Demonstrator







6. DISCUSSION AND CONCLUSION

- The Atlas reveals examples of how the dynamics between physical and digital spaces, are allowing the reviving of public space.
- The Atlas provides a perspective on new ICT mediated relations between citizens in public space, that allow to pursue SGDs with innovative strategies for inclusion, local economic opportunity and sustainability awareness.
- UCPDs have the potential to open public space to the most vulnerable.
- They develop digital literacy, community participation and environmental action.
- These devices also contribute to a reinvention and diversification of uses and activities in public space.
- As most of UCPDs are urban data sensors, they provide (big) data that also becomes a local social and economic opportunity.
- Many of the case studies in the Atlas depends on considerable financial, material and energy resources, and although sustainability problems are main design motivations, these concerns are not equally reflected in the production of the devices themselves.

The lessons learned from the Atlas fed the demonstrators' requirements and design guidelines, balancing digital integration and physical affordances, as well as needed resources and expected results.

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List of links to Atlas projects’ case studies in the web:

[1] https://carloratti.com/project/digital-water-pavilion/
[2] https://www.senseable.mit.edu/copenhagenwheel/
[3] https://www.dailytouslesjours.com/en/work/musical-swings/
[4] https://www.smartcitizen.me/
[5] https://ueberall.us/portfolio/airfield/
[6] https://www.juansadaba.com/projectbirloki/
[7] http://www.arrayofthings.github.io/
[8] https://www.ortlos.com/projects/responsive-public-space/
[9] http://www.puzzlefacade.info/
[10] https://developer.apple.com/ibeacon/
[11] http://www.tetrabin.com/
[12] http://www.urban-invention.com/
[13] http://www.underworlds.mit.edu/
[14] https://www.anaisafranco.com/heartofthecity/
[15] http://www.future-cities-lab.net/murmurwall/
[16] http://www.rossatkin.com/wp/?portfolio=responsive-street-furniture/
[17] https://carloratti.com/project/future-food-district/
[18] https://www.dpa.com.sg/projects/projectbusstop/
[19] https://interactivespaces.dk/tree-0/
[20] http://benchmark.mit.edu/
[21] https://www.trisonworld.com/en/projects/trison-digitalise-shopping-center-arenas-barcelona/
[22] https://www.itke.uni-stuttgart.de/research/icd-itke-research-pavilions/itech-research-demonstrator-2018-19/
[23] https://www.elkoep.com/smart-pole-in/
[24] http://www.ecaade2021.ftn.uns.ac.rs/session-16/

Lab4U &Spaces

Living Lab of Interactive Urban Space Solutions

Thank you

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