How to Design the Internet of Buildings?

An Agile Design Process for Making the Good City

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Abstract: In the context of data driven cities, this paper introduces the notion of an "Internet of Buildings" (IoB), and discusses the potential of connected devices, sensor networks and data analysis to support the purposeful design and development of a livable, well-designed urban environment. The key argument of this paper is that today's Internet of Buildings (IoB) permits the collection and analysis of rich data sets on users and usage, on building and city performance, thereby providing a reliable basis for design decisions and strategies that not only improve design processes, but also enable a more user-oriented, participative and human-centric approach. In addition, this article argues for a responsible and reflexive usage of data generated in living environments and for data literacy in the context of urban design and development. The key challenge addressed in this paper is how to translate urban data into design knowledge. To provide an answer to this important question, this article introduces a new methodology that links urban design, urban data, and the operational modelling of cities to an evidence-based, agile urban development process. On that basis, the article introduces the two tools of "BuildingID" and "UrbanOperationsModel" (UOM) – key instruments for data-based development and oriented towards the "good city" of the future.

Keywords: Internet of Buildings; cyber-physical systems; urban data; building information; urban operations.

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1. Introduction

Approximately a decade ago, the shift towards information society and ubiquitous data technology originated the term "smart city". This debate is supported by various predictions foreseeing a dramatic increase in the number of intelligent and networked objects in an urban context. Gartner Symposium ITxpo[1] has announced a 200% increase by 2020 with respect to 2016, while companies like Cisco announce even higher figures. A central tenet of the Smart City, largely technology driven, is the integration of ICT systems for creating synergies and improved urban quality of life (Batty et al. 2012, 483-518). Yet, multiple urban challenges accompany this development: how can Cyber-Physical Systems (CPS), the Internet of Things (IoT)[2] or the Internet of Everything (IoE)[3] meaningfully support the development of well-organized urban systems with a high quality of living, engagement, and social cohesion? So far, IoT applications are driven by the IT industry and digital business world. Urban environments and operations have only recently come into focus as strategic fields of application.

To highlight this new trend towards networked buildings and urban spaces, we introduce the term "Internet of Buildings" (IoB)[4]. We maintain that it is necessary to establish a focused debate on connected buildings and urban technologies from the perspective of an urban planner and architectural designer, given that digital technologies will have a direct impact not only on visual appearance, on functional infrastructures of buildings and cities, and on the operations and performance of cities, but also on professional key practices such as creative design, concept-creation and planning. Evidence-based practices are emerging that characterize design and planning activities as services, based on urban and building information, and on public and institutional data.

A telling indication can be given by the example of Sidewalk Labs, a Google/Alphabet spin-off[5]. The mother company clearly anticipates profitable opportunities in the field of digital urban services. Among other powerful applications and technologies, it has established urban mapping and home sensing systems, as highlighted by the acquisition of the sensor

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[1] See http://www.gartner.com/newsroom/id/3175418 (retrieved March 22, 2017).

[2] IoT is the vision of a ubiquitous digital machine to machine network connecting a high amount of everyday 'smart' objects embedded with sensors and processors to collect, exchange and combine data. There is no common consensus on how to systematically transform the data generated into social or economic value.

[3] The 'Internet of Everything' is an extension of the term 'Internet of Things', established in 2013 by IT company Cisco. In contrast to the Internet of Things, it implies not only connections of computer systems, but also of people, and the usage of behavior information measured by smart gadgets (cf. http://ioeassessment.cisco.com/).

[4] IoB consists of systematic and hierarchical structures with a clearly defined goal. It is a scalable network of relationships between quarters, streets, buildings, apartments, social life and quantitative physical factors like climate and air/water quality, aiming to get a profound understanding of the complex interplay of urban life. IoB can be considered a subordinate component of an IoT infrastructure.

[5] See https://www.sidewalklabs.com (retrieved March 22, 2017).

company Nest in 2015. Now, Sidewalk Labs is creating platforms for urban analysis based on data collected via these services. Apart from the specific urban services already up and running (e.g. optimizing traffic and transportation flow), the company is expected to commence experiments in data-driven urban design and city management with full-scale test projects soon. This is in line with large-scale digital city experiments such as WeSense by the Amsterdam Institute for Advanced Metropolitan Solutions[6]. This integrated data platform maps citizens' perceptions, use and evaluation of the public environment in Amsterdam. Another indicative project is City Keys (2017) which defines citizens' needs, analyzes results, and generates design recommendations by way of using performance indicators. These, in turn, are informed by sensor data from large urban areas in Europe. Also of note in the aforementioned Dutch city is the world's largest data bank of Smart city projects, the Amsterdam Smart City Platform[7].

Despite their rapid development in the field of ICT, Smart City projects and activities have created few links to the classical domains of urban design, architecture, and spatial planning in relation to procedures and methodologies. There is a surprising disconnection between the emerging digital city with its ubiquitous ICT components on the one hand, and the traditional design and planning processes for the physical city on the other hand. While new communication and information technologies gain ever more importance in personal and social life, aspects of urban life such as building construction, the public realm, and the provision of social or cultural facilities remain central concerns of the citizenry.

The authors perspective derives from a formal architectural training in various academic institutions (Germany, Austria, Japan, Poland, Czech Rep.) and design practice at an international level, ranging from architectural competitions to construction projects. With the exception of design tools like CAD, parametric design software and Building Information Modelling (BIM), the practice of urban and architectural design rarely integrates "smart" IoT or CPS technologies[8], which are traditionally not regarded as components in conventional design practice or education. We observe two directions; the first seeking to digitalize the built environment versus the main second direction continuing to revere human intuition and aesthetics as the sole methodological instruments of design. This latter direction is based on the principle that architecture is a discipline between science and art, and which can only be truly understood by professionals. Few research institutions actively engage in cross-disciplinary research combining design and IT (e.g. MIT Media Lab, HCU City Science Lab or the Institute for Computational Design and Construction of TU Stuttgart).

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[6] http://www.wesense-app.com/wp-content/uploads/WeSense_artikel–energie–spektrum_en.pdf (retrieved March 22, 2017).

[7] See https://amsterdamsmartcity.com/ (retrieved March 22, 2017).

[8] One example is the 'Smart Home' promoted by huge technology companies like Samsung or Bosch.

Consequently, the greater part of the profession resists current developments concerning advancing digitalization and automation. Perusing the latest architectural journals (such as “Bauwelt” 20/2017, “Detail” 10/2017, “Architectural Review” september 2017 and “Arch+” 229) there is a disproportionally small amount of discussion on ICT in the building sector.

As a result, the approach presented in this paper attempts to connect the domains of data technology and data science with planning and design sciences. The central question is how to inform and support user-oriented design work at the urban scale with data acquired from buildings and public spaces. In other words: how to derive qualitative design decisions from data collection and analysis?

As a starting point for the creation of a methodology that comprehensively uses urban data in urban design, we hypothesize that the goal of urban design and development should be the “making of the good city”. Following Jane Jacobs (1961), Ray Oldenburg (1999) and Edward Glaeser (2011), a good city can be summarized as a multitude of rich, lively, adaptable and organically developing places. Its structures and spaces grow steadily and incrementally, and possess the capacity to respond to the changing needs and emotions of its inhabitants. The development of historical cities with high urban quality (e.g. Italian Renaissance towns like Florence or Siena) is in stark contrast to current ad hoc developments, which often result in generic neighborhoods with low urban quality, uniform typologies and building patterns. Rapid land development and speculative investments have replaced the organic processes of urban self-organization and construction. Due to the financialization of the urban environment as a means of private property management, the social, emotional, and cultural needs of residents and inhabitants as key users of cities are often insufficiently respected. Due to well-established processes in real estate business, large districts are developed in a short timeframe without reference to local culture, history, or society. This leads to disconnected, insufficiently integrated urban quarters with low quality of life over long-time spans.

As a counter-reaction, however, alternative approaches such as incremental and participative planning have emerged, a trend that can be supported by advanced information and communication technology (ICT). For example, a Horizon2020 project called U_CODE Urban Collective Design Environment[9] will deploy a participatory platform for the purpose of co-creating urban environments on a massive scale enabled by digital technologies. Here, urban designers, architects and developers will collaboratively design and communicate projects with the various public stakeholder groups.

In ancient Greek towns, the emergence of agoras triggered communication between the citizens, pushing forward the public and democratic debate. Habermas (1989) calls public areas where social life comes together

[9] See http://www.u-code.eu/ (retrieved March 22, 2017).

as the "public sphere". Correspondingly, Oldenburg (1999, 22) defines those areas as the "neutral ground upon which people may gather", calling them "the third place", with the first place being "home" and the second "work". The main activity on neutral grounds is the informal conversation between citizens that forms a collective understanding of society, innovation, and diversity, as well as the "formation of public opinion, conference about matters of general interest or debate over general rules governing relations" (Habermas 1989, 27). This kind of social gathering forms the basis for raising quality of life in cities. Through public deliberation, factors defining quality of life like recreation areas, functioning infrastructure and a vibrant economy can evolve.

There are numerous examples of neutral grounds in different cultures, e.g. the French bistro, the German beer-garden, the English pub or the American main street (Oldenburg 1999). These examples show that not only actual urban places, but also business ventures can enable the public sphere. Historical towns like Siena or Florence developed a multitude of (third) places triggering the growth of a diverse society with complex urban interplay between voids and buildings. This process must develop over time and cannot be set up in ad-hoc developments. The prerequisite is the acceptance of those places as neutral grounds by society. Bridging the gap between the historic and the contemporary town we believe that "third places" necessarily do not need to be physical. Rather, they can be digital, and more importantly for future urban development, a combination of both. This fusion of digital and physical neutral ground can be defined as "hyperlocal forums".

Current digital urban infrastructures and algorithms model citizens mainly as "living sensors" or network clients within a larger cyber-physical system, which represents a narrow understanding of the interplay between human activity and the quality of the urban environment (Farías and Blok 2016). Data-driven urban design which works towards the Good City maximizes not only the gains on the side of technology vendors, but also expands the reach of political power and the roles and responsibilities of the social groups, neighborhoods, and communities that need to be defined with respect to urban data generation, governance, and utilization.

The key approach taken here may be called creative urban data literacy, as it implies the practical and creative usage of self-generated urban data by the local community. The goal is to pave a way towards hyperlocal forums that connect and empower citizens as individual data entrepreneurs, creative urban hackers, or service providers. Also in digital terms, cities need to be developed on a district-by-district basis, leading to a replacement of the neoliberal top-down approach. The "right to infrastructure" (Corsín Jiménez 2014), as derived from Lefebvre's "right to the city", also implies new forms of digital collaboration, as exemplified by fab-labs or hack-labs, for example. Such infrastructural enablers empower bottom-up development, or soft digital urbanism. Through the systematic extension of know-how and information, the simplification of construction processes and juridical frameworks, citizens can be enabled to design and build cities on the basis of their own data. Collective experimentation with urban data renders cities as socio-technical assemblages open to contingent political contestation (Jiménez 2014), created through digital participation and knowledge production, and its subsequent validation in terms of urban products and services. The concept of "urban learning forums" (McFarlane 2011) outlines such possibilities in urban planning. Ideally, such methodology might lead to self-sufficient communities even at the level of data-production and consumption, with a hybrid forum serving as a place for knowledge exchange between experts and lay people (Callon, Lascoumes and Barthe 2009).

Accordingly, the scheme proposed in our paper builds upon the idea of a hyperlocal community, or a "Quarter Community" which, via digital technologies, is able to recognize and interpret subjective indicators such as procedural constraints for urban development. Here, subjective and hybrid data generation that does not reduce citizens to passive objects of digital technology forms the core of the urban data community. We regard the human subjective dimension an enhancement of the objectivized, Euclidian urban space which still forms the basis for most conventional architectural and urbanist representations (Latour and Yaneva 2008).

2. Data for the Good City

2.1 The Livable City

The "good city" implies qualitative goals for urban development. Allan Jacobs and Donald Appleyard have defined a value framework for the good urban environment with seven characteristics: livability, identity and control, access to opportunity, imagination and joy, authenticity and meaning, open communities and public life, self-reliance, and justice (Jacobs and Appleyard 1987, 115-116). This indicates that a Good City shall not be equated solely with a Livable City, as the latter appears to be a subcategory among other influential values. A good urban environment balances these goals on both an individual and collective level (Jacobs and Appleyard 1987, 112-120).

For livability, there is certainly no universal definition. Charles Landry (2000, 21) points out that the inhabitants of Northern cities have higher standards of living and therefore can consider clean air, public realm, or cultural facilities as key quality of life factors for livability, whereas in poorer places quality of life is related to work and the education system, or infrastructure. Taking this relativity into consideration, indexes for livability (Quality of Life) have emerged in recent decades, measuring livability and its associated factors.

2.2 Quality of Life – Objective and Subjective Indicators

Quality of Life indexes utilize different benchmarking procedures to rank cities and countries. Relevant indexes for this approach are the Human Development Index from the United Nations (HDI)[10], the Happy Planet Index from the Economics Foundation (2016), the Morgenstadt Index (Tomorrow's City Index) from the Fraunhofer Institute (IAO)[11], and the ISO 37120 from the World Council on City Data (WCCD)[12]. This last index is the first to work on the development of an international standard applicable to all cities. Both the Morgenstadt Index and ISO 37120 are useful for determining data for the "Good City", as they collect qualitative city data at the local level.

The Morgenstadt Index was created through a detailed investigation of publicly accessible indicators to form a holistic picture of the future viability of a city, and as a first basis for an in-depth analysis of urban neighborhoods. The proposed indicators cover four basic pillars on which a city must be based: quality of life, resilience, environmental protection and innovation potential. These pillars were broken down into 28 detailed indicators informing quality of life, and evaluated according to their absolute and relative values.

The ISO 37120 index by WCCD encompasses an international network of innovative cities using open data to create a platform that maps standardized urban metrics. It has the aim of pushing innovation forward and envisioning livable cities. Here, the indicators are categorized into 17 themes on city services and quality of life, such as environment, economy, education, and transportation.

Our research group has analyzed these indexes to determine which relevant data need to be collected and processed to inform the design and development of the "Good City".

These indexes and indicators gave useful indications on which urban data to collect and analyze, but they do not fully indicate the dynamics and progression of urban areas. The indexes are very global in nature; they measure society as a collective, but do not represent individual subjective perception. Quality of life and well-being, however, need to be related to dimensions on which an individual's living conditions can be measured, which may range from rather objective indicators (e.g. economic well-being, human capital) to more subjective indicators (e.g. social capital, personal satisfaction) (Giap, Thye and Aw 2014, 178). To assign to these hard-

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[10] Human Development Index (2016) [United Nations Development Programme], http://hdr.undp.org/en/2016-report/download (retrieved March 22, 2017).

[11] See the Fraunhofer Institut für Arbeitswissenschaft und Organisation, http-://www.morgenstadt.de/de/loesungen2/loesungen_staedte/morgenstadt_index.-html (retrieved March 22, 2017).

[12] See the World Council on City Data Foundations, http://www.dataforcities.org/wccd/ (retrieved March 22, 2017).

to-survey subjective data a higher impact, individual feelings concerning urban surroundings (joy, imagination, opportunity) require a better definition and description, such as through explicit measures for identity, diversity and social network dynamics (Landry 2000, 21).

Combined subjective and objective indicators which comprise both individual and collective experience provide for a meaningful utilization of urban data for the design of the "Good City". Although technologies for the collection of individual subjective information are still in their infancy, such urban data will represent city dynamics on a higher value level, and thus positively inform urban interventions. Collected and analyzed by Internet of Building technologies, their very value may arise from short-term (soft) spatial interventions as well as from long-term, permanent deployment. In both cases, they supply the development of urban areas with user experience and citizen knowledge. "Livehoods"[13] is a current example for mapping social dynamics, structure, and character through the analysis of users' behavior data in diverse cities. Here, the aim is to observe patterns in locations across the city to map different dynamic areas using social media check-ins. Accordingly, the hypothesis is that an individual Livehood's character is shaped not only by objective data, but also through the subjective behavior of citizens.

3. Key Questions

We have developed our methodology for data-driven urban design with three questions in mind:

- *Identification:* Which data are relevant for designing good urban quarters?
- *Acquisition:* How to systematically collect relevant data in urban environments?
- *Intelligence:* How to derive design knowledge from collected data?

3.1 Identification: Which Data Are Relevant for Urban Design?

We examined the Morgenstadt and ISO 37120 indices and devised a comparative representation. Based on relevant urban design categories, all related information from the indexes were assembled into one table. The table has been extended by further data, not yet covered by these indexes like food quality to mirror broader economic and social relevance in the districts[14]. The resulting shortlist of key data to be collected from urban

[13] http://livehoods.org (retrieved March 22, 2017).

[14] See Government of Canada, Agriculture and Agri-Food http://www.agr.gc.-ca/eng/industry-markets-and-trade/statistics-and-market-information/agriculture-

and building environments can serve as a basis for decision-making in urban design and planning (see Table 1). The table is divided into the City Data section which comprises information referring to the natural and artificial environment collected with quantitative methods (e.g. statistics, remote sensing, observations) reported as values or numbers, and the Individual Data section which comprises relational information on individuals and communities connected to their immediate environment collected via qualitative methods (e.g. surveys, questionnaires, interviews, gamification). Both data types are interrelated and can be juxtaposed. To get more detailed insights, both data types (City Data & Individual Data) can be recombined: e.g. combining data about "Square meters of recreation & green space" with "Individual perception about the atmosphere of recreation & green spaces" could lead to the new data set "Efficiency of distribution of green spaces in a city". Furthermore, the combination of the juxtaposed data sets "Number of businesses" with "Individual impressions about availability of businesses and services in a city"« could lead to the data set "Diversity and fair distribution of businesses and services in a city". Recombination and mining for data relations will be necessary to approach a comprehensive understanding.

3.2 Acquisition: How to Systematically Collect Relevant Data in Urban Environments?

A major challenge for data-driven urban design is the definition of appropriate sources from which design-relevant data can be collected. Thus, we have further differentiated data resources according to their dynamics. First, there are resources like municipal archives holding data collected and structured over long periods. Second, there are streaming data of events and processes, such as comments on social networks or real-time mobility data.

A metaphor for stored and structured (Big Urban Data) data collection is the so-called data lake which constantly accumulates data, having a physical limit and time delay. In contrast, the real-time data stream (Smart Urban Data) resembles a river whose items pass by quickly and disable long term storage or permanent observation.

On a tentative basis, Table 2 shows data already available (marked green), data that are only available for authorities, like police or city departments (marked yellow) and data that imply technologies not yet developed (marked red).

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and-food-market-information-by-region/europe/market-intelligence/consumer-profile-germany/?id=1421933900883 (Retrieved March 22, 2017).

	City Data (Objective Data) Examples of data sets collected in a city with quantitative methods; reported as values or numbers	**Individual Data** (Subjective Data) Examples of data sets connected to the direct contemplated area of an individual; expressed as perception of the individual cognition area; collected with qualitative methods
Environment:	Squaremetres of recreation space & green spaces	Individual perception about the atmosphere of green spaces
	Fine particulate matter concentration / level of air pollution	Individual feeling about city's air quality
	Level of noise pollution	Individual feeling about the noise in direct surrounding
Economy:	Unemployment rate / average household income	Indivdual perception about monthly income
	Number of businesses	Individual impressions about availibility of businesses and services in the city
Population:	Percent of population that are child/adults/specific age	Individual impressions about the age, social and/or origin of people in social environment of a person
	Percent of population foreign born	Individual perception about the amount of foreigners meet in the direct social environment of a person
	Total number of households	Individual perception about the density of a city
Education:	Number of students completing school & number of higher education degrees	Individual impressions about the educational level of others in the social environment of a person
	Student / teacher ratio	Individual perception about teaching quality
Infrastructure:	Frequency of traffic jams	Individual perception about time spent in traffic jams
	Water quality and frequency of malfunctions	Individual perception about water waste in household/community
	Number & distribution of garbage collection points	Individual perception about quality of waste collection service
Governance:	Voter's participation in last municipal election	Individual perception about the work quality of local policy makers
	Number of police officers; Crime rate	Individual perception about the safety of the quarter
Transportation:	Number of personal automobiles	Individual need for a car
	Annual number of public transport trips per capita	Individual satisfaction about the quality of public transportation service
	Kilometres of bicycle & pedestrian paths or lanes	Individual impressions about the availibilty, usage and frequency of bicycle & pedestrian paths
Health:	Annual per capita expenditure for healthy (organic) food	Individual awareness about the need for healthy food
	Weight prevelance of population	Individual perception about health standard
	Number of doctors & health institutions	Individual satisfaction about the deployment of doctor's and about their quality of work (data source: work rating platforms)
Sustainability:	Total residential electrical energy use per capita	Individual energy consumption
	Use and development of renewable energy	Individual need for renewable energy
	Recycling quote (up-cycling) - quote of recycling for solid waste	Individual recycling habits
Culture:	Number of sport facilities	Individual possibility of access, quality and choice of sport opportunities
	Number of cultural spots and events	Individual possibility of access, awareness and perception of cultural offer
Building Function:	Age of a building	Individual perception about the appearance of the city
	Use of a building	Individual perception about the social environment settled in a building
Social Cohesion:	Number of social organizations	Individual perception about collective social engagement
	Annual number of direct democratic decissions	Individual possibility and willingness to participate in direct democratic decissions
	Number of cultural events	Individual perception about the local identity

Figure 1 – Urban data relevant for urban design and development.

	Stored & Structured Data Samples	**Real Time Streaming** Data Samples
City Data	**City's offices & authorities**	
	Urban Planning Office e.g. Development plans	**Smart Traffic Lights** e.g. Traffic / Pedestrian flow
	Cadaster office e.g. Collection of landowners	-
	Urban Cyber-Physical Systems (CPS)	
	Speed traps e.g. Cars number plates / Speed	**Buildings** e.g. Occupation, utilization
	-	**Urban Furniture** e.g. Climate / Pedestrian flow
	Municipal companies & services	
	Public transportation companies e.g. Fluctuation & frequency of passengers	**Public transportation companies** e.g. People's behavior
	Waste disposal companies e.g. Picked-up waste	**Waste disposal companies** e.g. Households producing different waste
	Public libraries e.g. Book turnover	**Public libraries** e.g. Frequency, room acceptance
	Private companies & services	
	Energy suppliers & Infrastructure e.g. Amount of used energy	**Energy suppliers & Infrastructure** e.g. Energy consumption
	Logistic post companies e.g. Number of delivered packages	**Logistic post companies** e.g. Delivery routes / Time needed for delivery
Individual Data	**Citizen's workshops**	**Citizen platform's**
	Participative planning workshops e.g. Citizen design ideas	**Co-Design Collaboration Platform** e.g. Engaged citizen groups
	Serious Urban Gaming e.g. Crowd design preferences	**Information / Idea Platforms** e.g. Idea collection for urban intervention
	Existing Platforms e.g. Social Media	
	Citizen Administration e.g. Opinions & feelings of citizen on Urban Environment	**Facebook, Twitter** e.g. Opinions & feelings of citizen on their neighborhood
	Urban Cyber-Physical Systems (CPS)	
	-	**Wi-Fi Kiosks** e.g. Wi-Fi user profiles
	-	**Home Sensors** e.g. Temperature, humidity, noise, air quality
	City's offices & authorities	
	Employment office e.g. Persons in full time employment	-
	Registration office e.g. Identification of citizens	**Registration office** e.g. Digital ID tracks
	Municipal companies & services	
	Schools & Universities e.g. Number of students graduating (dropout rate)	**Grading systems of schools and universities** e.g. Students' performance
	Private companies & services	
	Internet & mobile providers e.g. Number of signed contracts / Number of calls	**Internet & mobile providers** e.g. Location of cell phones
	Security companies e.g. Number of sold security products	**Security companies** e.g. Camera recordings / Door locking records

Figure 2 – Data resources according to their dynamics:
City Data vs. Individual Data.

The column "Stored and Structured Data" is of immediate relevance for city science due to its inferences of categories of urban quality. Open source platforms such as "Open City Smart"[15] allow for extensive collection and structuring of information, yet these formats and systems widely lack the standardization that would allow effective integration and processing of different kinds of (streaming) data. A serious obstacle is posed by the complex Graphical User Interfaces of these systems which require users, mostly urban planners, to work at the level of IT experts. From an urban design perspective, there is a clear need for data collection and analysis tools in combination with easy-to-use applications to support design creativity and decision making.

As a resource for the "Real Time Streaming Data" column, multiple sensor solutions already exist that allow real-time data collection. Many of these systems are designed for system maintenance, resource optimization, and technical control, but rarely for design intelligence.

Furthermore, data can be collected through surveying a community or society, such as in the "Quarter Community" proposed in this paper. Here it is necessary to first analyze the contexts and target group (e.g. via questionnaires) and to design an appropriate interface to address the community. This phase of (social) data acquisition is of key importance for the shaping of identity, and for identifying deficits as well as target qualities in the quarter.

3.3 Intelligence: How to Derive Design Knowledge from Data Collections?

In urban design and master planning, current practice is still widely based on subjective evidence. In most cases, only information relevant to planners is being considered in planning. Today, however, there is a chance to comprehensively collect data in response to actual needs. Data-oriented and evidence-based approaches provide an altogether new perspective in design disciplines. It is from here that the Internet of Buildings may find its biggest momentum. The multiplicity of available sensor systems (electronic, physical, social) in urban and architectural environments allow for a rich and target-oriented harvesting of design-relevant data. Systematically collected and structured, they form a reliable basis for design and decision making. However, the challenge of translating data into design is far from trivial.

How design intelligence can be derived from urban and environmental data is still unclear, despite a multiplicity of ongoing discourses on data-driven design. Focusing its research on this aspect, the WISSENSARCHITEKTUR Laboratory of Knowledge Architecture at TU Dresden endeavors not only to inform urban and architectural design, but also tech-

[15] https://wiki.osgeo.org/wiki/Opencitysmart (retrieved March 22, 2017).

nological development including sensors, communication media, and analytic systems. The method presented in this paper is a first step towards a design and development process that acknowledges data as a starting point for creative urbanist and architectural work, as well as for technological innovation.

3.3.1 Adopting Operations Modelling in Urbanism

In the past, many settlements and cities were built to last by the residents themselves. Today, however, cities and buildings have become objects of speculation with ever shorter expiration dates. However, cities remain places for the long-term production of cultural value, social wellbeing, and community cohesion. New urban operation systems are needed to maintain the creation and evolution of these urban qualities. From an operational point of view, cities can be seen as social enterprises that run a multiplicity of social, economic, environmental and other processes. Just as public or private ventures need to operate on sustainable plans, cities too must balance their forms of partnership, investments, expenditures, revenue streams, and value creation. It is important to highlight here that value does not necessarily mean maximizing monetary profit, but rather quality of life enhanced by technology and innovation. Cities are large-scale social ventures, and therefore not merely objects of short-term investment, real estate speculation, and fast-track profit.

On this assumption, we have adapted methods of operations modelling from the field of urban management and development and termed it "Urban Operations Modelling" (UOM). UOM is a method that models complex urban operations and services, and assesses them for their urban quality as well as their economic feasibility. While UOM may be applied to all kinds of urban services, this paper holds that urban and architectural design is a value-creating public service, which may yield greater benefits by utilizing urban data.

A key reference for the UOM is a creative method developed in the context of innovation management that schemes and validates operations and business design of enterprises (Osterwalder and Pigneur 2010). The method was re-modelled by its originators into a highly popular "canvas" tool (see Figure 3). As a decision-making tool, the canvas has become a new standard for policy makers, public bodies, and enterprises, as it is easy to comprehend and already works effectively at the prototype stage. The canvas gives a well-structured overview of all necessary items for planning a venture of any kind. The left-hand side ("Enterprise") and the right-hand side ("Market") are connected via a central column "Value Proposition" – a representation of the values created by the enterprise, and estimated by user or clients. The aspects on the enterprise section include Key Partners, Key Activities, Key Resources, and Costs. The parts on the market section define Customers, Customer Relationships, Channels and Revenue

Streams. The arrangement of the canvas enables rapid definition of the individual components, and also the quick outline of their connections. As a result, the canvas sheds light on the level of integrity of the venture at stake.

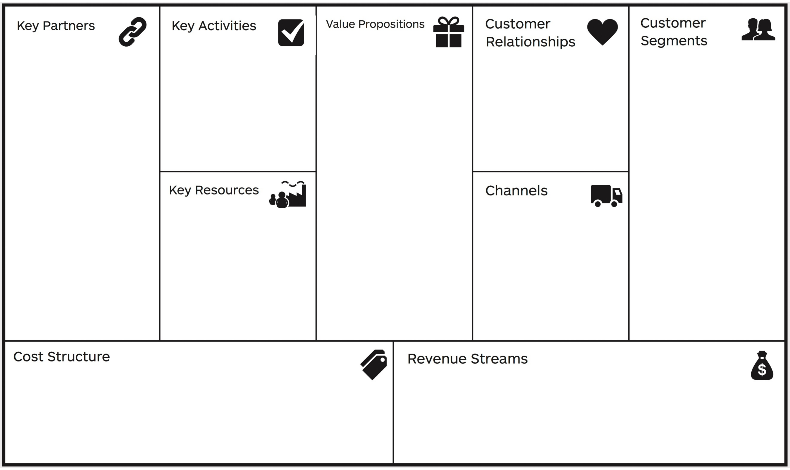

Figure 3 – The Business Model Canvas (source: strategyzer.com).

By viewing the components of the canvas from an urbanist perspective rather than an entrepreneurial perspective, the tool and method can be adapted to issues of urban development and management where it may be applied to all scales. This includes urban micro-business operations as well as the maintenance of large-scale urban infrastructures needed to fulfill conditions such as feasibility, value creation, and resource-effectiveness.

A possible complication of adapting a business model canvas, based on explicit rules, is that it may inhibit creative design decision-making. By outsourcing and decentralizing the decisions to a wider range of participants, such as a "Quarter Community", these rules might be supplemented by a consensus of implicit design ideas.

3.3.2 Urban Operations Model

The UOM helps to outline the otherwise hidden operational structures of cities which form the basis for their successful spatial and physical development. At the Wissens-Architektur Laboratory of Knowledge Architecture, we have sampled historical cases of prosperous cities, and demonstrated how UOM-descriptions can be applied as an analytic tool. We could show that vital cities usually possess a well-integrated urban operation system. Examples are plenty: Hellenistic Athens, the cities of the Hanseatic League, the transcontinental city corridor along the Silk Road, the creative city of Florence in the 15th century, or the city of Amsterdam as a center of trade of the 17th century. These cities were running on operational models that balanced partnerships, resources, markets, channels to accumulate and amplify knowledge and cultural production as well as wealth and political power.

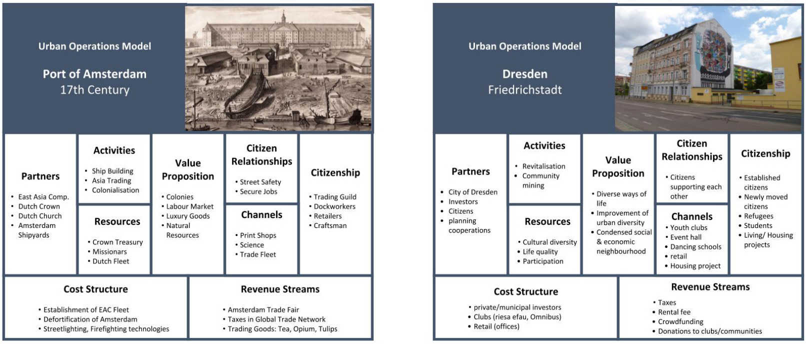

Figure 4 – Urban Operations Models for the Port of Amsterdam, 17th century (left) and for the contemporary Friedrichstadt residential quarter in Dresden (right).

However, these cities did not build their success on data and information technology which may be assumed a key resource and ingredient for UOMs in the 20th and 21st century. Arguably, no operational model and development scheme can be composed for cities, quarters, and buildings in the future without reference to digital data. The current capacity of data analytics, legal access to necessary data and the quality of available data may limit UOMs. We have extended the UOMs by processes of data acquisition and processing, and have shown how to integrate digital assets into the overall operations model of individual quarters or buildings.

The difference between urban and enterprise operations models lies in their different purpose as well as in the scale and application of the individual components. UOM consider socio-cultural benefits as prominent value propositions. Furthermore, certain original components need to be appropriated. “Customers” may be replaced with “Citizens”, indicating the urban context of the models.

3.3.3 Data Exploitation – Building ID and Quarter ID

The UOM, once established and comprising environmental as well as social datasets (City Data, Individual Data), needs to be analyzed and evaluated on a qualitative and quantitative basis. To do so, we introduced the “Building resp. Quarter ID” (BID / QID) (see Figure 5) as a visualization tool to describe this relationship. BID and QID are a kind of passport for the Internet of Buildings: they summarize all the indicators shown in Table

1 and rank their values. The aim of BID / QID is to valorize data linkages and create value for the various stakeholder groups such as citizens, planners, facility managers. The BID / QID thus functions either as an information display, aid, or a decision-making tool. Every new physical intervention, both temporary or permanent, alters the digital image of the BID / QID. While QID operates on a District-to-District basis, showing larger scale notions, BID operates on small-scale urban units, showing a larger data context[16].

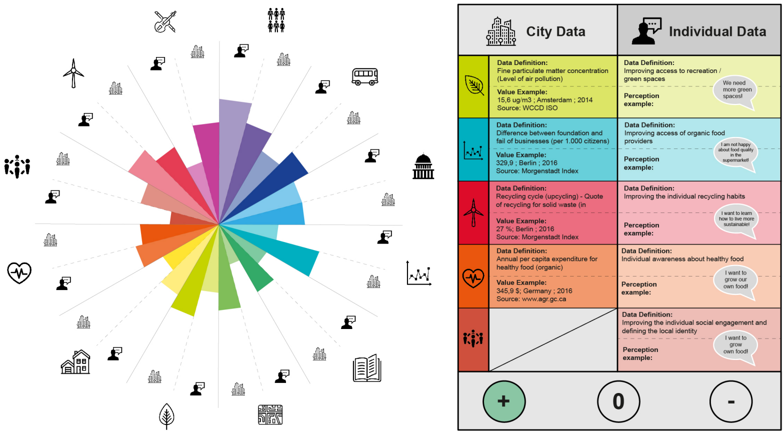

Figure 5 – Quarter ID (left), Building ID (right): Relationship between City and Individual Data at different urban scales.

3.3.4 Beyond Master Planning: Towards Data-driven, Agile Urban Development

Data collection in the urban Internet of Buildings plus the above-mentioned operations modeling may replace the practices of urban master planning with an agile and incremental development process. Somewhat paradoxically, data-based UOM may reenable the natural growth of cities and neighborhoods, eventually leading to high-value living environments.

Beyond master planning, we have schematized a process that builds ca pacity into urban quarters to structurally and flexibly react to changing

[16] As an example, Bert Spaan of the Waag Society created and organized a map (http://code.waag.org/buildings/) of all buildings in the Netherlands according to their age and described their brief function and size. This can be considered a basic Building ID.

needs and environmental conditions. The process – which actively utilizes ad hoc construction – can be described by a sequence of iterative phases.

The "Initiation Phase" starts with analyzing given datasets comprising City Data and setting up a Quarter Community for detailed insights into the needs of the inhabitants, summarized by Individual Data (see Table 1 above). The Quarter Community shall consist of at least one hundred participants who are periodically surveyed on quality of life in the quarter. This results in an initial Quarter ID (QID). By applying and downscaling the QID to a specific location or building, a Building ID (BID) is developed, and then a tentative UOM can be established.

In the "Seed Phase", the process starts with a temporary pioneer or pilot construction in accordance with a first UOM. The site of development is equipped with Cyber-Physical-Systems for monitoring the initially defined usage. Prior to determining the nature of the pilot, qualitative and development-relevant urban data are collected (see Tables 1 and 2) through surveys or Soft Urbanism measurements (festivals, events, containers, light-material structures etc.). These data are collected and interpreted with the BID. Importantly, the Seed Phase does not necessarily imply concrete spatial or structural intervention. Moreover, there is a difference between greenfield developments and locations within existing urban blocks. Greenfield development may be more ambitious due to a lack of existing users, data streams and preestablished linkages to the surroundings.

By analyzing the BID, planners and analysts clarify whether positive impulses were given to the site, and thereupon decide further development scenarios. The seed intervention may either be continued, enhanced, or stopped. Following this feedback, planners outline an updated operations model which informs the next step of development, possibly leading to concrete structures. Thus, at the end of the Seed Phase a development brief is set up in the form of an Urban Operations Model, determining rules and orientation for the follow-up intervention. This UOM ensures, in any case, that the next step is socially and economically valuable, responding to the primary interests of citizens, developers and investors alike. During the subsequent steps of the development, the quarter develops more UOM as the demands, needs, and activities of users and citizens evolve and change. Past developments without sufficient response and attraction from the local community will not be followed further. As some activities will certainly fail, established and existing structures will need re-programming by other Seeds. Without a final masterplan, this iterative open-ended and potentially open source development continues, and importantly, is validated with every iteration. Thus, this agile process enables feasibility and calculability, and secondly, aids demand-matching and user acceptance. For developers and investors, this process offers an alternative to speculative ad hoc master plans: Financial risks become minimal through continuous validation (see Figure 6).

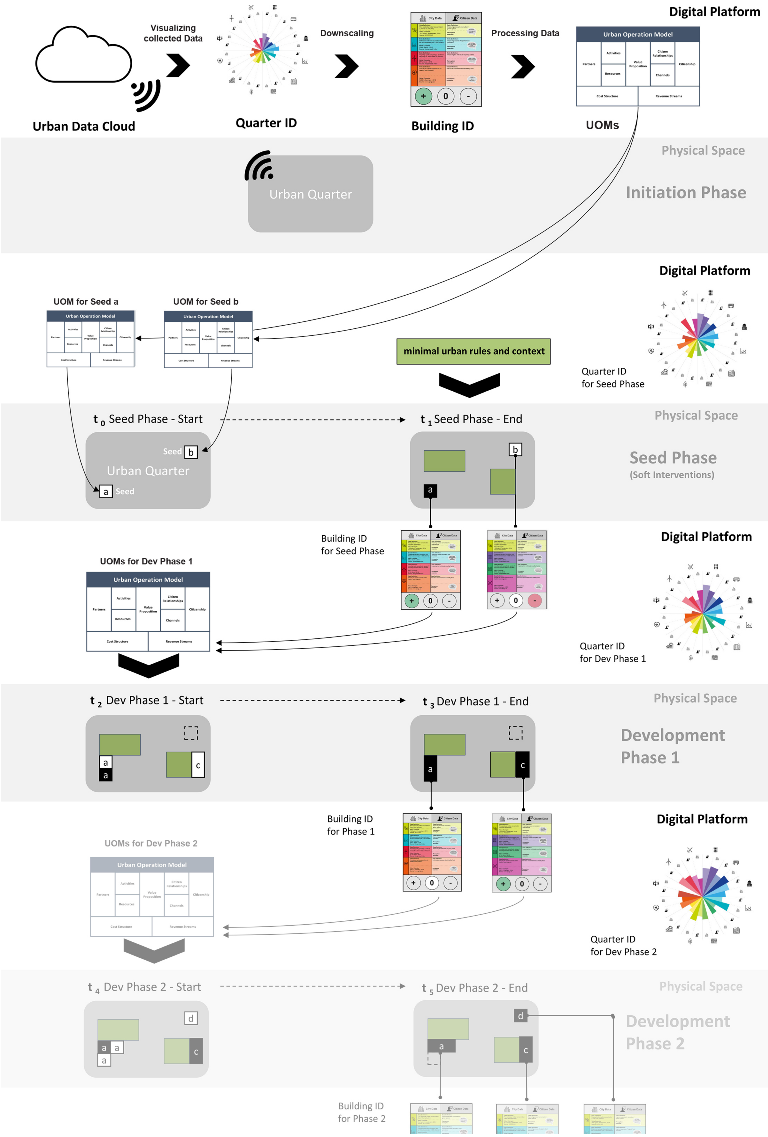

Figure 6 – Urban Data Operations Modelling: iterative steps.

The needs of cities for long-lived infrastructure networks can be addressed by iterative decentralization of embedded frameworks. Natural demand-driven city evolution beyond path dependencies at a large scale necessitates evolutionary and self-organizational processes that enable testing and experimenting at all levels.

3.3.5 Data Concierge and Urban Legislative

A key component for agile urban development is a data platform connecting different groups of interests in a network. These include municipal planning offices and municipal providers as the top-down actors, citizen organizations and entrepreneurs characterized as bottom-up participants and the investors, and developers and architects as hybrid figures (see Figure 7). On the one hand, the UOM is a formalization tool of ad hoc top-down urban planning rules. On the other hand, it supports a bottom-up dynamic catalyzing urban development, transmitted by processes and data visualizations. Appropriate data acquisition and evaluation is necessary to support design decisions and subsequent development. Today, both capitalist urban development and government-led master planning usually lead to undesirable urban conditions. A data platform, supported by UOM removes the discrepancies between experts and non-experts and may improve top-down master planning by harnessing data collection for progressive ends.

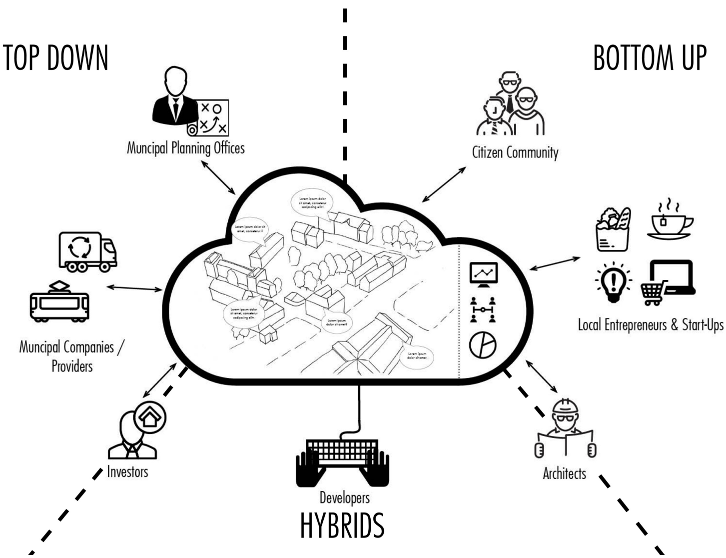

Figure 7 – Data4City: Data Platform and Stakeholders.

A first step beyond the conventional master planning paradigm towards evidence-based design is the re-definition of the roles and actions of individual participants. The linear workflow between investors, planners, municipalities and constructors needs to be replaced by iterative interaction and continuous evaluation of interventions as well as dialogue with end-users. Circular processes between the actors, as described in the previous sections, may eventually lead to an inclusive "Good City" with high quality of life.

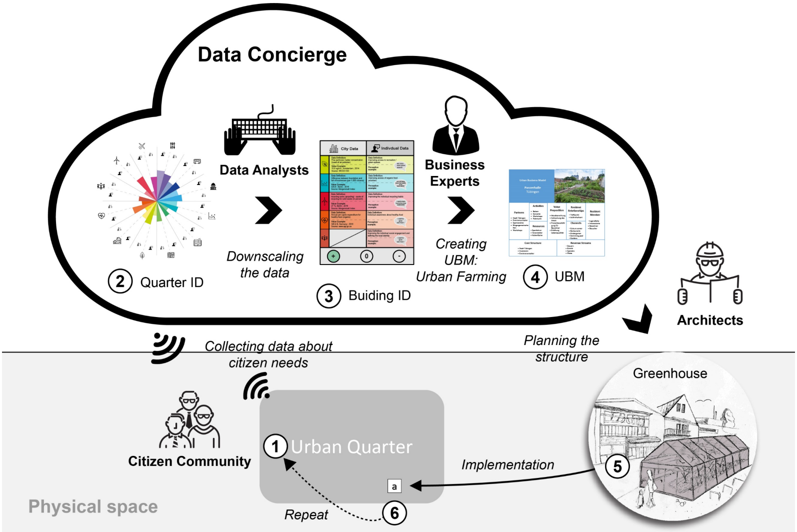

Figure 8 – Data Concierge: How data lead to design decisions (stakeholder map).

It is the task of an interdisciplinary team of data scientists, development experts and planners controlled by democratically elected citizen participants to take the role of a so-called Data Concierge who is responsible for managing, evaluating and processing locally generated data (Figure 8). An overall legal background can be established through an interdisciplinary team building the Data Concierge to guarantee its independency. Another important task is to guard against misuse of data. The Data Concierge can be furthermore seen as a hybrid authority (comprising both top-down and bottom-up decisions), making the legislative, background and general decisions according to the information derived from the datasets, democratic decision making.

A supplementary possibility for navigating and organizing the data concierge is an open-source peer-to-peer network with a flat hierarchy. Every interested inhabitant has access to most of the data flow and hence power to decide. The first method can be compared with the structure of a representative democracy, whereupon the second method resembles the structures of direct democracy. Both options have constraints and benefits. On the one hand, a method with representative elements is faster in decision-making, but power is not equitably distributed. On the other hand, a method with direct democratic constituents allows a nearly comprehensive rendering of inhabitants' needs and opinions, but impacts on performance.

4. Reflections – Limitations of Data-Driven Approaches to Urban Design

The limitations of smart city initiatives and data-informed design, as argued by Kitchin et al. (2015), lie in the generalization and over-simplification of diverse urban systems, disregarding regional and historical differences and rationalizing urban and social mechanisms. Arguably, the smart city agenda is driven primarily by corporate interests to capture financial and governmental opportunities (Hollands 2008; Kitchin et al. 2015). Furthermore, there are ethical consequences when people are categorized and reduced to mere numbers (Pentland 2014). This brings up the question of the general openness of any smart city system and how the data are being harvested. The distinction in the two methods for data collection (quantitative sensor-based vs. qualitative sociological approaches) in the proposed method may lead to over-simplifications of the terms "objective" and "subjective". Only the raw data collected by technical systems and sensors might be observed as fully objective and non-ideological, yet as soon as any filter is applied the objectivity disappears. Otherwise urban data cannot be seen as raw; they are always pre-defined for a specific use leading to a specific cause (Bowker 2005; Gitelman 2013; Kitchin et al. 2015). An approximation might be to define the filters through participatory decision making. This would eliminate more design contingencies resulting in a normative design model with less subjective and personal design decisions, which are in many cases driven by the ego of the architect.

Here, data types and resources were chosen that can directly inform design decisions, i.e. have implications for form, function and construction of urban structures. Only data resources, which are accessible and digestible for designers (who are typically not data scientists or statisticians), e.g., public data that are easily representable in diagrams and visualisations have been considered. These data sets are easily translatable to architectural or urban design decisions. Yet such a simplification of data, already observable in contemporary digital architecture, needs to go along with hierarchization and prioritization, leading again to subjectivity. By decentralizing these decisions through a network of interconnected users and stakeholders, objectivity might yet be achieved. Such a system based on peer-to-peer sharing might also be difficult to hack by a third party through blockchain technology[17]. Using blockchain, instant decentralized organisations can be developed, independent of any intermediaries or outside influences[18] (Ethereum 2017). This could also lead data-informed urbanism to a networked and possibly fully autonomous urban environment.

It is necessary to consider social conditions and issues of openness, especially in the context of data generation, collection, and economization. In this respect, hackability (modifiability) and open-source code must be considered central elements of the overall design in the light of technical democracy. The social impact of data-driven urban design and development requires bottom-up oversight (Farías and Blok 2016). Instead of giving away (personal) data to corporations and governments, the hyperlocal community presents a model to utilize and valorize data in the community and place where they are generated. In this model, urban space is being created by a constant iterative process of change and adaptation in response to the current demands and the actual needs of citizens. Latour and Yaneva (2008) described this idea as an active datascape informing the evolution of urban space, and modifying the social and physical context.

5. Conclusions

Max Weber (1921) considered that quality of life does not depend on the density or size of a city, but on its intermixture. This way, people of different ethnicities, cultural backgrounds and social classes can live together. Unfortunately, the appearance of radical functionalism and its zoning principles after the second world war rendered it impossible. Digitalization is a tool helping us move towards a healthy and appropriate dispersion of urban functions. Yet, there are principles which need to be respected in the context of data-driven cities, protecting the end-users who supply platforms with sensitive personal data.

Massive collection of Big Urban Data (individual data) can only be justified if a process is given for streaming essential data without the necessity of storing (Smart Urban Data).

Yet, in urban management and planning, urban data are not tapped as a major resource for design intelligence. In addition, cities are still not viewed as social enterprises which could be represented by way of operations models (Barquet et al. 2011). Addressing these deficits, Urban Operation Models (UOMs) provide for the purposeful application of urban

[17] A blockchain is an iteratively growing list of records (blocks), operating on a cryptographically secure, decentralized peer-to-peer network. Once recorded, the data in any block cannot be altered retrogressively without the alteration of all subsequent blocks. The first example of a blockchain is Bitcoin.

[18] See Ethereum Foundation: https://ethereum.org/ (retrieved October 5, 2017).

data, especially in the design and development of high quality living environments. Cities are places of value creation. This claim may be even more urgent in the digital age given that "wealth is created by turning data into information' (Landry 2000, 33). The case presented in this paper advocates the systematic usage of information and intelligence for valorizing urban design. The UOM provides a conceptual tool for urban managers, planners, administrators, and residents to capitalize on the rich urban data sources generated in the emerging Internet of Buildings (IoB). As a key component for data-driven urban design, this paper has shown how UOM can enable agile and secure urban development processes. Policy and decision makers can balance the interests of citizens with those of investors, developers, and managers through UOM. The primary aim is to get a more holistic and comprehensive understanding of the urban metabolism and hence give more power to citizens to design their own city and environment. The method moves beyond established practices in urban and forestalls real estate speculation driven primarily by expectations of return-on-investment. The power of the proposed method lies in the simple workflow procedure and the capacity to strategize and assess future development by way of operational modelling.

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