

Digital Urban Imaginaries:
Digital models transforming citizen-centred design processes
/
Digitale Urbane Imaginarien:
Digitale Modelle transformieren bürgerzentrierte Designprozesse

Dissertation zur Erlangung des akademischen Grades
eines Doktors
der technischen Wissenschaften

eingereicht an der Universität für angewandte Kunst Wien bei:
Betreuer: ao. Univ.-Prof. Mag.arch. Anton Falkeis
Fach: Special Topics in Architecture Design

1. Externer Beurteiler: Univ.-Prof. Hubert Klumpner, ETH Zürich, Institut für Landschaft und Urbane Studien,
Lehrstuhl für Architektur und Städtebau
2. Externer Beurteiler: Univ.-Prof. Dr. Reza S. Abhari, ETH Zürich, Institut für Energietechnik

vorgelegt von Michael Walczak

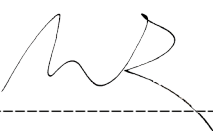
Wien, im Februar, 2021

Ich erkläre hiermit,

dass ich die Dissertation entsprechend den Grundsätzen guter wissenschaftlicher Praxis selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe, sowie

dass diese Dissertation bisher weder im In- noch im Ausland in irgendeiner Form zur Beurteilung vorgelegt wurde.

Datum 14.02.2021

Unterschrift 

Abstract

This dissertation proposes a methodology of collecting (i), processing (ii), and communicating (iii) *DIGITAL URBAN IMAGINARIES*, as a digital model and tool for citizen-centred urban design processes. The metrics presented in this doctoral thesis allows measuring (iv) a dynamic baseline of how citizens perception influences their decisions.

The first step of collecting (i) is developing the required quantitative data structure as a baseline environment.

The second step of processing (ii) is developing the input framework for dynamic and adaptive data, producing a networked system of interrelated evidence-based content.

The third step of communication (iii) is developing the visualisation framework for citizens, synthesising the generated data.

The fourth step of measuring (iv) is developing metrics for citizen design, allowing for a better understanding of stakeholder reactions for the transfer- and scalability of results: introducing a performance index for the methodology developed.

Improved time-related and immersive visualisation and communication technology permit an overall improvement in understanding urban transformation processes by 80 percent of the general audience. Such a communication method can affect a change in opinion by 35 to 50 percent. *DIGITAL URBAN IMAGINARIES'* impact on human perception and its power to mediate and improve exchange among citizens in urban transformation processes is at the core of this dissertation.

Kurzfassung

Diese Dissertation schlägt eine Methodik zum Sammeln (i), Verarbeiten (ii) und Kommunizieren (iii) von *DIGITALEN URBANEN IMAGINARIEN* vor, als digitales Modell und Werkzeug für bürgerzentrierte Stadtgestaltungsprozesse. Die in dieser Dissertation vorgestellten Metriken ermöglichen die Messung (iv) eines dynamischen Ausgangswertes, wie die Wahrnehmung der Bürger ihre Entscheidungen beeinflusst.

Der erste Schritt des Sammelns (i) ist die Entwicklung der erforderlichen quantitativen Datenstruktur als Ausgangswert.

Der zweite Schritt des Verarbeitens (ii) ist die Entwicklung des Eingabe-Rahmenwerkes für dynamische und adaptive Daten, die ein vernetztes System von miteinander verbundenen faktenbasierten Inhalten erzeugen.

Der dritte Schritt des Kommunizierens (iii) ist die Entwicklung des Visualisierungsrahmens, der die generierten Daten, für die Bürger, zusammenfasst.

Der vierte Schritt des Messens (iv) ist die Entwicklung von Metriken für die Bürgergestaltung, die ein besseres Verständnis der Reaktionen der Stakeholder für die Transfer- und Skalierbarkeit der Ergebnisse ermöglichen: Einführung eines Leistungsindex für die entwickelte Methodik.

Verbesserte zeitbezogene und immersive Visualisierungs- und Kommunikationstechnologien ermöglichen eine Verbesserung des Verständnisses von urbanen Transformationsprozessen bis zu 80 Prozent des allgemeinen Publikums. Eine solche Kommunikationsmethode kann einen Meinungswandel von 35 bis 50 Prozent bewirken. Der Einfluss von *DIGITALEN URBANEN IMAGINARIEN* auf die menschliche Wahrnehmung und ihre Kraft, den Austausch zwischen Bürgern in urbanen Transformationsprozessen zu vermitteln und zu verbessern, steht im Mittelpunkt dieser Dissertation.

Preface

Computer science and architecture are closely linked not only through definitions such as “models” or “architecture” itself but also through the concept of “design patterns”, which were first introduced by Christopher Alexander in his book “Notes on the Synthesis of Form” and adopted in software engineering by the gang of four (Gamma et al. 1994) in 1994.

Further, the graphical user interface was conceptualised and developed within the context of architecture itself, namely the framework of MIT’s “Architecture Machine Group”. This group included thinkers such as Nicholas Negroponte and Ivan Sutherland who worked on human-machine interaction, both mentored by Steven Anson Coons (Fankhänel 2020b). Coons, a computer scientist himself, was a visionary in interactive computer graphics and the use of computers as a design tool to support the engineer. Coons held the first class in CAD¹ at MIT² in 1959 – the first time the term CAD was used.³ The “Architecture Machine Group’s” primary interest lay in developing digital design and planning tools. These tools were not concerned with the perception of architectural space or its material nature, but with the design of media-technical chains of operation⁴ at the interface between physical and virtual space (Vrachliotis, 2018). In 1984, William Gibson dubbed that interface the “cyberspace” (Rheingold 1992) and had continued to gain currency through the notion of the “digital twin” (Grieves and Vickers 2017).

The interface can be seen as a mediator between different digital frameworks, which in turn mediates an interdisciplinary group of actors and practitioners. The interface not only serves an intrinsic purpose by mediating between different software frameworks but also serves to mediate between various stakeholders. The interface concept is closely related to computer science, while the concept of the mediator idea references citizen science, social science, psychology, problem- and conflict solving, and citizen-centred design processes. However, for purposes of this dissertation, the “interface” as the *DIGITAL URBAN IMAGINARY* and the “mediator” as citizen-centred design process shall be considered as almost equivalent, something in-between, the opposite of an oxymoron, maybe a pleonasm. Looking to history for previous references, we could consider the “Whole Earth Catalog” (Brand 1968), an “interface as mediator” between the combination of tool and individualisation theory in the light of belief in progress and optimism about technology (Vrachliotis 2018) – and which, as an initial analogue version of a search engine, provided “access to tools”. In the early 14th century, Ramon Llull completed the “Ars generalis ultima”, an analogue interface for mediation that related a multitude of different combinations to one another, in his case various philosophical contexts (Vega et al. 2018).

This dissertation will measure and provide an insight into how the mediation of such digital interfaces can change human decisionmaking by engendering evidence-based *DIGITAL URBAN IMAGINARIES*, illustrated by the example of processes in the context of urban transformation, governance and policymaking. To achieve the “interface as mediator”, we need to “collect, process, and

¹ Computer-aided design uses computers to aid in the creation, modification, analysis, or optimisation of a particular design task, such as in the field of architecture or urban planning.

² Massachusetts Institute of Technology, Department of Mechanical Engineering

³ Course by Mario Carpo on the 13.12.2020 in the context of the “Theory of Architecture 1” format from the Institute of Architecture at the University of Applied Arts in Vienna

⁴ “Media” in this case is the visualisation of computational output, and “technical” is the technology to be able to do so, while “operation” is the necessary interlinkage between both.

communicate" (CPC), which notions will be introduced in this dissertation. Particular emphasis is made on "processing". Since processing, in this case, is not a linear sequence, but a simultaneous network and cross-referencing of evidence from scientific knowledge (e.g. simulations), it permits the bridging of disciplines and enables adequate communication. The goal of communication is to evoke emotions and affect perception. The "image" is the medium/interface to be communicated. Many of the qualities we consider specifically human can be improved by evolving the way we see the world – by finding and inventing new ways of seeing (Rheingold 1992), inventing or envisioning the world. Kevin Lynch (1989) calls his new ways of seeing "Vorstellungsbilder" (English: imaginations), Armando Silva (2006) introduced "imaginarios urbanos" (English: urban imaginaries). In this dissertation, we call them *DIGITAL URBAN IMAGINARIES*.

Table of Content

p.

1. Introduction.....	13
1.1. Relevance and Motivation.....	13
1.2. Research Question and Strategy.....	14
1.3. Terms and Definitions.....	15
1.3.1. Digital.....	15
1.3.2. Digital Twin.....	15
1.3.3. Digital Model.....	15
1.3.4. Digital Urban Imaginaries.....	16
1.3.5. Percept.....	16
1.3.6. Citizen-Centred Design Processes.....	17
1.3.7. Cybernetics.....	17
1.3.8. Shifting Baselines.....	17
1.3.9. Interdisciplinary.....	19
2. Literature Review.....	21
2.1. <i>DIGITAL URBAN IMAGINARIES</i>	22
2.1.1. Digital Model.....	24
2.1.1.1. From Simplicity to Complexity.....	26
2.1.1.2. No-Scale and Transferability.....	27
2.1.1.3. Quantitative and Qualitative.....	28
2.1.1.4. 4D Imaginary Immersion.....	29
2.1.1.5. Unframed Image.....	30
2.1.1.6. Art Representing Abstraction.....	30
2.1.1.7. From "Historical" Prediction/Forecasting to Real-Time "What If" Scenarios/Influencing.....	31
2.1.1.8. From Misunderstanding to Understanding.....	32
2.2. Citizen-Centred Design Processes.....	34
2.2.1. From Specialised to Generalised.....	34
2.2.2. Evidence-Based Decisionmaking.....	34
2.2.3. Initiation and Co-Design.....	35
2.2.4. Making.....	36
2.2.5. Interdisciplinary Autodidact.....	36
2.2.6. Interdisciplinary and Specialised.....	37
2.3. <i>DIGITAL URBAN IMAGINARIES</i> that Impact Percept.....	37
3. Research Strategy.....	43
3.1. Research Question.....	43
3.2. Research Locations.....	44
3.2.1. CPC: Agglomeration of Lausanne (CH).....	44
3.2.2. CPC: City of Sarajevo (BiH).....	46
3.2.3. CPC: Caracoli Neighbourhood in Bogotá (COL).....	46
3.2.4. Measuring: PJS Settlement in Cape Town (SA).....	47
3.2.5. Measuring: Bogotá (COL).....	47
3.2.6. Transferability: Vienna (AT), Toronto (CA), and Shanghai (CN).....	48
3.3. Methodology.....	53

4. Research Implementation and Results	59
4.1. Chapter 1: Technological Framework.....	60
4.1.1. Techniques.....	61
4.1.2. Objects	62
4.1.3. Tools	64
4.1.4. Users/Medium/Interface.....	65
4.2. Chapter 2: Evaluation of Technological Framework.....	68
4.2.1. Pixel and Visual Comparison.....	68
4.2.2. From XML to Binary.....	68
4.2.3. Real-Time Ray Tracing.....	69
4.3. Chapter 3: Step 1 , Collection (i).....	82
4.3.1. Agglomeration of Lausanne	83
4.3.2. City of Sarajevo	84
4.3.3. Caracoli Neighbourhood in Bogotá.....	84
4.4. Chapter 4: Step 2 , Processing (ii)	96
4.4.1. Agglomeration of Lausanne	97
4.4.2. City of Sarajevo	98
4.4.3. Caracoli Neighbourhood in Bogotá.....	100
4.5. Chapter 5: Step 3 , Communication (iii).....	106
4.5.1. Agglomeration of Lausanne	107
4.5.2. City of Sarajevo	108
4.5.3. Caracoli Neighbourhood in Bogotá.....	109
4.6. Chapter 6: Step 4 , Measuring (iv).....	118
4.6.1. Mediating: Citizen Mapping.....	118
4.6.2. Shifting Baseline	121
4.6.2.1. Cape Town: General Audience.....	121
4.6.2.2. Bogotá: General Audience.....	132
4.7. Chapter 7: Policy Exploration.....	136
4.7.1. Cape Town: Specific Audience with Policymakers.....	136
4.7.2. Bogotá: Specific Audience with Policymakers	136
4.7.3. Sustainable Development Goals (SDGs).....	137
5. Discussion and Conclusion	141
5.1. <i>DIGITAL URBAN IMAGINARIES</i> as Adequate Communication Medium in Citizen-Centred Design Processes	142
5.2. <i>DIGITAL URBAN IMAGINARIES</i> Require a Mediator	146
5.3. Technical Characteristics of <i>DIGITAL URBAN IMAGINARIES</i>	146
5.4. Socio-Technical Recommendations for the <i>DIGITAL URBAN IMAGINARY</i> Implementation	147
5.5. Policy Recommendations for the Citizen-Centred Design Processes and <i>DIGITAL URBAN IMAGINARY</i> Implementation	148
5.6. Synthesis of the "Immersion Elicitation" Method	149
5.7. Synthesis of the Collecting, Processing and Communicating Method.....	150
5.8. Dangers, Limitations and Implication of Results on Further Research	152
5.9. Transferability of the Research Findings	153

6. Epilogue	159
7. Acknowledgments	163
8. Appendix	165
8.1. Policy Outreach Transcription (Excerpt)	166
8.2. List of Digital Models.....	170
8.3. State of the Art Digital Tools.....	171
8.4. Publications During the Doctoral Studies (Excerpt).....	174
8.5. Exhibitions During the Doctoral Studies (Chronological Order).....	188
8.6. Teaching During the Doctoral Studies.....	190
8.7. Conferences During the Doctoral Studies (Chronological Order)	194
8.8. Online Publications During the Doctoral Studies (Chronological Order).	200
8.9. Policy Brief	203
8.10. C++ Code Excerpts	207
8.11. Unreal Engine Blueprint Code Excerpts	213
8.12. Curriculum Vitae.....	214
9. Bibliography	219

1. Introduction

1.1. RELEVANCE AND MOTIVATION

The main driver behind this dissertation is the process of rapid urbanisation. Currently, a billion people live in conditions of a predominantly informal mode of urbanisation (UN-HABITAT 2016). Urbanisation is characteristic of living conditions for the vast majority of human beings today, for example, 81%⁵ of the Colombian (see figure 04) or 67%⁵ of the South African (see figure 02) population. The method of this dissertation investigates the use of technology in collecting, processing, communicating and measuring 21st-century urban phenomena and issues such as climate change, migration (emigration and immigration), urban metabolism (energy demand, nutrition, food production and management of resources), and rapid urbanisation (von Borries et al. 2019). Improved technological capacities need to overcome "[...] laws administered by municipalities that date from the colonial era" (Mamdani 1996) which "[...] continued to serve as template for urban planning, land use regulation and public housing provision [...]" (Pieterse et al. 2014). The (doctoral) research can directly contribute to several aspects of UN Sustainable Development Goal 11 "Sustainable Cities and Communities" (United Nations 2015) through evidence-based simulations and visualisations (see chapter 4.7.3.), for example, in the fields of air quality; participatory, integrated and sustainable human settlement planning; transport systems; affordable housing; strengthening national and regional development planning; and disaster risk management.

⁵ Data retrieved from the World Bank depicting the year 2019. Source: <https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS>; accessed 08.02.2021

On the one hand, formal planning instruments fail to understand and manage the scale and speed of transformation, resulting in the rapid development of informal settlements and compromised habitats for over 60 percent of the respective urban populations in the light of "[...] new ways of grasping the urban world, its orders and its patterns, which are more complex than imagined (Kalisch et al. 2016)." Conversely, digital processes have uncovered a potential for addressing the failures of traditional planning frameworks to visualise the complexity and dynamic of both contemporary urban environments and citizen

agency urbanism. However, there are as yet no instruments (Girardin 2018) “[...] which help planners sort the abundance of data, ideas and concepts available, and turn them into practical tools” (Kalisch et al. 2016). We can conclude that “we still believe in outdated models of urban development” and with that, it follows that “even in the context of the European city, the planning instruments provided are barely functional anymore” (Falkeis 2017). Those outdated models, therefore, create a situation where “the city today is perhaps more radical than those operating within it. It computes unknown possibilities, conducts high-risk experimentation, and telegraphs previously unknowable futures more quickly and more completely than the raft of professionals tasked with its stewardship, analysis or design” (Brillembourg et al. 2015).

Citizen-centred design processes and *DIGITAL URBAN IMAGINARIES* could be the philosophy for tackling such 21st-century issues. Inspired by the field of “citizen science”, citizen-centred design processes and *DIGITAL URBAN IMAGINARIES* represents a method via which we can expose human beings to multiple fields and disciplines. These overlaps are intended to create understanding, insights, and knowledge that we would not acquire in usual disciplinary processes. In the spirit of Vitruvius (Ten books on architecture (Rowland 1999)), ten areas of expertise are anticipated in the fields (drawing, music, astronomy, medicine etc.) in which an architect should be proficient for the benefit of his or her architectural work. We should expand this expertise by the field of computational communication technology and machine-readable languages – first to be able to understand them and second to use such technologies in a meaningful and sustainable way for the good of our ecosystem (Colman et al. 2018).

Within four years at the University of Applied Arts (Angewandte), Department for Special Topics in Architecture Design (STARCH), this dissertation linked to research in qualitative arts-production and media-theory to the quantitative simulation of urban environments transformation processes. Simultaneously, within four years at ETH Zurich’s interdisciplinary Urban Research Incubator (URI) embedded in the Institute of Science, Technology and Policy (ISTP), this dissertation aggregated the work of a group of eight researchers. Together with the Angewandte, it linked a variety of research lines from social science, urban planning, architecture as well as lighting, software, and mechanical engineering, from which this dissertations knowledge is also based on.

1.2. RESEARCH QUESTION AND STRATEGY

Research question:

Is it possible to apply a methodology of collecting, processing, and communicating to measure whether *DIGITAL URBAN IMAGINARIES* of urbanisation processes can shift the baselines of how citizens form percepts, take decisions, and come by opinions?

The research strategy we selected comprised a multi-method qualitative

component combined with a quantitative aspect to answer the research question and additionally integrated actors from a range of disciplines. The process includes the collection and generation of new sets of data, the processing and combination of information, and the development of a communication framework. We evaluated the method's effectiveness by considering the technological improvements and measuring the impact in the baseline shifts of the human percept. The final step addresses the aspect of policymaking with local policymaking actors.

1.3. TERMS AND DEFINITIONS

The following sub-chapter introduces a standard glossary of the terminologies most commonly used in this dissertation:

1.3.1. DIGITAL

Signals and data represented or displayed in digits (i.e. in steps and not in a continuous or analogue fashion) are "digital". Digitalisation is the conversion of analogue signals and data into digital values (usually binary digits) (Digital 2010). In this dissertation, the word "digital" references, in particular, the use of computers, their computational power, and their resulting aesthetics.

1.3.2. DIGITAL TWIN

For the purposes of this dissertation, a digital twin (DT) is a digital replica of an urban structure and behaviour along with the associated interactive connections. "These connections transmit information (status, usage or analysis data, control commands etc.). Moreover, a DT can take different forms depending on the level of detail, the degree of automation, and the type of connections and information depicted. Thus, a DT can map various states (structural and operational)" of a real urban environment over time. It can represent an existing, currently realised (Wahbeh et al. 2020), imagined, envisioned, destroyed, or past urban environment. In addition to static elements such as buildings or vegetation, a DT can include dynamic elements such as moving pedestrians, public and private transport, or weather, which are both input by and the represent outcome of a digital model.

1.3.3. DIGITAL MODEL

In the Oxford English Dictionary alone, the word "model" (2021) has 55 entries from various disciplines from architecture and music to mathematics and biology. The digital model itself is closely linked to the digital twin. In this dissertation, therefore, we mainly focus on and navigate between two

aspects of the broad terminology of a "model": first, a replica of something in three dimensions (Model 2000), whereby we add the fourth dimension in our definition to include the component of time and potential dynamic simulations of urban environments (moving pedestrians, public and private transport etc.); and second, "a system of postulates, data, and inferences presented as a mathematical description of an entity or state of affairs", which may be stored in a computer (Model 2000). Digital modelling entails the technique for creating digital models and combining them in a digital twin.

1.3.4. DIGITAL URBAN IMAGINARIES

A specific line in William Shakespeare's epic verse "Venus and Adonis": "All is imaginary she doth prove" is particularly interesting. We can read this line in two ways. Either that all that we see and experience is a form of imaginary, or that imaginaries require some dimension of proving. The second interpretation draws our attention to the evidence needed to verify whether imaginaries are valid, which is especially significant if we add the word "digital" in front of "imaginary". The "digital" sphere could provide the evidence we need for the existence of the imaginary. This dissertation considers both interpretations. Nevertheless, the definition of an imaginary is that it can only exist in our imagination or fantasy, having no real existence, not being real or actual (Imaginary 2021). In mathematics, the word "imaginary" is used to describe complex fictional units - imaginary numbers that enable equations without real solutions to be solved (Imaginary 2000). The imaginary number equals the complex number, which brings us again to a consideration of the "digital" (Imaginary 2000). Armando Silva (2006) coupled the imaginary with the "urban" in his "imaginarios urbanos" (Engl.: urban imaginaries) towards the development of urbanism from the citizens. Through methods of "temporality of citizens", "traces of citizens", and "routines of citizens" it allows to understand, perceive and construct the "actual" city—a new way to approach the pressing urban questions on a global, regional and local scale. In our case, we correlated the urban imaginary with the digital and additionally to Silva's "actual" we are envisioning the "future" "virtual" city. This method couples pictorial and descriptive thinking with computational scale and power.

1.3.5. PERCEPT

A percept is necessary for the perception of a *DIGITAL URBAN IMAGINARY*. Specifically, a percept is the consequence of an act of perception that results in a new imaginary and is always related to the recipient's unique background, location and context (Percept 2021). In other words, a person who sees, hears, or touches a *DIGITAL URBAN IMAGINARY* also interprets this imaginary, which produces a new and unique imaginary in his or her mind.

1.3.6. CITIZEN-CENTRED DESIGN PROCESSES

Citizen-centred design processes are inspired by the notion of citizen science. The main component of citizen science is the scientific work (opinions, preferences, observations, or data) undertaken by members of the general public with different backgrounds, "often in collaboration with or under the direction of professional scientists and scientific institutions" (Citizen Science 2021). A citizen scientist is a "scientist whose work is characterised by a sense of responsibility to serve the best interests of the wider community or a member of the general public who engages in scientific work" (Citizen Scientist 2021). Citizen-centred design processes are scaling the method of citizen science and the work of citizen scientists to an urban level: not looking at one individual, but the public.

1.3.7. CYBERNETICS

The term cybernetics was coined by Norbert Wiener in 1948 and originates from the Greek term of "kubernetes" (ancient greek: κυβερνήτης (kubernētēs)) could be translated as the "pilot of a boat" or a "steering man" (Cybernetics 2021). And that is the chief focus of cybernetics: the knowledge of control systems, communication, action, reaction, input, output, feedback, and iteration in living organisms and machines (Cybernetics 2021). For example, an automatic pilot in aeroplanes continually evaluates the flight situation and re-adjusts the aircraft to suit the conditions: strong wind coming from the left, adjusting the rudder and flaps to continue to fly straight, and so forth (see figure 01).

The impact and inspiration of cybernetics on architecture is also clearly visible. Architecture groups such as "Archigram" invented the "Computer City" in 1964 and the "Instant City" in 1968. In 1964, Cedric Price liaised with Gordon Pask as his cybernetic consultant and initiated the "Fun Palace", a building which can be continually re-programmed, re-configured, and re-designed. Price and Pask began an exciting collaboration between the qualitative discipline of architecture and the quantitative field of cybernetics. A combination of this type went public in 1969 in the form of the exhibition "Cybernetic Serendipity". In this exhibition, the curator Jasia Reichardt correlated arts with computers. Contributions to the exhibition ranged from topics such as combining the computer and music to produce computer-generated compositions, computer-programmed choreography, computer paintings, or the cybernetic light tower, where light was used as a medium of communication. It included significant thinkers of this time such as Norbert Wiener, Stafford Beer, Gordon Pask (who, as mentioned earlier, collaborated with Cedric Price), all of whom were "cyberneticians" with an interest in interaction with the arts.

1.3.8. SHIFTING BASELINE

For the purposes of this dissertation, the "baseline" shall be considered as the starting point for comparisons (Baseline 2000) and in particular the baseline as the starting point of citizens and their inscribed biases and beliefs as a result

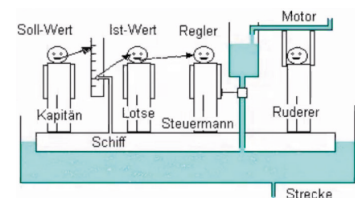


Figure 01: Figure shows exemplarily the cybernetic principle of the "steering man" as a controller of the system, in this case, the captain of a boat.

Source: Screenshot from the course "Grundzüge der Medientheorie" by Univ.-Lekt. Dr. phil. Arantzazu Saratzaga Arregi at the University of Applied Arts Vienna, Sommersemester 2020.

of their environmental, social, and governmental (ESG) background. The aspect of "shifting" indicates and is measured if the initial baseline can be or has been modified.

In the epilogue chapter of this dissertation, the notion of "shifting baselines" is also observed from another perspective, namely a climatic one.

1.3.9. INTERDISCIPLINARY

While speaking about the concept of the "interdisciplinary", we have to understand all the other "prefixes" that could apply to "disciplinary" – predominantly inter-, trans- or multi-disciplinary. "Interdisciplinary" is the broad terminology for collaboration among several disciplines. Multi-disciplinary is a traditional working environment where numerous fields contribute to a common problem or solution whilst having little interaction with each other. Interdisciplinary includes a "mediator" who collects the various actors' contributions and synthesises them for the problem or solution at hand. The role of an architect could be an example of a "mediator".

In contrast to multi-disciplinary environments, actors in interdisciplinary processes collaborate among each other. Transdisciplinary is an integrated approach in which all actors continuously engage with each other towards a common problem or solution that is evolving and adapting. In this dissertation, the glossary of the interdisciplinary approach is applied, with the *DIGITAL URBAN IMAGINARY* taking the role of the mediator.



Figure 02: Khayelitsha, Cape Town, South Africa
Source: Michael Walczak (2018)



Figure 03: Sarajevo, Bosnia and Herzegovina
Source: Michael Walczak (2019)



Figure 04: Bogotá, Colombia
Source: Michael Walczak (2020)

2. Literature Review

The main research question of this dissertation is whether *DIGITAL URBAN IMAGINARIES* of urbanisation processes can shift the baselines of how citizens form percepts, take decisions, and come by opinions. The literature review indicates the research gap and the reason why such a research question was defined.

The first part of this literature review examines the notion of *DIGITAL URBAN IMAGINARIES*. The digital model is the medium used to create *DIGITAL URBAN IMAGINARIES* to potentially impact citizen percepts in decision- and policymaking processes. The second part examines the notion of citizen-centred design processes. The third part of this literature review introduces state-of-the-art techniques that can potentially impact citizens' percepts. The literature review on the assessment of the chosen methodology is further explained in chapter 3.3. The evaluated list of state-of-the-art tools is presented in the appendix (see chapter 8.3.).

2.1. DIGITAL URBAN IMAGINARIES

Why did the dissertation choose to focus on the digital model as medium of the *DIGITAL URBAN IMAGINARY*? Falkeis (2015a) introduced the use of digital models as the art-based "Notation Projects" (Falkeis 2015a), which can describe a novel perception of space and therefore could anticipate the unexpected. Carpo (2017) points in his "Second Digital Turn" to the fact that three-dimensional models have replaced text and images "as our tools of choice for the notation and replication, representation and quantification of the physical world around us: born verbal, than gone visual, knowledge can now be recorded and transmitted in a new spatial format". We should use images for all kinds of reasons and tasks as long as we have eyes to see (Carpo 2017). Key advantages are that such three-dimensional models "contain much more information than any single planar projection of the same" (Carpo 2017). Three-dimensional (3D) models can process complex and repetitive command structures (Schneider and Fankhänel 2020a). A 3D model can be exploited or experienced in countless ways (Carpo 2017). Simultaneously, however, they offer possibilities for new forms of representation and production as these will also most likely change "the way we see almost everything, and represent and know the world around us" (Carpo 2017). The whole idea of 3D on a computer is to create a realistic simulation of the real world (Marinčić 2019). However, this does not necessarily mean a photorealistic representation, since the more detailed a scenario is, the more convincing it will be, but at the same time, it will be considered less probable (Kahneman 2012) with less imagined and conceptual space for observers. Still, the aspect of "realistic" will be considered by this dissertation in conceptual terms. Representation techniques such as animation are rarely attempted on personal computers but instead sent to render in "farms" that combine thousands of powerful computers (Marinčić 2019). Yet, due to the rapid development of GPU technology, such animation can in fact now be computed on today's personal computers, even in real-time, which opens up vast potential for applications. Compared to reductionistic techniques, the processing of information and data, in this case, is considered complex. Hence, the purpose of the communication is to reduce its complexity for the observer while grounding its evidence on complexity. In short, we can say that the purpose of a model is to reduce complexity and create new information (Marinčić 2019). The reduction of complexity to benefit communication is particularly essential for us observers if we are to understand the information, which further implications concerning urban transformation processes are not yet fully exploited in current research in terms of the chosen communication medium, level of detail or perspectives. Today, the computer is both the technical instrument required to produce such digital models and also – consequently – a creator of human imagination (Weizenbaum 1978). In other words, a computer can generate a multitude of simulations of the, in Paul Virilio's⁶ term, "actual" reality, from which, for example, a decisionmaker may draw conclusions. The only limitation is simply ourselves, since "man is only able to create little that he has not previously created in the imagination" (Weizenbaum 1978). A theory in the form of a computer program is both a theory and – once input into and processed by a computer – a model to which the theory is applied. The theory solves the task it explains. Strictly

⁶ <http://www.ljudmila.org/scca/urbanaria/txt/e/pvirilio.htm>; accessed 11.02.2021

speaking, a theory cannot “solve” anything. But a model can, and therein lies the sense of its statement (Weizenbaum 1978).

Such a synthesis of theory into models thus opens the possibility that “[...] the basic numerical logic of the digital encouraged transfers, generalisation, and confluences of tools” (Bottazzi 2020), which allows evidence and knowledge to be applied on a much broader and impactful scale, such as to policymaking (Avrami 2019). Reality consists of a linear process bound to space, time, and location. In comparison, the virtual or digital is a non-linear process, meaning that “[...] space is no longer seen as static and fixed, as it had been since Descartes and the Cartesian coordinate system, but as polymorphic, changeable, and flexible. According to this view, space is relativistic, and time becomes an important dimension in the experience of, for example, architecture. Movement, time, and architecture influence and depend on each other in this virtual architecture” (Fankhänel 2020a).

Furthermore, we can apply cybernetic theory to the method of such adaptive digital models, which affirm the concepts of control, automation, regulation, and optimisation (Marinčić 2019). This allows the use of Wiener’s legacy by relying on feedback chains to automate and optimise the operation of the model (Wiener 1948). During a discussion⁷ with Peter Eisenman, Greg Lynn pointed out that a computer between the end of the 1980s and the beginning of the 1990s would go through iterations at the same speed as a human would draft them. For Lynn, that was an incredibly exciting moment. The Book “Archeology of the Digital” edited by Lynn illustrates the particular interest in that specific human-computer relationship in architecture, showcasing four projects by Frank Gehry, Peter Eisenman, Chuck Hoberman, and Shoji Yoh. The computer can now go through iterations faster than a human, which opens up different opportunities. Nevertheless, this dissertation will not be a simple “black box” (Glanville 1988) in cybernetic terms with a system “where the output of a machine is linked to its input and compared against some intended performance measures (Marinčić 2019)”. It is a more dynamic system in which multiple quantitative inputs, as well as qualitative stakeholder engagements, create numerous outputs.

The power of our imagination in the form of the imaginaries of the future is immense. Imaginaries can not only show us how the future may look like but can also fundamentally influence or even create it. For example, in the technological discourse, “Moore’s Law” initiated in 1965 the trend of imaginations influencing the future, which anticipated that the number of transistors on integrated circuits doubles approximately every two years (Bridle 2020). Historically this trend followed since technology firms have had a tradition of imagining the future via the use of films as a medium. Apple Computers released a video in 1987 imagining the year 2011 (see figure 05) where the tablet was invented as a device for video communication, enabling digital assistants, or remote teaching. Sun Microsystems released a video in 1994 imagining the year 2004 (see figure 06), which re-invented our vision of how the workspace of the future would look. Governments also joined in: Chile’s administration drafted in the help of “cybernetician” Stafford Beer, and attempted to imagine how



Figure 05: “Apple Knowledge Navigator” film released 1987 imagining the year 2011. Source: <https://www.youtube.com/watch?v=umJsITGzXd0&t=217s>; accessed 12.01.2021

⁷ <https://www.youtube.com/watch?v=DUrA1Lod--g>; accessed 26.10.2020



Figure 06: “Starfire” film released 1994 imagining the year 2004 by sun microsystems. Source: <https://www.youtube.com/watch?v=w9OKcKisUrY&t=124s>; accessed 12.01.2021

computers could help run a country in future in the form of a decisionmaking space called the "Opsroom".⁸ Imaginaries are also used in mathematical theory to communicate to a broader audience, as an example, Mandelbrot (1967), used the imaginary of the coastline to communicate his theory of fractals and self-similar curves. These imaginations of a future gave the impetus to an entire industry which strove to fulfil them, a scenario which is still valid today and which shapes our lives.

⁸ <http://countercultureroom.cl>;
accessed 12.01.2021

In the following sub-chapters, the specific literature gaps are identified and informed the definition of the research question.

2.1.1. DIGITAL MODEL

Model is a treacherous word. It denotes several realities with different natures. They do not contradict each other; indeed they often overlap, but according to Stachowiak (1973), we cannot combine them. A model can denote 1. a representation (scaled architectural representation); 2. a reduction (mathematical equation); and 3. a pragmatism (cybernetic usage) (Stachowiak 1973). In terms of the last definition, cybernetics has contributed massively to the proliferation of diagrams globally, and probably no other science has relied so much on advancing arguments via visual analogies. The (flow) charts that are frequently used in cybernetics play an essential role in the production of analogies. "Building a model" does not mean already materially implementing it, but only producing a hypothetical (or heuristic) "machine", whose characteristic is to include heterogeneous elements into the "machine" through recursion and communication. The basic model of such a machine on which the most diverse phenomena can still be cybernetically "grounded" is the control loop. Within the visual argumentations of cybernetics, we can lay its diagram over all possible images like a transparent foil. For example, "Cooking means rules: again, and again the actual value must be checked, compared with the presented target value and the correct control must be carried out. If the cook is not herself a captain, she follows a "recipe" as a controller (Pias 2003)." In architecture, for example, it is the computer that assists with the drawing during the design, recalculates the statics, checks the costs, etc. Humans then fill in the gaps.

This literature review applies the terminology of cybernetics theory concerning abstraction, forgetting, and its synthesis in the form of models: "The foundations of such powers of abstraction or forgetting concerning concrete circumstances and material complications are not due to any "false" or simplistic popularisation but date back to the very beginnings of cybernetics which are, i.e., active, purposeful, feedback, and predictive. It is precisely this neglect that drives the productivity of a model, which in turn allows the application of always identical models [...]. And that means that in the similarity of machines and organisms, there is at the same time a radical dissimilarity (just as one uses wheels and not legs on a train), but that this dissimilarity is at the same time utterly irrelevant if and as long as one limits oneself to behavioural equivalents or models" (Pias 2003).

In the case of this dissertation, the model will potentially be applied in a variety of different contexts, fields, and professions ranging from spatial policies to environmental measurements including wind, air-quality, and solar-radiation, and lighting simulations. Such dissimilarities of the case studies and topics focus on the testing of the durability, flexibility, replicability, and scalability of the developed model. It forms the universal language of the dissertation.

Nevertheless, in order to answer the research question, a model needs to be communicated before it can impact human perception. In communication theory, human communication is a series of proposals to codify the world. So why, we must ask, does one codify? To communicate with others – we code to create order. The intention behind such structuring techniques is also the intention behind informing. Thus, “informing” means changing, and “changing” means doing something the way it should be (Flusser 1996). From the perspective of Vilém Flusser, communication is always artificial (compared to animal communication forms of birds, for example, which are not artificial). The main reason for communication is to give meaning to life. If communication is always artificial, we can produce communication with digital images, as potentially in the case of this dissertations.

In order to communicate a digital model, it has to be translated into an understandable language: a “digital image” (see chapter 2.1.). For example, radio and television culture has only existed since the radio and television programs have been collected and recorded. You only broadcast what you have been able to keep. Comparing forms of communication: the word communicates, the stone conveys. In other words, long-term messages improve their chances of survival if we reduce them to their bare essentials (the sketch is more appropriate than the drawing) (Debray 2003). From the perspective of art, analogue elements are present in digital art and digital aspects in analogue art. And that is precisely what, for example, digital art does: it digitally represents analogue processes of nature or creates analogue images from numbers. These digital images, the basis of which is the number, are called artificial images, synthetic images of the computer (Weibel 2019) – *DIGITAL URBAN IMAGINARIES*.

“Actual?” reality is not the ultimate goal of a digital image. It essentially seeks to represent non-reality, realistically, with the interaction between soft- and hardware’s help – creating the image of a new “virtual?” reality, a new imaginary, which might become “actual?” reality. Non-reality is the opposite of reality, but is not in Paul Virilio’s term “virtual?” or “actual?” reality. Historically, Kevin Lynch (1989) introduced the representation methods of a physical experience. The age-old human desire to give tangible form to our experiences and fantasies – the insatiable need to exercise our imagination, judgment, and thought in worlds, situations, and characters that are different from those of our everyday lives (Rheingold 1992). The digital image as one possible form of representation combines the possibilities of painting (subjectivity, freedom, unreality) and photography (objectivity, mechanics, reality) (Weibel 2019). Through video, and animation in particular (creativity, technology, imagination), the digital image even takes on a temporal aspect. We reconcile the reproduction and the fantasy

⁹ <http://www.ljudmila.org/scca/urbanaria/txt/e/pvirilio.htm>; accessed 11.02.2021

in the digital image. We can realise the digital image in any medium (Weibel 2019), but as Pias (2003) stated above, the underlying model stays the same.

Peter Weibel (2019) suggests that scaling, layering, contour/texture, speed, and perspective, have to be considered, as the core of a digital image's aesthetic strategy. In order to understand what the digital images can provide additionally to the commonly used methods, the following chapter will examine these aspects from a literature point of view. Particular interest lies in scaling and speed, which represent the aspect of animation and time. Among others, we add the ability of real-time generation to the digital image strategy.

2.1.1.1. FROM SIMPLICITY TO COMPLEXITY

A static image can represent complex information, but it is only through animation that we can transmit complex data and the impression of reality over a series of images shown in time – it comes to suggest truth (Weibel 2019). Film is truth in 24 frames per second, Jean-Luc Godard used to say (Rheingold 1992). Animation is a suitable medium for recording and analysing computer output and data reduction and also for creating models for the presentation and illustration of processes in architecture and urban planning (Weibel 2019). It can represent processes running parallel to each other. We can use animation to create new visual phenomena. Olafur Eliasson (2019) came to similar conclusions by stating that particular phenomena cannot be fully taken in without movement and time: "Our ability to sense depth and understand dimensions is intensified through (...) motion."

Continuing the study of Peter Weibel (2003), we can see two fundamental formal principles for the visualisation of time and space. The method of simultaneity developed by Etienne Jules Marey (see figure 07) and the practice of succession comes from Eadweard J. Muybridge (see figure 08). Marey combined different stages of movement side by side on one screen, showing different moments simultaneously. However, Muybridge came remarkably close to current animation techniques when he used images in a sequential manner. Various phases of movement in succession are dissected in image sequences. His method founded the three-dimensional art (area and time) of moving images. If you break an action down into at least 16 phases (parts) in a second and then perform them again within a second, they appear to the eye as a continuous unit: we must first break up the movement into different individual images to create the illusion of continuity later.

However, the first apparatus for artificial stroboscopic movement simulation on a mechanical basis was constructed by Michael Faraday in 1829, the "Faraday Discs", the first homopolar generator (see figure 09). Yet it took T. A. Edison and his team, and many other inventors, especially Louis Aime Augustin Le Prince (1842-1890), to invent the machine through which the Muybridge photo sequences ran at a certain speed. This invention heralded the achievement of graphic simulation and the two-dimensional illusion of movement: the kinoscope (movement viewer) (see figure 10).

Complex topics and "big data"¹⁰ previously needed to be presented in a very



Figure 07: Chronophotograph of a pelican flight, around 1882 by Étienne-Jules Marey.

Source: https://de.wikipedia.org/wiki/Étienne-Jules_Marey#/media/Datei:Marey_-_birds.jpg; accessed 15.12.2020

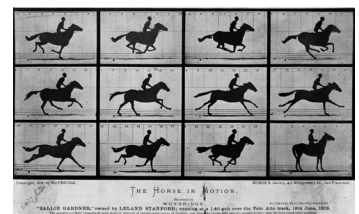


Figure 08: Eadweard Muybridge "The Horse in Motion", 1878.

Source: <https://www.monopol-magazin.de/eadweard-muybridge/>; accessed 15.12.2020

abstract and reduced way to enable their analysis by a human. The creation of specialists to understand and convert these topics was inevitable. This abstraction is now obsolete with the advent of the methods of *DIGITAL URBAN IMAGINARIES* since we can harness computational power to process, cross-reference and visualise large amounts of data. We can “embrace” the complexity (obstacle) as an opportunity (Zafirir 2019). No longer do we need stereotypical models such as one expert for each problem, but instead, we gain and develop understanding through a process of mediating various citizens with diverse disciplines using *DIGITAL URBAN IMAGINARIES*.

Since any given task has certain boundary conditions and inputs and is reduced to a product/goal through a process, the basic architecture/structure of this described problem-solving approach remains the same within the *DIGITAL URBAN IMAGINARIES*. It remains the same because until now, the development of such technologies has been initiated based on humans’ capabilities, knowledge, and their specific training sets. And, at the same time, the general field of computer science cannot yet perform fully autonomously since it cannot yet set its own goals in a manner detached from any human input (Socher 2019), and perhaps may never do so. However, in terms of the visibility and transparency of the process, of a black (process not visible) or grey box (process slightly visible) or a white and transparent box (process fully visible) (Glanville 1988), the process can be vastly different. This model can change and adapt depending on which input, which desired output, or which operation is requested. A black box can become a transparent white box or the other way around (Stalder 2019). *DIGITAL URBAN IMAGINARIES* propose performing such assessments and even processing the complexity in real-time. It argues that the algorithmic accessibility allows the complexity to be broken down – without reducing the complexity. In other words, the user front end (graphical user interface such as Windows or Mac OS) reduces information to the maximum of what a human can perceive, but the back end (“invisible” computational power) retains the highest possible level of complexity with no scaling. This reduction of perceived information is crucial since we humans fall into apathy in the face of too many emotions, worries, or issues (Eliasson 2020).

2.1.1.2. NON-SCALE AND TRANSFERABILITY

In digital imaging technology (Weibel 2019), scaling means the capability to reduce or enlarge any object digitally, i.e. computational manipulation. Through this “digitality”, the size of an object can be isolated from its natural context and given any desired size and location, which means that the scale is no longer critical (Weibel 2019), but can improve and unveil through multiple viewing angles a new understanding of certain phenomena. Such a feature can, for example, help in the field of criminology as “[...] the visualisation of crime at different spatial and temporal scales is critical to both our understanding of crime and our ability to devise ways to reduce it.” (Brantingham, Brantingham, Song and Spicer 2018).

Furthermore, in digital aesthetics (Weibel 2019), a figure or an object is also regularly decomposed, quasi automatically, into its contour (outline) and

¹⁰ The term “big data” was initially coined by Roger Magoulas from O’Reilly media in 2005. Source: <https://www.researchtrends.com/issue-30-september-2012/the-evolution-of-big-data-as-a-research-and-scientific-topic-overview-of-the-literature/>; accessed 11.02.2021

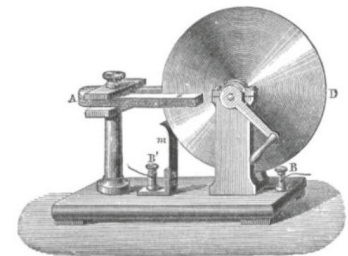


Figure 09: Historical unipolar generator, so-called Faraday disc. Source: https://de.wikipedia.org/wiki/Unipolarmaschine#/media/Datei:Faraday_disk_generator.jpg; accessed 15.12.2020

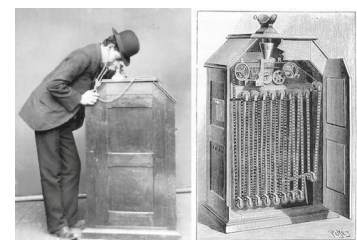


Figure 10: Kinetoscope. Source: <https://todayinottawashistory.wordpress.com/tag/kinetophone/>; accessed 15.12.2020

its texture (surface). Once the item is dissected in this way, one can play autonomously with these elements, similar to how one plays with size. Texture no longer plays a role (Weibel 2019). Both aspects, the term which we coin “non-scale” as well as Weibel’s “decomposition” are necessary to de-contextualise, transfer, scale and re-configure, for example, objects or technology, to other contexts or locations, mainly while speaking about urban transformation processes.

Peter Weibel (2019) introduced the terminology of the scale as one of the core elements of the “digital”. Present-day computational power enables existing urban settings to be documented and codified in the form of a “digital urban twin”. Whether you want to show one building, a whole city, an entire country, or a continent has been irrelevant to the processing unit since the paradigm shift from the central processing unit (CPU) to the graphical processing unit (GPU). GPU technology allows a large number of processes of very low complexity to be performed compared to CPU technology, which can perform a few complex operations. Such large-scale visualisations could become a key element in spatial planning since they allow us to understand relationships and interdependencies between buildings and humans in a broader context, which to date has been impossible for reasons of size (Garber 2018). Iterative decision loops can be made, for example, in current, and future planning policies and their impact on the built environment can be computed on a countrywide scale and visualised in a three-dimensional space (Walczak 2019). The ability to perform such large-scale assessments can support the relevance and applicability of such *DIGITAL URBAN IMAGINARIES* in the form of transferability, scalability, and replicability into other contexts. Looking at such dimensions affects both quantitative and qualitative insights.

2.1.1.3 QUANTITATIVE AND QUALITATIVE

Research findings point in a direction that neglects the overlap of quantitative and qualitative methods. Natapov et al. (2017) state that “current methods used in the study of urban systems are based mostly on economic and transportation demands and ignore human spatial cognition processes, like visual perception, while cognition is an active player in the evolution and dynamics of urban space.” Historically, the computer was mainly used for quantitative evaluations. The Cambridge (England) Centre for Land Use and Built Form Studies, founded in 1967, was inspired by Ivan Sutherland’s presentation on his Sketchpad and used the computer to quantify the geometry of built form and plan layout (Steadman 2016). In the 1960s, Constantinos Doxiadis was a pioneer in the adoption of computers in regional planning and used computers for statistical calculations.¹¹ The 1968 exhibition “Cybernetic Serendipity” curated by Jasia Reichardt, shown at the Institute of Contemporary Arts, London, United Kingdom (Reichardt 1968), can be seen as a first attempt to link or shift the quantitative aspect of algorithms and computing with qualitative features. In other words: computers were being used to make art and drawings. Today, the metric recording of reality is widespread, whereby only that which we can represent in numbers can be considered as “fact” – with a claim to

¹¹ Course by Mario Carpo on the 13.12.2020 in the context of the “Theory of Architecture 1” format from the Institute of Architecture at the University of Applied Arts in Vienna.

almost sole methodical validity (Kammasch 2020). Baecker (2018) visualises this phenomenon between the quantitative and the qualitative by using the example of light and sound. We do not see the light (photon waves), but we see all the objects that it illuminates. We do not hear the sound (short wave), but we hear the tone that it makes audible. Another significant contribution to architecture and urban planning perception is the research done by Kevin Lynch. His "The image of the city" (Lynch 1989) describes the physical experience and impact of urban elements on the perception of the layperson and the professional. Lynch evaluates this experience through surveys and mapping, representing a more qualitative approach. At this point, it is also essential to mention Jan Gehl with his introduction of a qualitative analysis toolbox into the urban jargon with the mechanics of analogue research such as on-site counting, recording, tracing, tracking, photographing, forensics, strolls, and keeping a diary should be acknowledged (Gehl & Svarre 2016). Gehl performs such analyses on an exceptionally handcrafted small scale. Another attempt at the overlap of quantitative and qualitative methods is the mentioned work of Constantinos Doxiadis, who organised the complexity of urban phenomena through the use of algorithms, computational data analysis, and visualisation. As a result – in addition to the qualitative spatial visualisation – he visualised quantitative measures in the field of architecture and urban planning such as daily movement patterns of residents to work, leisure, and supply activities (Theodosis 2017). Such methods require multi-dimensional representations in order to depict all required information.

2.1.1.4. 4D IMAGINARY IMMERSION

As one of Peter Weibel's (2019) digital image strategies (Weibel 2019), "perspective" means that it is possible to choose any distinct viewpoint and any distinct location from an eye-level perspective to a bird 's-eye view in digital image technology. Weibel (2019) is considering another strategy, "layering", which means that it is possible to navigate and superimpose between various objects displayed in digital image technology. These characteristics underline our thesis of the "non-scale" (see chapter 2.1.1.2.) and the gain in understanding while observing certain phenomena from different viewing angles with different objects displayed.

The next level is, in the context of Dirk Baecker's (2018) society 1.0: Language, society 2.0: font, society 3.0 letterpress, and society 4.0 electronic media, the discourse of immersion and volumetric representation of interaction is the extended version of society 4.0. By literally being immersed in the virtual space, we can "[...] see the patterns unveiled when looking from various contexts and perspectives" (Kalisch et al. 2016). Baecker (2018) also strengthens this hypothesis by using technology to visualise social practice and its citizen relationships. Through the use of technology within a context and purpose for which it was not initially developed, it creates much more valuable and meaningful results. An example is the use of game engine technology in architecture and urban planning, which has already become very popular among architects because the program environment is very close to that of standard Computer-Aided Design (CAD) programs (Pedercini 2019). Such technology now allows us not only

to look at one specific image – as Mitchell introduces the “pictorial turn” which he fixed in time – but virtual environments instead introduce multiple possibilities that are unframed by any predefined conditions. Virtual space or cyberspace is not an either/or, but a both-and-also (Rheingold 1992). For example, game development tools allow us to wear multiple “hats” through the provision of simulation, modelling, visualisation, and useful procedural generation tools (Dimopoulos 2019).

2.1.1.5. UNFRAMED IMAGE

An image such as a printed photograph, a painting or a screen usually has a frame. The frame is limiting the image to a particular surface. While using virtual reality (VR), this limitation is no longer the case since we are fully immersed in that specific image displayed. “VR [...] is, indeed, a very powerful new medium” (Kaganskiy 2017). First ideas related to this technology date back to 1932’s text by filmmaker Rudolf Arnheim, who proposed an extension of spatial depth by exhibiting his “Raumfilm” (English: “stereocinema”) (Arnheim 1932), which was similar to a stereoscope and recorded two strips of film a couple of centimetres away of each other and then exposed the left eye to the left film strip and the right eye to the right film strip (Arnheim 1932). The power of immersing humans in such virtual environments to enhance understanding is clear: “[...] using Virtual Reality as a therapeutic tool [...], rel[ies] on VR simulations to perform a kind of exposure therapy wherein patients are asked to confront a traumatic experience or event in order to overcome it. The results have been remarkable [...]” (Kaganskiy 2017). Such virtual multi-dimensional environments can even serve to uncover evidence in investigating human rights violations by merging data points into one platform (Weizman 2019). “Virtual Reality’s true potential, I believe, is that it allows us to experience radically different environments and perspectives, and to challenge the dominant and habitual perceptual states we’ve come to know and understand” (Kaganskiy 2017). VR lets us begin to understand the content of the medium – even if it does not precisely represent “actual” reality – by immersing us into a “virtual” reality world.

2.1.1.6. ART REPRESENTING ABSTRACTION

Starting with the representation of literature and rhetoric, the concept of ekphrasis¹² uses text and the reading of that text to evoke a described object as vividly as possible: the spoken representation enables the recipient, as it were, to have the described thing in front of his or her own eyes (Kammasch 2020). In the 1930s, film theory measured the quality of a moving image by the accuracy with which the film captured the representation of reality, the better the copy, the higher the shot was rated (Vertov 1923). Yet even now, as with film, computer-generated images are a construct of simulated reality that we evaluate depending on their truthful representation (Niquille 2018). Human perception and the ability to imagine non-realistic representations are different nowadays compared to the pre-digital age. Non-reality can also be seen as something abstract. Such abstraction can be a powerful tool to imagine the improbable or the impossible as opposite to Dunne and Raby’s (2013) 4-fold

¹² Ekphrasis is the description of visual work as a rhetoric statement.

society plays in such a system. Such discussions about multiple futures, in our case urban futures, are also the institutional frame of this dissertation at the Department for Special Topics in Architecture Design (STARCH) at the University of Applied Arts Vienna. Otherwise, we lose the ability to change trajectory and align ourselves with alternative goals and agendas. Comparing the impacts of multiple scenarios allows us to understand the different interdependencies and differences between these various solutions in the form of a white box - in cybernetician terms. We do not need to rely on biased and/or prejudged and/or predefined and/or incorrect techniques such as the "Google Translator". We base many such models on a machine learning technique known as, in this specific case, "word embedding", which are systems created by, for example, software engineers, and that have a specific cultural background, including associated biases and prejudgments, which is directly fed into such algorithms. As an example, the method of "word embedding teaches language by giving machines numerous texts, such as Google News articles. The machine processes them and creates links between words, which result from how they are associated with one another. [To illustrate such prejudgments which the machine learns, we can see, for example,] that kitchen has a stronger relationship with the word "she" than "he" because it occurs more frequently with the female pronoun in sentences" (Rozenberg 2019).

Another example is visualised by the exhibition and accompanying publication of artist Trevor Paglen at the Barbican in London, which takes as its starting point how we teach artificial intelligence networks "how to "see" and "perceive" the world by taking a closer look at image datasets." For example, if you want to use technology to detect if somebody is smiling, you need a thousand images of people smiling and not smiling, "teaching" the neural network to distinguish between those two things for it than to classify other things based on these images. "This dataset is archived and pre-selected in categories selected by humans" (Paglen 2019). The people who build training sets rarely think about which training categories we will use and what those images contain. Depending on the person classifying the training set, hidden politics, biases, and stereotypes may be rife in the result of the artificial intelligence (Paglen 2019). Especially now with the "digitalisation" of our lives, it is necessary to increase the understanding of the impacts of these technologies that are being implied in our everyday lives, since 84 percent of the western European population has access to such information and knowledge (Artheau 2018). We need to develop a "critical reading" of such technologies: it is crucial to understand who is developing such methods and techniques, who fed what information in, and the information the digital strategies learned from.

2.1.1.8. FROM MISUNDERSTANDING TO UNDERSTANDING

In many developing countries, there is a lack of data and/or fragmented provision of data as well as a lack of tools and methods to understand the available data (Schechtner 2017). "Only by identifying more comprehensive ways to map [visualise], understand and engage urban real economies can the momentum for infrastructure-led and environmentally sustainable economic growth be maintained" (Simone 2014). However, raw data, do not convey any

information – to generate knowledge and communication, they have to be organised and put into a format that makes sense to the reader (Doyle et al. 2019), which is ultimately resulting into a knowledge society rather than an information society (Falkeis 2015). As Olafur Eliasson (2020) puts it, “the language to communicate the data matters.” The method of communication is critical in the philosophy of *DIGITAL URBAN IMAGINARIES* in order to facilitate knowledge. It is not a question of showing quantitative numbers, rather qualitative images – *DIGITAL URBAN IMAGINARIES* – powered by quantitative values in the back end. Humans have a very visual perception, or at least have become very visual in our modern society (Mitchell 2018), and understand things much better in three dimensions (Beck 2019). We also need to be very careful in choosing how we communicate and visualise information since there is evidence that the results can vary drastically depending on how we visualise and share data (Walczak 2019). Methods such as VR (Virtual Reality) facilitate our human understanding of cross-referenced parameters and their impacts onto the built environment (Walczak 2019). This approach is also manifest in the exhibition “Knowledge in Images – Information Design today” at the “Museum für Gestaltung Zurich” which took place around the turn of the year 2019 to 2020: never before have we exchanged as much information as we do today. Whether for visualising big data, publishing journalistic findings, spatial orientation, or as material to promote effective learning and teaching – information design explains the most diverse content in the shortest time by combining a quantity of visual material with few words (Janser 2019). Images have the power to simplify and communicate complex facts and help us make decisions that are more well-founded.

Conclusory, following research gap can be identified in the application of a method, which we coin *DIGITAL URBAN IMAGINARIES*, particularly towards the use of real-time visualisation technologies on a large geographical urban extend, exploring the technological capabilities of dynamic time-related objects to increase the observers understanding.

Furthermore – and more general – could be a reflection on the potential of this novel methodology as a vehicle to reduce complexity for the observer and what it entails on the necessary level of detail within the “Non-Scale” (see chapter 2.1.1.2.) hypothesis.

2.2. CITIZEN-CENTRED DESIGN PROCESSES

From the literature point of view, the medium of the digital model and its materialisation in the form of a digital image seem to be promising for *DIGITAL URBAN IMAGINARIES*. It can contain a multitude of information spanning from the ability to be trans-scalar to being trans-local. The following chapter will see whether the literature indicates evidence if digital models can interact with citizens.

2.2.1. FROM SPECIALISED TO GENERALISED

From an individual perspective, speaking of "citizen science", citizen-centred design processes means allowing yourself to be exposed to topics that you do not cover within your profession. Through trial and error of computationally simulating issues from other disciplines, it generates thinking, understanding, and knowledge from that specific discipline. It allows more similar glossaries to be used than are commonly found among experts. It enables us to explore diverse methodologies. It allows us to make the "disciplinary boundaries and barriers more porous", which underlines the basic principle that we cannot solve current "multifaceted problems from the perspective of a single discipline" (Falkeis 2015b). Citizen-centred design processes allow for much more robust citizen inclusion, engagement, and exchange with each other. Through a better understanding of the other disciplines, the exchange among citizens can be inclusive and fostered; suddenly, you understand a lighting designer, a wind engineer, or a software developer (Falkeis 2015a). It enables us to broaden the spectrum to include a variety of urban issues, which is essential if we are to take a highly interlinked view. A specialist can fix one specific point in a network, but we need to be able to oversee the whole system so we can consult a specialist when one is needed. Knowing the whole network allows for complex evidence-based decision making.

2.2.2. EVIDENCE-BASED DECISIONMAKING

From a global perspective, citizen-science and citizen-centred design processes are allowing laypeople to understand complex phenomenon, stakeholders who are not trained in a specific professional field are suddenly enabled to engage in interactions such as a discussion between, for example, a city planner and a choreographer (Falkeis 2015b). The status of a layperson itself warrants further comment. Laypeople – citizens – are often the real experts in certain situations, i.e. residents who have lived in a particular neighbourhood for many years and therefore understand its dynamics much better than an expert observing this specific neighbourhood for a shorter, fixed period. This interaction of those familiar with the status quo and outside observers generates new "hybrid ideas", the recombination of knowledge which results in more inclusive solutions, innovations, and new instruments that can be interwoven into a discourse around the very fabric of society (Falkeis 2015b). Such recombination logic had

already been introduced by Adam Smith in the "Wealth of Nations" in terms of combining "the powers of the most distant and dissimilar objects" (Smith 1776).

For a decisionmaking process to be documented and archived, *DIGITAL URBAN IMAGINARIES* can serve as a visual protocol in each decision step and phase. Each phase has associated boundary conditions and parameters. Carmen Sirianni and Jennifer Girourd (2012) subdivide a "good planning support system [...]" related to "[...] alternative policy choices" into four categories. The philosophy of citizen-centred design processes focuses on the fourth point of "[...] instantaneously view[ing] the results graphically in the form of charts, maps, and video/sound display that enhance citizen understanding". The concept thus not only allows participation in any process but also the initiation of real and meaningful ideas. Here it is interesting to refer to Daniel Kahneman (2012) and John Bargh (2018), who studied how we as humans make judgments and decisions. Kahneman (2012) distinguishes our cognition into two systems, System 1 and System 2. All human assessments are automatically performed by System 1, and one of the tasks of System 1 is to determine whether any additional input is required from System 2. Bargh (2018) refers to those two systems as the unconscious and the conscious. For the purposes of this dissertation, System 1, the unconscious, refers to the *DIGITAL URBAN IMAGINARIES*; and System 2, the conscious, represents citizen-centred design processes in form of a decisionmaking or policymaking process evoked by us as human actors.

2.2.3. INITIATION AND CO-DESIGN

Since the 1990s, there has been a visible trend of opening up formal planning processes to a bigger number of participants (Healey 1992). Conversely, however, communication between experts and non-specialists can prove to be difficult during these exercises. Because of the visualisation tools used (architectural drawings, plans, images, models), it is often impossible for laypeople to imagine the future proposals (buildings, neighbourhoods, districts) sufficiently precisely (Neuhaus et al. 2015). Only a minuscule proportion of dwellings for the world population was designed by architects (1 percent) (Brillembourg et al. 2005), which gives an idea of proportionally how few people may understand such described forms of representation. The broader audience generally does not know what they might want since any proposal is usually just accepted, an outcome that is not least due to the way in which such recommendations are communicated (Walczak 2019). The will of political institutions and agencies drives such participatory processes towards implementation, and exerting influence over them is often challenging (Kubicek 2010). Thus, it is critical that responsible and sustainable proposals are initiated so that local communities can adopt them and help co-design, develop and execute their realisation.

2.2.4. MAKING

"Painting with a mouse on the computer screen has a high entertainment value, but [...] drawing a stroke with a pen is no different from drawing a stroke with a mouse. The real challenge is to discover the intrinsic properties of the new medium. To find out how the stroke you draw via computation is one you could never draw, or even imagine, without computation" (Maeda 2001). This paradigm has remained unchanged up until today. When we look at architectural tools described as "architectural aids", they often just replicate analogue architectural tools (Hanspal 2018). Stanislas Chaillou (2019) is achieving a shift away from this with an initial approach that proposes a "generative adversarial network" to aid the design of plan layouts for buildings. In today's information society and data accessibility through network technology, the entry point into the field of citizen-centred design processes is low and therefore accessible. Massive online community platforms that are robust, that exchange knowledge, and that support each other by debugging code are critical. Outstanding online education through highly applied tutorials is essential. Such online platforms allow each individual to customise and combine snippets of code for individual projects and purposes (Gross et al. 2018). Through the process of initiation, making, and combination, we are exposed to different disciplines and topics and therefore learn from these fields in an interdisciplinary way.

2.2.5. INTERDISCIPLINARY AUTODIDACT

Citizen-centred design processes and *DIGITAL URBAN IMAGINARIES* are changing the way we make decisions. Suddenly, laypeople and residents can apprehend a complex urban phenomenon without actually understanding it. A layperson can use and implement specialist knowledge (such as data collection with air measurement devices which feed a more extensive database of air quality across the whole world¹³) without actually having such knowledge themselves. *DIGITAL URBAN IMAGINARY* technology could provide instant and iterative feedback loops, trial and error, learning by doing and making.

¹³ <https://air.plumelabs.com/en/>; accessed 17.01.2020

Historically, Marvin Minsky, who founded the notion of "artificial intelligence" in 1961, theorises this method as the problem-solving machine. In other words, the machine solves problems by trial, error, and learning (Minsky 1961). Nicholas Negroponte made an initial attempt at such a problem-solving machine in 1973 with "URBAN5", which enabled any layperson to become an architect with the use of computers (Negroponte 1973).

We all use certain technologies without actually understanding how they work, for example, a car and its engine. The improvement of understanding has the capability to change, for example, politics drastically and maybe even disruptively. When we vote for any political initiative, its mostly communicated verbally or via text and thus does not fully communicate its intentions as compared to, for example, immersive environments.

A "model" for a software engineer is a mathematical equation, whereas for an architect, it is a "scaled physical representation of reality". Learning the glossary, the thinking, the methods – a sort of common platform of exchange – of the

other discipline is key to interdisciplinary projects, and we can acquire this through citizen-centred design processes.

2.2.6. INTERDISCIPLINARY AND SPECIALISED

We do not generate new knowledge within closed disciplines and professions (von Borries et al. 2019); instead, it is generated through interdisciplinary exchange and insights. At the same time, this exchange has to be applied on a personal level for its insights to be properly understood. Thus, interdisciplinary knowledge is the utility that emerges from communication, collaboration, and working with multiple stakeholders: the "citizen-centred design processes" methodology allows stakeholders to be activated at the most meaningful moments, using the appropriate communication channels, within the process of the task, project, etc. At the same time, the work itself is done by creating a novel, interdisciplinary specialist in each case who – through the "citizen-centred design processes" method – can metaphorically act as an "integrator" in the whole process and holistically become a key figure in interdisciplinary approaches.

Conclusory, following research gap can be identified in the application of a method, which we coin "citizen-centred design processes", particularly towards the use of *DIGITAL URBAN IMAGINARIES* and their impact on human percept in decision- and policymaking.

Furthermore – and more general – could be a reflection on the potential of this novel methodology as a vehicle for a more inclusive communication medium, regarding the understanding of complex and multifaceted urban transformation processes.

2.3. DIGITAL URBAN IMAGINARIES THAT IMPACT PERCEPT

Can *DIGITAL URBAN IMAGINARIES* impact citizen-centred design processes? In other words, can they impact the baseline of human percept?

From the perspective of art and art production concerning perception, a significant distinction needs to be made between the German notions of "erfahren" (English: to experience in the sense of to hear about/to learn) and "erleben" (English: to experience in the sense of to see/to witness) as well as "handhaben" (English: to handle) and "wahrnehmen" (English: to perceive) or "wahrhaben" (English: to believe) (Ries 2020). For example, if old image techniques apply "differential logic", i.e. they maintain the distinction between image and reality, this distinction is absent in virtual environments, and the observer is a co-actor within the simulation.

The key to perception is summarised well by Haefner: "As ophthalmic animals,

we have always been used to capture any structures visually" (Weizenbaum et al. 1990), because "to find words to what you have in front of your eyes – how hard can that be" (Benjamin 1929).

Because of the absence of research on the impact of immersive experience on perception, the review in the following paragraphs outlines some of the evidence that suggests that more commonly used visual material (photo or video) impacts perceptions.

Considerable research exists on the use of videos and their impact, especially in marketing and education research. For instance, a 2012 review (Kay 2012) found that video had a positive educational impact on the skills and test scores of students and an advertising research review (Tellis 2009) confirmed the correlation of sales elasticity with advertising spending.

Looking at the impact of negative perceptions, a meta-analysis of 72 research articles looking at ways to decrease the stigma of mental illness concluded that educational interventions in the classroom and face-to-face contact or contact through video had a positive impact on the reduction of stigma. However, while both interventions had a positive effect, face-to-face contact was more effective than video contact (Corrigan et al. 2012).

In another widely cited review of 985 papers or reports about interventions aimed at reducing prejudices, Paluck & Green (2009) identified 107 randomised field experiments. Among those experiments, they found 17 reading interventions and 13 media interventions. Most of the studies did not measure any change in behaviour but found suggestive positive evidence that attitude – measured by surveys – was indeed impacted. They also found that narrative persuasion (through media content) worked to create empathy, perspective-taking, and communication of social norms.

Building on this literature, the hypothesis of this dissertation is that immersive experiences of *DIGITAL URBAN IMAGINARIES* allow for effective communication of information and should therefore be deemed an incredibly useful medium for affecting perception. The underlying theory behind our belief is that an immersive environment allows the communication of denser information (sounds, visuals, voices, interactive charts etc.), which are thus more likely to impact the person undergoing the immersive experience.

Social researchers have been using film and video for decades, but only recently has video equipment become widely affordable and available, enabling a broader audience to use these tools today. The most common research approaches in social sciences using video and film are participatory video (where research subjects are provided with video equipment to make their experiences visible), videography (an ethnographic approach), repurposing of existing videos (e.g. CCTV footage, YouTube), video-based fieldwork (to collect naturally occurring data in the field), and the method used in this dissertation, video-elicitation, a way of stimulating discussion or reflection in interviews and surveys of focus group situations.

Key to elicitation methods is the use of a media material (video, photo) as a stimulus for an interview, as "it aims to trigger responses and memories, and

unveil participants' attitudes, views, beliefs, and meanings or to investigate group dynamics" (Meo 2010). There is very little literature on video-elicitation and, to the best of our knowledge, no literature on 360° video or immersive elicitation methods. Nevertheless, there is a lot of research on photo-elicitation, which is a well-established qualitative method.

The main advantages of using visual material in research have been presented by Pain (2012) in a review of 109 research articles that make use of visual material. He found the recurring advantages mentioned by researchers were 1) the "enrichment of data collection or presentation" and 2) the effect that visual material had on "the relationship between participants and researchers" (Pain 2012). We expect to strengthen both of these aspects by the use of immersive media experience, which represents even denser data. Besides using elicitation in empirical research, it may also be a useful tool in the context of interdisciplinary research in the dialogue between researcher and policymaker. Video eliciting "can also be used to provide a basis for reflection on practice and continuing professional development", as stated by Moss et al. (2007).

As physical medium to display visual material, until now, researchers have used a "visualisation dome" (Gawlikowska et al. 2018) or a "fulldome"¹⁴ (Department of Digital Arts under Prof. Ruth Schnell at the University of Applied Arts Vienna). Artists such as Jeffrey Shaw used an inflatable dome (1992) or a circular space (1993) (Duguet et al. 1997). At the same time, Shaw started to think theoretically about VR in 1992 (Shaw 1992) and envisaged immersing subjects into a virtual environment to communicate certain aspects and phenomena. However, with such techniques, the human eye is not fully occupied by the virtual environment, but limited to the size of the projected surfaces (not accounting, i.e. for ground surface). Compared to, for example, VR, this "dome" requires a much longer installation and transportation time. Still, it can accommodate multiple users within one physical environment, which can be advantageous for participation and interactions regarding standard decisionmaking processes (Hübner et al. 2018).

The visualisation dome (Gawlikowska et al. 2018) was evaluated in respect of the perception change of the individual subjects, in this case, the acceptance of offshore wind parks. The visualisation dome had a very insignificant impact. VR as a medium is impacting multiple senses (such as sight, hearing, touch, and movement) compared to the medium of the video which is affecting two senses (sight and hearing) or the medium of the image which is just impacting one sense (sight).

Several studies investigate the way in which information is experienced in an immersive environment and the effects on the decisionmaker's perception (Yilmaz et al. 2014). Yilmaz et al. (2014) asked non-expert users to find a target building and to gather information about this building in an immersive environment. The evaluation of the study included a time component (time needed to complete this task) and memory-error component (participants recalling the right information) in two different environment exploration modes (passive and active exploration). The "Unity" game engine was used in this study by Yilmaz et al. (2014) to manually import one selected building

¹⁴ https://www.dieangewandte.at/ausstellungen/fulldome__vr__ar_lab; accessed 11.02.2021

perimeter containing four building blocks and a terraced housing unit. To better understand the environment, Yilmaz et al. (2014) provided additional orientation maps and graphics in the user interface. An interesting conclusion was that the animated illustrations and charts about building information were not helpful for the user and stood in the way of rapid understanding. Many different studies used a similar approach to the evaluation, such as Wang (2017), which looked at the elapsed time of task completion for his "Web3D Forest". Gygli et al. (2013) assess visual material with the introduction of an initial approach called the "interestingness of images". The research introduces a set of central aspects of visual interestingness such as unusualness and aesthetics including colourfulness, arousal, complexity, and contrast from which an interestingness predictor is built computationally (Gygli et al. 2013).

Conclusory, following research gap can be identified in the application of a method, which uses immersive experiences instead of video or photo, we coin the term "immersion elicitation", can be applied in an interdisciplinary research context, exploring the impact on the perception of citizens, policymakers and practitioners when presented with research as an immersive experience.

Furthermore – and more general – could be a reflection on the potential of this novel methodology as a vehicle of dialogue and mediation in an interdisciplinary research process.

3.

Research Strategy

In the subsequent chapters, the research question is defined and informed by the literature review. The research locations are determined based on the institutional setting of the Department for Special Topics in Architecture Design at the University of Applied Arts Vienna (STARCH), the Urban Research Incubator (URI) at the Institute of Science, Technology and Policy at the Swiss Federal Institute of Technology in Zurich (ISTP), the Chair for Architecture and Urban Design at the Swiss Federal Institute of Technology in Zurich (LUS), and the Laboratory for Energy Conversion at the Swiss Federal Institute of Technology in Zurich (LEC) in which this dissertation is embedded, and the chosen research methodology is explained in detail.

3.1. RESEARCH QUESTION

After the evaluation of the state of the art literature and tools, the overarching research plan of this dissertation focuses on the design of *DIGITAL URBAN IMAGINARIES* (see chapter 1.3.) in the form of digital models (see Chapter 1.3.) of urban transformation processes in three or four (time) dimensions, to measure the shifting baseline in percept-formation and decisionmaking processes, specific steps are required. To generate *DIGITAL URBAN IMAGINARIES* as well as to measure shifting baselines using *DIGITAL URBAN IMAGINARIES*, the main research question is as follows:

Research Question:

Is it possible to apply a methodology of collecting, processing, and communicating to measure whether *DIGITAL URBAN IMAGINARIES* of urbanisation processes can shift the baselines of how citizens and policymakers form percepts, take decisions, and come by opinions?

3.2. RESEARCH LOCATIONS

To test whether the method of collecting, processing, and communicating (CPC) of urban transformation processes is useful in impacting human perception, we chose the following case studies from different climatic, cultural, and geographic regions with varying scales in population and build density (**see figure 12 and table 01**). This trans-local selection of case studies allows the transferability and scalability of the different methods to be tested in terms of the definition of the digital model (see introductory chapter 1.3.). The selection of the case study locations was amplified by the doctoral research context of the Department for Special Topics in Architecture Design at the University of Applied Arts Vienna (STARCH), the Urban Research Incubator (URI) at the Institute of Science, Technology and Policy at the Swiss Federal Institute of Technology in Zurich (ISTP), the Chair for Architecture and Urban Design at the Swiss Federal Institute of Technology in Zurich (LUS), and the Laboratory for Energy Conversion at the Swiss Federal Institute of Technology in Zurich (LEC). The case study of Lausanne, Sarajevo and Bogotá show the development of the method of collecting, processing and communicating, while the “measuring” study locations serve as metrics and index in the change and impact in human percept to test and measure the method of collecting, processing and communicating. The case studies are listed according to their correct order indicated by the iterative spiral model explained in the research methodology.

3.2.1. CPC: AGGLOMERATION OF LAUSANNE (CH)

This research chose Lausanne as the first case study since it is the fastest-growing urban agglomeration and one of the biggest cities in Switzerland. It has experienced a relative population growth of 17 percent over the last ten years (2007-2017) (Swiss Federal Office for Statistics 2018). It is ranked fourth compared to the population size of other Swiss cities (Swiss Federal Office for Statistics 2018). Lausanne is situated in the Swiss canton of Vaud on the shores of Lake Geneva. It is significant in that the current regulatory framework of the City of Lausanne has only left itself resources for additional building volume until the year 2022 – based on current migration trends (Marini et al. 2019). We can observe that the canton of Vaud’s regulatory frameworks for the built environment are extraordinarily complex compared to other Swiss municipalities.

Furthermore, Lausanne and its agglomeration expect future growth of 100,000 inhabitants by 2030. Comparing total population growth between 2007 and 2017, it is apparent that the governmental bodies are extrapolating past increase in a linear fashion up to the year 2030. In contrast to the official data, Marini et al. (2019) identified a population growth of approx. 55,000 by 2035 as the average of all three scenarios simulated in this study. We can observe that the agglomeration of Lausanne is composed of 30 different communes, including the City of Lausanne itself.

This initial (building) collection framework developed in the frame of this case study was later transferred to the context of Bogotá and Cape Town and extended with lighting visualisation capabilities. The study of the agglomeration



Figure 12: Worldmap indicating all locations which we considered within the frame of this dissertation. The different hatching shows the form of engagement within these contexts: primary case studies, research/workshop, exhibitions or conferences/lectures. Red lines are indicating the transferability and scalability of the developed technology to other contexts: 01 from Switzerland to Cape Town (see chapter 4.5.), 02a from Cape Town to Bogotá (see chapter 4.6.), 02b from Bogotá to Bogotá, 03 from Bogotá back to Switzerland (see chapter 4.1.), 04 from Switzerland to multiple locations (Serbia, Bosnia and Herzegovina, and Vienna), as outlook locations 07 from Vienna to Canada and 08 from Vienna to China.

Source: Michael Walczak (2021)

of Lausanne included four research trips: April 18, 2018; April 25, 2018; June 27, 2018; and October 24, 2018.

3.2.2. CPC: CITY OF SARAJEVO (BiH)

This research chose the City of Sarajevo (**see figure 03**) as a case study since it is one of the most polluted cities in the CEE (Central and Eastern Europe) region, assessed by the most recent data (2018) by the World Health Organisation (WHO).¹⁵ Poor air quality is also amplified by weather inversions, a natural phenomenon that results from Sarajevo's "basin" topography, among other things. However, heavy individual traffic and domestic solid fuel stoves are the main CO₂ emitters. Socialist-communists based Sarajevo's urban planning on the General Urban Plan (GUP) – instrument of socialist-communist centralised resources planning dating back to 1965 – and its revision in 1985, which is still in power until today.

¹⁵ https://www.who.int/airpollution/data/aap_air_quality_database_2018_v14.xlsx?ua=1; accessed 10.12.2019

Moreover, modernistic dogma saw Sarajevo designed as a "functionalist city": the division of the main functions into industry, recreation, housing, and commerce; and traffic in-between. This model is highly outdated today and one of the reasons for the current state of Sarajevo.

This dynamic processing framework developed in the frame of this case study was later transferred to Bogotá, Toronto and Vienna and extended with pedestrian and mobility visualisation capabilities. The study of Sarajevo included four field research trips from: October 20, 2017 to October 26, 2017; February 10, 2019 to February 14, 2019; May 6, 2020 to May 10, 2020; and May 16, 2020 to May 19, 2020.

3.2.3. CPC: CARACOLI NEIGHBORHOOD IN BOGOTÁ (COL)

Bogotá was chosen as the context for a third case study. Huge parts of cities in the Global South may be informally built: 50 percent of Bogotá, for example, is of informal origin (Hernández-García 2013). Hernández-García (2013) characterises informal settlements by constant physical transformation. We chose a 183-metre-long pedestrian street in Bogotá's Caracolí settlement as the detailed area of observation. An 88-metre area of the road was lit by four high-pressure sodium street lights (referred to as "formal" lighting), with the remaining 95 metres lit by nine self-built luminaires installed by the residents (referred to as "informal" lighting). The street begins at an altitude of 2,720 metres. The road ends at an altitude of 2,770 metres, resulting in a very steep incline of over 35 percent. Official planning documents regard the majority of the dwellings as illegal. The land classification categorises these illegal buildings as high risk due to the threat of landslides. The improved visualisation technology developed initially for the case study of Cape Town was applied and extended with lighting visualisation capabilities in this context of Bogotá and transferred to the context of Europe, namely Zurich and Vienna. The study of Bogotá included two field research trips from: August 22, 2019 to September 13, 2019; and October 19, 2019 to October 26, 2019 as well as an online stakeholder

engagement session on July 23, 2020 (see chapter 4.7).

3.2.4. MEASURING: PJS SETTLEMENT IN CAPE TOWN (SA)

The “measuring” study locations focus in particular on the evaluation of the change in perception using *DIGITAL URBAN IMAGINARY* techniques. The first case study to measure percept is Cape Town. Cape Town, South Africa, and predominantly the township neighbourhoods including Khayelitsha, still struggle with the legacy of apartheid. In this context, there is an assumed population of no less than 400,000 inhabitants. High mast lighting is one of the remaining “apartheid tools” and reminiscent of this historical period of segregation. Nevertheless, even now, it still serves as a template for the implementation of future lighting solutions in the informal settlement domain (Pieterse et al. 2014). City officials perform lighting simulations to evaluate effectiveness, but on a plane surface without considering the spatial conditions of informal settlements (Mamdani 1996). This starting point results in inappropriate lighting which in particular casts very dark shadows, illuminates roof surfaces with resulting light pollution, and allows for very non-homogeneous lighting conditions, creating high crime rates and fear. We chose this location to identify whether it is possible to elicit lighting preferences from local citizens in the informal settlement and to illustrate and communicate the issues mentioned to policymaking stakeholders in Cape Town. The developed visualisation technology in the frame of this case study was later transferred and scaled to the context of Bogotá. The study of Cape Town (see chapter 4.6.) included two field research trips from: January 27, 2018 to February 9, 2018; and March 11, 2019 to March 24, 2019.

3.2.5. MEASURING: BOGOTÁ (COL)

The second case study to measure percept is Bogotá. Another important factor of the City of Bogotá is the unprecedented share of gated communities at almost 40 percent (Kostenwein 2021). Gated communities have restricted access, controlled entrances and create barriers with no relationship and interaction with the surrounding public space. This creates a worst-case scenario for inclusive and safe public spaces (Kostenwein 2021). We chose the location in order to establish whether it is possible to elicit the perception of the local citizens towards gated communities and to measure the change in perception if the current speed of development of gated communities is extrapolated into the future. The study of Bogotá included a museum exhibition with the setting for the survey and two field research trips from: August 22, 2019 to September 13, 2019; and October 19, 2019 to October 26, 2019 (see chapter 4.6.).

3.2.6. TRANSFERABILITY: VIENNA (AT), TORONTO (CA), AND SHANGHAI (CN)

The well-described parameters and simulations for the primary case studies and necessary research implementation steps of this dissertation are the topics concerning lighting, densification, air-quality, wind, pedestrians, and mobility. The cities Vienna, Toronto and Shanghai, are intended to show how the methodology presented within this dissertation could be applied, transferred, and scaled elsewhere. Furthermore, a different outlook on relevant aspects is described and serves as an example of the flexibility of the method which we introduced as a platform with this dissertation.

Vienna is one of the European cities that is most affected by global warming, particularly in summer (Smid et al. 2019). An understanding of Vienna's cold airstreams and wind corridors is therefore essential to be able to cool down its urban heat. The city is already active in this respect through selective interventions such as planting trees, green facades, reducing asphalt/sealed surfaces, shade-giving measures, or water sources. Nevertheless, an integrated large-scale city concept is as yet absent. Apart from such climatic simulations, we chose Vienna in order to perform traffic simulations within a photorealistic virtual environment (see chapter 4.1.) due to the access to homogenous urban data and "GEMSim" (Saprykin et al. 2019). Vienna is also characterised by constant migratory influx mostly from central and eastern European countries. While in 2020, approximately 41%¹⁶ of the Viennese population have a foreign origin. As part of the "Society in Motion" program at the Department for Special Topics in Architecture Design at the University of Applied Arts Vienna (STARCH), which was mainly addressing the topic of migration in Vienna, the agent-based population model embedded within "EnerPol" (Marini et al. 2019) was used to perform different migratory scenarios (see figure 13). These simulation results formed a *DIGITAL URBAN IMAGINARY* for further speculative interventions in the city within the program.

We chose Toronto as a case study to theoretically imagine and test whether we can apply the method presented within this dissertation to an extra large-scale context, with a sufficient amount of data access but remote exposure to the context. We focused primarily on Toronto's waterfront area. A script automated the process to reconstruct a 3D digital twin of the whole city so that various simulations could be performed using the Rhinoceros3D (Robert McNeel & Associates 2017c), Grasshopper3D (Robert McNeel & Associates 2017b), Elk¹⁷, atit¹⁸, and Ladybug/Honeybee (Roudsari 2019b; 2019c) frameworks (see figure 16). We rebuilt the digital twin using open source data from OpenStreetMaps and official data provided by the city. Topics of interest included the study of daylight/solar radiation concerning passive and active energy production, shadow casting, wind exposure and corridors including potentials for wind energy production, view analysis towards the lake, airport air corridors and its noise pollution, and reflection from the water. The south-facing lake Ontario is a hallmark of Toronto. This geographical characteristic allows for perfect exposure to daylight, the reflection of light by the lake, and exposure to natural

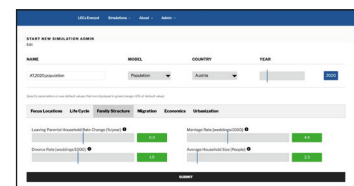


Figure 13: Accessibility through the intuitive graphical web interface to set parameters and run and display EnerPol agent-based simulations. We can access the output in the form of 2D maps and tabular data. Source: Michael Walczak (2018)

¹⁶ <https://www.wien.gv.at/menschen/integration/daten-fakten/bevoelkerung-migration.html>; accessed 11.02.2021

¹⁷ <https://www.food4rhino.com/app/elk>; accessed 10.02.2021

¹⁸ <https://www.food4rhino.com/app/it>; accessed 10.02.2021

wind flows (see figure 17). Buildings with a less performative and less optimal orientation could be compensated by building clusters and microgrids.

We chose Shanghai as a case study to theoretically imagine and test whether we can apply the method presented within this dissertation to an extra-extra large-scale context, with a minimal amount of open-source data access and remote exposure to the context. We focused particularly on Shanghai's "Bund" as well as "Pudong" areas. A script automated the process to reconstruct a 3D digital twin of the whole city so that a variety of simulations could be performed using the Rhinoceros3D (Robert McNeel & Associates 2017c), Grasshopper3D (Robert McNeel & Associates 2017b), Elk¹⁷, atit¹⁸, and Ladybug/Honeybee (Roudsari 2019b; 2019c) frameworks. We rebuilt the digital twin using open source data from OpenStreetMaps. Topics of interest included referencing and reflecting on the "active energy building" exhibition (see description below) as with the case of Toronto.

By reflecting on the "falkeis²architects" exhibition at the Future Lab in the Museum for Applied Arts in Vienna (MAK) (from June 6, 2018 until July 29, 2018) and the AEDES Architecture Forum in Berlin (from August 24, 2018 until October 11, 2018) entitled "Active Buildings - Innovation for Architecture in Motion" (see figure 14), we saw an example of how an observation of building clusters ("active energy city") rather than individual units could compensate for less well-oriented buildings and their shortcomings, and therefore create a much more efficient decentralised system for energy production and planning. By energy planning, we essentially mean the study of sun hours, shading, radiation, and associated solar energy production. An essential factor is the understanding of the city morphology and its building heights, street widths, building courtyards, program, and public spaces in terms of the city's climate. The application of the method presented by "falkeis²architects" in the exhibition to the scale of the whole city as well as the technique presented in this dissertation was intended to open a whole new dimension on how regulatory zoning policies could inform energy-efficient city planning. In addition to Vienna, Toronto and Shanghai, this reflection on the "active energy building" exhibition would also be applicable to the "Collection", "Processing", "Communication" and "Measuring" case studies of this dissertation.



Figure 14: Exhibition of "falkeis²architects" at the AEDES Architecture Forum in Berlin (from 24.08.18 until 11.10.18) titled "Active Buildings - Innovation for Architecture in Motion", the picture is showing the 3D printed model of the actual "active energy building" as well as the urban simulations in the background on four screens.
Source: <http://www.falkeis.com>; accessed: 22.01.2021

		Case Studies			
	Phase	1. COLLECTING, PROCESSING AND COMMUNICATING (CPC)	2. CPC	3. CPC	
	Study Title	<i>Application of the methodology of collecting, processing and communicating.</i>	<i>Application of the methodology of collecting, processing and communicating.</i>	<i>Application of the methodology of collecting, processing and communicating.</i>	
Model: Urban Informatics	Case Study	Agglom. of Lausanne (CH)	City of Sarajevo (BiH)	Caracoli, Bogotá (COL)	
	Urban Scale	Large	Medium	Small	
	Policy Scale	Large (Agglomeration)	Medium (City)	Small (Neighborhood)	
	Digital model	Spatial policy model, new Grasshopper3D definition	Computational fluid dynamics (CFD), existing Grasshopper3D definition	Dynamic VE, based on game engine technology	
	Medium	2D, tables, plots	3D, Virtual environment	4D, VR	
	Communication to ... (Stakeholders)	Service du développement territorial (SDT) in Lausanne	Meteorological Institute of Bosnia & Herzegovina (BiH)	Unidad Administrativa Especial De Servicios Públicos - UAESP, Subdirección Servicios Funerarios y Alumbrado Público, Bogotá	
		Ville de Lausanne, Service de l'urbanisme, Bureau d'études et planification	Institute for Public Health of Canton Sarajevo	Secretaría Distrital de Planeación - SDP, Bogotá	
			Ministry of Planning, Construction and Environmental Protection of Canton Sarajevo	Local residents from Caracoli district, Bogotá	
			Sector of protection and improvement of the environment		
	Urban transformation process		Current maximum building volume within building regulation, "what-if" scenarios	"what-if" scenarios	Current and future (extrapolated) densification process
			One of the highest formal urbanisation in Switzerland	Informal urbanisation and shrinking city	Rapid informal urbanisation process
	Quantitative/Qualitative	Quantitative	Quantitative and Qualitative	Qualitative	
	Dimension	2D, 3D	2D, 3D	2D, 3D, 4D	
	Input	Cadastral plans, zoning plans, building regulations	Existing build environment, wind measurements	Existing build environment, dynamic data (pedestrian movement, building years, etc.), materials, environmental data (wind)	
Output	Maximum building volume in 3D, existing build environment in 3D	Impact of building structures on wind	Dynamic virtual environment, digital twin of reality, graphical user interface (GUI)		

Legend

	Implemented
	Potential future implementation

Table 01: Crossreferencing the case studies of this dissertation to the general methodology of collecting, processing and communicating as well as its reference to the digital model and its achieved development status during the dissertation.
Source: Michael Walczak 2021

Case Studies				
4. MEASURING	4. MEASURING	5. TRANSFERABILITY/ SCALABILITY	5. TRANSFERABILITY/ SCALABILITY	5. TRANSFERABILITY/ SCALABILITY
<i>How can DIGITAL URBAN IMAGINARIES aid decision making in public lighting, administering more appropriate lighting solutions for informal settlements?</i>	<i>How can DIGITAL URBAN IMAGINARIES elicit and change perception of urban transformation processes?</i>	<i>Digital Twin Vienna</i>	<i>Digital Twin Toronto</i>	<i>Digital Twin Shanghai</i>
Cape Town (SA)	Bogotá (COL)	Vienna (AT)	Toronto (CA)	Shanghai (CN)
Small	Extra-large	Large	Extra-large	Extra-large
Small (Neighborhood)	Medium (City)	Medium (City)	Medium (City)	Medium (City)
Dynamic VE, based on game engine technology	Dynamic VE, based on game engine technology	Dynamic VE, based on game engine technology	Grasshopper3D definition	Grasshopper3D definition
4D, VR	VR in museum/exhibition	4D environment	2.5D environment	2.5D environment
Public Lighting Development, City of Cape Town	Museum visitors spanning from university professors, ambassadors, students, local residents and politicians	Energy Department City of Vienna	City of Toronto, Deputy Mayor	Tongji University, D&I
Transmission System Development, City of Cape Town	Museum staff to assist museum visitors with VR experience	Building Innovation Lab, falkeis²architects	Ryerson University, Architectural Science	Building Innovation Lab, falkeis²architects
NGO, Social Justice Coalition (SJC)		University of Applied Arts Vienna, Digitale Kunst	Building Innovation Lab, falkeis²architects	
Local residents from Khayelitsha, Cape Town				
Rapid informal urbanisation process	Current and future development in share of gated communities	Improve climatic response of urban areas on a large-scale	Improve climatic response of urban areas on a large-scale	Improve climatic response of urban areas on a large-scale
		Public and private mobility		
Quanti. and Quali.	Quanti. and Quali.	Quanti. and Quali.	Quantitative	Quantitative
2D, 3D	2D, 3D, 4D	2D, 3D, 4D	2.5D	2.5D
OpenStreetMap, building heights, luminaire positions	Existing build environment, dynamic data (transformation of build environment), satellite images	Existing build environment, cadastral plans, zoning plans, public and private mobility (GEMSim), materialisation	Cadastral plans, building heights	OpenStreetMap
Virtual environment, graphical user interface (GUI)	Dynamic virtual environment, digital twin of reality, graphical user interface (GUI)	Dynamic virtual environment, digital twin of reality		

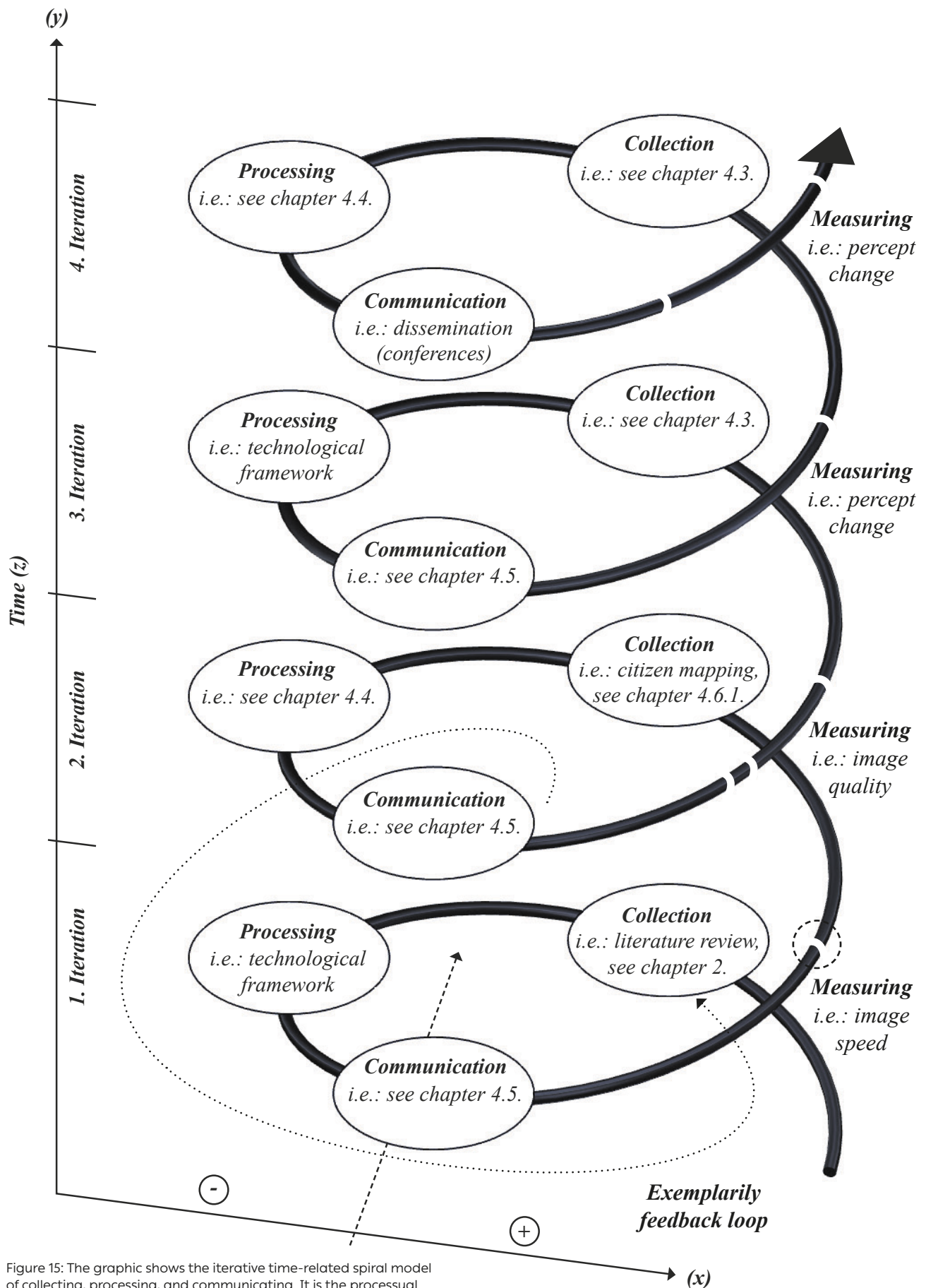


Figure 15: The graphic shows the iterative time-related spiral model of collecting, processing, and communicating. It is the processual structure of this dissertation, which is including multiple time-related iterations and feedback loops. The various gaps in the continues spiral are indicating the moments of measuring.
Source: Michael Walczak (2020)

3.3. METHODOLOGY

The orchestration of the research question requires evidence acquired through data collection and for this data to be processed and interpreted, and the message conveyed via a communication medium.

These three aspects – collecting, processing and communication – have become the main pillars of the method to design *DIGITAL URBAN IMAGINARIES*. We introduce them in the following chapter.

We will structure the methodology of this dissertation into “collection”, “processing”, and “communication”. The literature suggests using the triadic notion inspired by the “Turing machine” (Turing 1937) and a more extended version of the “Theory U” by Claus Otto Scharmer (Schneidewind 2018). The Turing machine is considered as one of the first abstract and theoretical models to describe the notion of algorithms – even before computers were born – and structures the digital process into reading, processing, and writing.

To achieve the defined research plan, we translated the glossary of Turing and Schneidewind into our own. We translated the glossary of reading (Turing 1937), downloading, seeing, and sensing (Schneidewind 2018) into collection; processing (Turing 1937) and “presencing” (Schneidewind 2018) into processing; writing (Turing 1937), crystallising, prototyping, and performing (Schneidewind 2018) into communication.

The step of “collection” is mostly associated with the real world. The first step of this dissertation implementation shows this aspect of “collection” by gathering, for example, the built environment data. This step has the potential of involving lay people in “citizen-centred design processes” terms.

The processing mostly concerns the digital twin, the *DIGITAL URBAN IMAGINARY*, of the imagined real world. The second step of this dissertation implementation shows the element of “processing” by aggregating, for example, climatic data and correlating these with the built environment of the third step.

The communication primarily takes place through extended realities such as virtual reality, and it also houses the aspect of visual decision support. The third step of this dissertation implementation mainly focuses on the aspect of “communication” of, for example, policies by using virtual reality techniques using the first and second step as input. The audience can – in “citizen-centred design processes” terms – be, for example, a broader local. To not rely only on expert knowledge due to the opacity and incomprehensibility of natural and human-made phenomena, communication nowadays is critical (Weizenbaum et al. 1990).

We have now distinguished these three phases very clearly and linearly. However, the treatment of information only through these steps is not enough. In order to achieve meaningful results, this dissertation identified the necessity of an iterative process. This is what distinguishes our triadic “machine” from the

Turing and Schneidewind systems.

When we look at this proposed process from above, we can observe a simple continuous circle with three phases. Tilting the view from a plan view to an axonometric 3D view suddenly shows that the circle is instead a spiral with many phases, iterations, and feedback loops (**see figure 19**). Such generation does not begin in a linear fashion with collection and processing than resulting in communication; instead, an iterative process around those three categories is proposed.

We call our method the iterative time-related spiral model (**see figure 15 and 19**). Historically, bringing multi-layered complex content consisting of interactions into a linear form (e.g. into that of a text) has always been problematic. Oriental thinking alternatively offers another approach in which problem and solution are approached simultaneously at the outset. The processing phase moves along a spiral, which already contains the complete solution at any given time (McLuhan et al. 2008).

In our case, the length of the spiral represents the time component of the process on the y-axis. Conversely, the negative value on the x-axis represents the number of backward feedback loops, and the positive value on the x-axis represents the number of forward feedback loops. The designation of negative and positive is not a qualitative interpretation but instead indicates that the negative aspect refers to an iteration of the process back to phases that have already passed, while the positive connotes the process proceeding to the next stages that have not yet been processed.

Another essential characteristic of the spiral model is that it is designed similar to a "for-loop" in software-engineering terms. For each loop/iteration, the process must undergo the phase of "collection", "processing", and "communication". We cannot skip any of these steps. The process can keep iterating in one phase (for example, "collection") as long as it is necessary, but once it has proceeded to the next stage (for example, "processing"), it cannot merely iterate backwards.

Several iterations can follow each other. In case of a feedback loop, it has to iterate back to the previous step within the preceding phase. For example, from "communication" in iteration two, to "collection" in iteration one, if data has to be re-collected because the "processing" and the "communication" identified gaps and inconsistency (**see dashed feedback loop in figure 15**). This technique assures the learning factor in the form of synthesis and reflection of each step. The more iterations you make, the better the result gets.

In any given moment within the spiral model, we "measure" the performance and status in the form of citizen-centred design processes and stakeholder engagement, as a fourth step. We invite selected stakeholders ranging from local citizens to specific disciplines to participate in a before and after study. Citizens' initial baseline and the potential shift in the baseline are quantitatively assessed through survey and elicitation techniques, and qualitatively through interviews. The before and after comparison shall indicate if the participant's



Figure 16: Large-scale solar radiation and sun exposure simulation of the waterfront area in Toronto, Canada, as part of research at the Department for Special Topics in Architecture Design (STARCH) at the University of Applied Arts Vienna. The black dashed line indicates the perimeter for the CFD wind simulation seen in figure 17.
Source: Michael Walczak (2020)

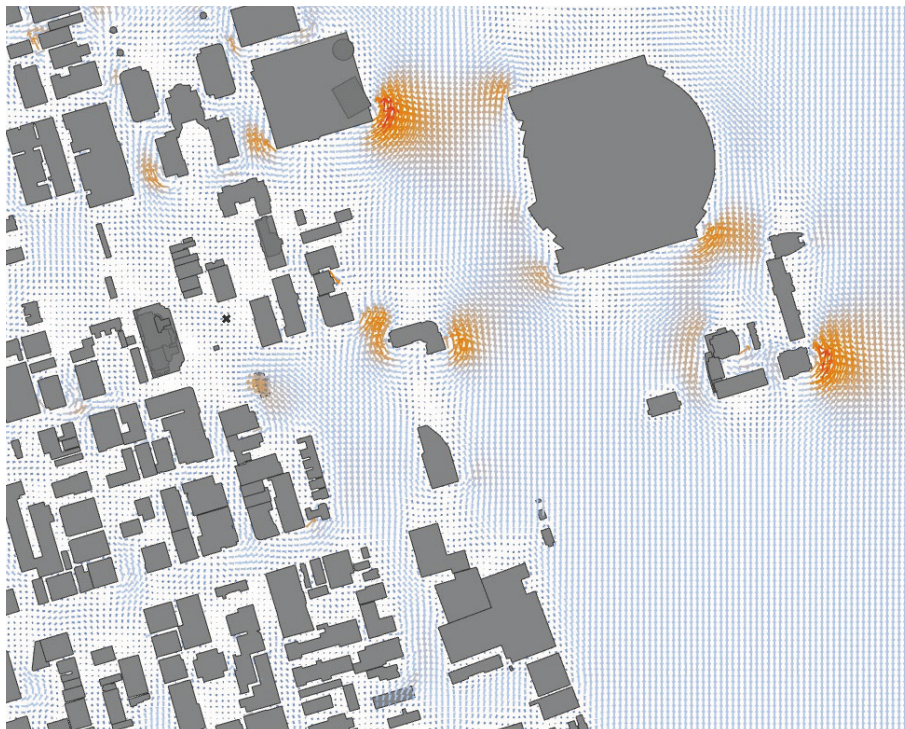


Figure 17: Large-scale wind exposure simulation of the waterfront area in Toronto, Canada, using Computational Fluid Dynamics (CFD) frameworks, as part of research at the Department for Special Topics in Architecture Design (STARCH) at the University of Applied Arts Vienna.
Source: Michael Walczak (2020)

percept and decisionmaking baseline has been shifted while being exposed to this dissertation's methods. The baseline is the initial condition (for example, cultural background, political position, living conditions, natural environment etc.) in which the participant is, before undertaking any interaction with the research of this dissertation.

Additionally, to the study of the shifting baseline, qualitative interviews and workshops with local policymaking actors shall understand current policy processes and examine the developed methodology's potentials to enhance these decisionmaking processes.

The medium to materialise the *DIGITAL URBAN IMAGINARY* and its process of collecting, processing, communicating, and measuring is the digital model.

The following specific *DIGITAL URBAN IMAGINARIES* shall exemplarily illustrate the case study of Lausanne, Sarajevo and Bogotá within the threefold "collecting, processing, and communicating" process. This process shall generate the necessary methodological foundation to impact humans' percept. Each of the process steps is using *DIGITAL URBAN IMAGINARY* as a medium of understanding and communication.

Step 4, the "measuring" study locations measure the impact of *DIGITAL URBAN IMAGINARY* on human percept within the case study of Cape Town and Bogotá. The *DIGITAL URBAN IMAGINARY* is being generated with the method of collecting, processing and communicating.

The "transferability" cities' role is to test whether the developed method within this dissertation can be transferred and scaled to other contexts. A world map (see figure 12) introduces and indicates each imaginary's location and its transferability, and scalability from/to other contexts within this dissertation. This will allow us to compare and relate chapters to each other.

Similarly, a stakeholder matrix (see figure 18) shall serve as comparison index between imaginaries and chapters, to understand several interrelated questions: which imaginaries had which impacts on which groups of stakeholders (indicated with a red circle) within this dissertation's frame (see figure 21, 50, 63, 69, 85 and 119). The matrix is structured into actors from the quantitative-, qualitative-, and policy-field or case study related topics (see chapter 4.6.1).

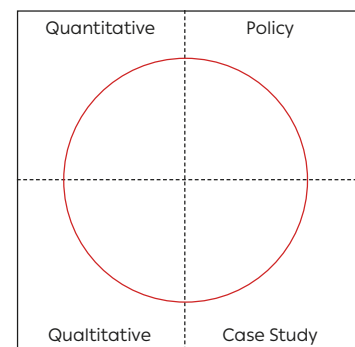


Figure 18: Stakeholder matrix structured into four fields of quantitative, qualitative, policy and case study, see chapter 4.6.1. for more details. Source: Michael Walczak (2021)

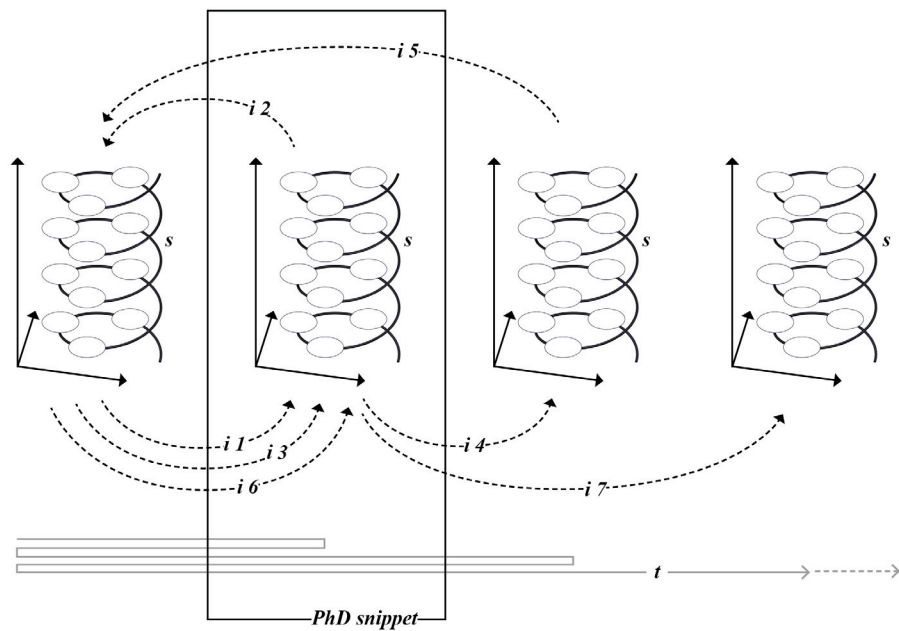


Figure 19: We can see the spiral (s) of Figure 15 as one component, as a snippet of a more significant process including the element of time (t) and multiple iterations (i) between multiple (s).
 Source: Michael Walczak (2020)

4.

Research Implementation and Results

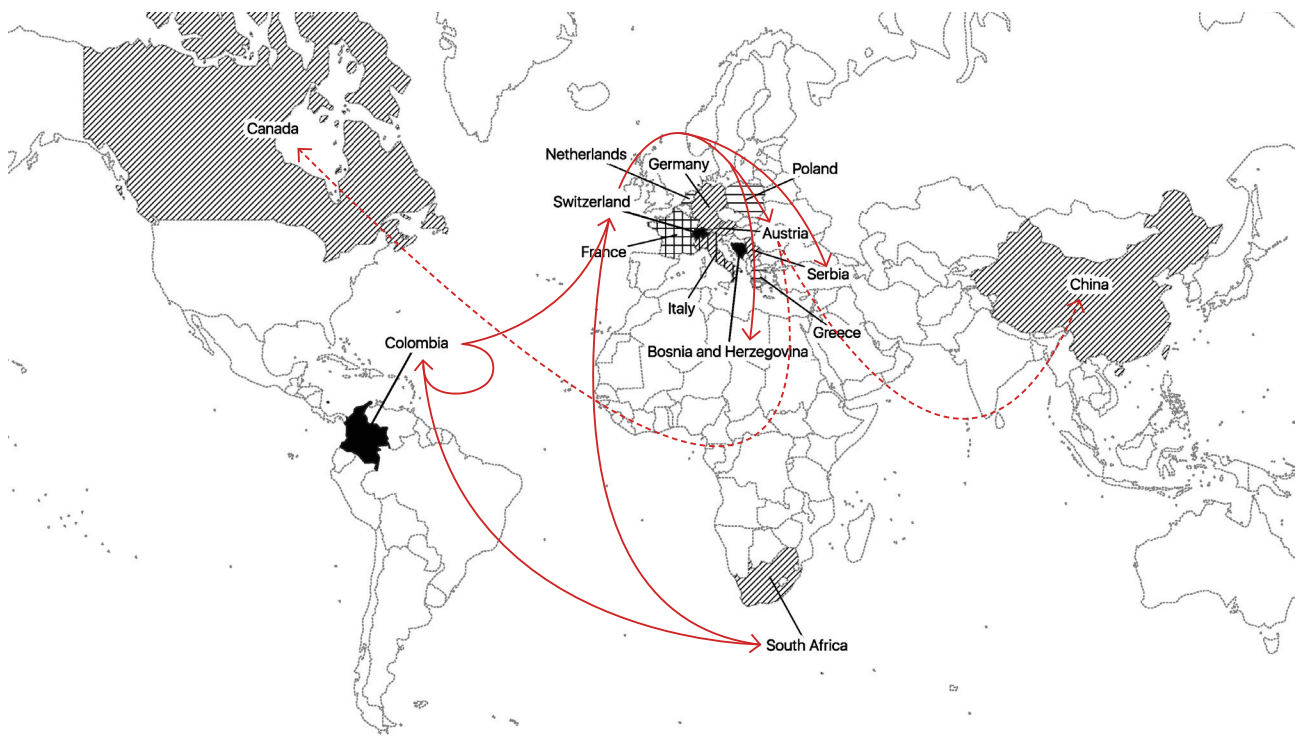
The first chapter of the implementation of research for this dissertation develops the necessary technological framework for the generation of *DIGITAL URBAN IMAGINARIES* in order to answer the defined research question. The second chapter evaluates the technological framework in terms of its performance and validity.

The main focus of the first step (i) is the collection of new sets of data. Such data is raw, not processed, and does not yet supply any evidence. The second step (ii) focuses on the processing of such data in order to be able to scale and extrapolate collected data points to the size of a country. The third step (iii) focuses in particular on how we can communicate such results and evidence to make more well-founded decisions. The fourth step (iv) measures the impact of the *DIGITAL URBAN IMAGINARIES* on the baseline of the human percept.

The seventh chapter uses 1. local actors for a qualitative evaluation of the usefulness of the method (step 1 to 4) for policymaking and 2. the contributions of the method to the UN's sustainable development goals.

At the same time, this sequence is not a static process. We need to see the seven chapters (chapter 1 to 7) in the cybernetic sense of an iterative process. For example, the processing step can create data that could be relevant for collecting new data. Or: communication with stakeholders can generate evidence on how different data need to be collected. Each of the four steps (step 1 to 4) generates a distinctive form of *DIGITAL URBAN IMAGINARY*. Each step is described in more detail in the following chapters.

4.1. CHAPTER 1: TECHNOLOGICAL FRAMEWORK



To achieve the presented results as well as the method of collection (i), processing (ii), and communication (iii), we shall use the medium of the digital model and *DIGITAL URBAN IMAGINARIES* (see chapter 2.1.1.) as well as the following technological components. By assessing the current landscape of available tools for digital modelling (see chapter 8.3.), we can observe gaps especially in terms of the use of dynamic 4D (three dimensions plus time) modelling techniques as well as communication output in the form of virtual or augmented reality (see chapter 4.1.). Augmented reality (AR) uses devices such as glasses to extend human vision with additional information projected into reality. In other words, it's the combination of the real environment and digital data. In comparison, virtual reality (VR), is also the use of devices such as glasses but the immersion is into a fully digital environment without the cross-link to actual reality. Nevertheless, we shall not consider this assessment of the current digital modelling landscape to be complete, but instead, it suggests a research gap and points towards a direction and guidance for this dissertation.

The main technological component consists of the visualisation/communication framework developed within multiple contexts (see figure 20). We structure the framework into four categories, namely the techniques used to visualise/communicate, the objects visualised/communicated, the additional tools which we can use within the framework, and the medium through which we can expose the user to such visualisation/communication. We interlink all of these elements with each other.

Figure 20: Location and transferability matrix, see chapter 3.2.
Source: Michael Walczak (2021)

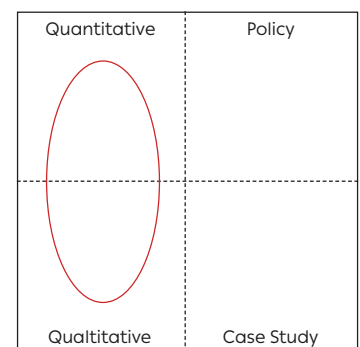


Figure 21: Stakeholder matrix, see chapter 3.3.
Source: Michael Walczak (2021)

4.1.1. TECHNIQUES

We run the simulations and visualisations on multiple (six) CPU cores (9th Generation Intel(R) Core i7(R) CPU 9750H clocked at 2.6 GHz.) with 32GB of RAM. The GPU-accelerated visualisation model runs on a single NVIDIA RTX 2070 with Max-Q Design and 8GB RAM. As a basic visualisation framework, we use the Unreal Engine version 28 (Epic Games 2020). Such a game engine allows for real-time rendering and ray-tracing features of virtual environments as well as custom coding in the native C++ language. It enables visualisation of moving, changing, and dynamic objects since we render everything in real-time. In addition to game engine, we also used Rhinoceros3D (Robert McNeel & Associates 2017c) in conjunction with Grasshopper3D (Robert McNeel & Associates 2017b).

UNREAL GAME ENGINE

Compared to other game engines such as Unity or CryEngine, the Unreal Game Engine (see figure 22) affords particular advantages in terms of the overall visualisation quality, including lighting and ray-tracing features. For further explanation, see for instance, Kretzer and Walczak (2021).

REAL-TIME RAY TRACING

Nvidia RTX graphics card and technology enables the use of real-time ray tracing to achieve adequate lighting and reflection results. For further explanation, see for instance, Kretzer and Walczak (2021).

LIGHTING SIMULATION

The lighting framework that is built into the Unreal Engine (Epic Games 2020) is applied to visualise the physical and dynamic characteristics of the light within the dynamic environment. The framework allows for the use of three-dimensional photometric data in the form of IES files for each luminaire. For further explanation, see for instance, Kretzer and Walczak (2021).

RHINOCEROS3D/GRASSHOPPER3D

A visual programming language (see figure 23) such as Grasshopper3D (Robert McNeel & Associates 2017b) is more common in architectural and urban planning discourse. As well as game engines, specific tasks require the computational power of such visual programming language such as Grasshopper3D (Robert McNeel & Associates 2017b). Grasshopper3D (Robert McNeel & Associates 2017b) is embedded as plugin within Rhinoceros3D (Robert McNeel & Associates 2017c). In the case of this dissertation, Grasshopper3D (Robert McNeel & Associates 2017b) was primarily used for the development of the spatial policies framework. For further explanation, see for instance, Walczak (2021a).

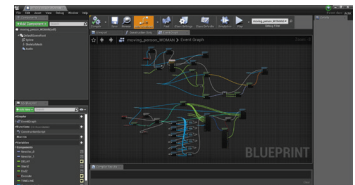


Figure 22: The Unreal Engine allows for Blueprint programming, a visual programming language, similar to the Rhinoceros3D/Grasshopper3D framework.
Source: Michael Walczak (2020)

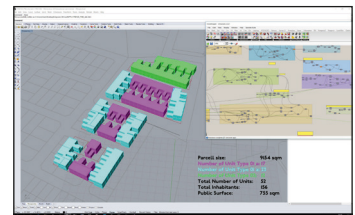


Figure 23: Grasshopper3D linked to Rhinoceros3D, showing the "Empower Shack" methodology.
Source: Michael Walczak (2018)

4.1.2. OBJECTS

We developed and custom-coded the following features within the game engine environment and the scope of this dissertation. We structured the visualisation/communication of objects into static and dynamic objects. Static objects include buildings, topography, and spatial policies. Dynamic items include the materialisation, traffic, pedestrians, densification processes, and meteorological data.

STATIC BUILDING LOADER

We expanded the Unreal Engine (Epic Games 2020) with custom C++ code. GDAL Library is used to be able to load all geo-located building footprints and provide their respective numeric building floors. The multiplication of a given floor height, such as 2.5m, extrudes the building footprints as generic building heights with their number of storeys. Only 3D geometries are displayed within a radius of 1km to optimise computation power (see figure 24). These geometries update to the current user location every ten seconds. For a C++ code excerpt, see chapter 8.10.

STATIC TOPOGRAPHY LOADER

For the static topography visualisation, we access the GeoTIFF raw data through the NASA Shuttle Mission for the sample case of Bogotá. Within Q-GIS Version 3.4.8-Madeira (QGIS Development Team 2018), we use the QGis2Threejs plugin to convert GeoTIFF data into the gltf format. "Aspose.3D" conversion¹⁹ is used for translation from the gltf to the stl format, which allows the topography to be opened in Rhinoceros3D (Robert McNeel & Associates 2017c) and translates the format to the Unreal Engine (Epic Games 2020) readable format, fbx.

STATIC SPATIAL POLICY FRAMEWORK (SPM)

Unlike all the other objects/components, this framework is built on the Rhinoceros3D/Grasshopper3D (Robert McNeel & Associates 2017b; 2017c) framework. It allows current building regulatory frameworks to be modelled and simulated in an automated manner. This framework includes the feature to automatically identify the commune and zone in which each specific building lot is located so that the correct building regulation can be selected. This all operates at a national scale.

DYNAMIC TRAFFIC

The data input to visualise public and private traffic is "GEMSim". We can find the descriptions of "GEMSim" elsewhere (Saprykin et al. 2019). "GEMSim" provides binary data of nationwide agent-based traffic simulations at a one-second resolution. A custom C++ parser allows the binary data to be read and the time-frame and location for visualisation selected. "GEMSim" data is structured into two main components. The first is the network itself, comprising the infrastructure in form of roads with all specifications such as lanes and speed limits. Second, we have all the events, comprising all vehicles/agents with specifications such as start and end time, start and end location coordinates on the network. Custom C++ code allows the correct location in the network to



Figure 24: Generation of 3D topography including satellite imagery and 3D building geometries, in this case, Spreitenbach, agglomeration of Zurich, Switzerland. Source: Michael Walczak (2020)

¹⁹ <https://products.aspose.app/3d/conversion/gltf-to-stl>; accessed 19.03.2020



Video 01: Real-time traffic visualisation using "GEMSim" and Vienna 3D data within Unreal Engine. Source: Michael Walczak; <https://www.youtube.com/watch?v=19W-kmZ02yQ>; accessed 15.12.2020

be identified for the respective agent. Depending on further specifications such as public or private traffic, we then apply random 3D vehicles to each visualised "agent". 3D vehicles are included in the materialisation with head and taillights for night-time visualisation. Finally, a custom C++ code at a one-second resolution than executes and launches the vehicles/agents in real-time for the corresponding time-frame for each vehicle/agent (see video 01 and figure 39 - 42). For a C++ code excerpt, see figure 38.

DYNAMIC PEDESTRIANS

Although "[d]ue to their complexity, living beings were for a long time the most difficult entities to model and animate" (Fankhänel 2020a), such complex animation has now become more accessible thanks to recent development of the graphics processor unit (GPU). Input for the pedestrian visualisation can be either "GEMSim" (Joubert 2020) or pathways in the form of splines or end and start points. Additionally, we can adjust the walking speed. Each "agent" receives a randomised 3D avatar that includes materialisation and "bones" to animate body movements such as arms and legs. We can also use this framework to animate any geometry, including custom vehicles, objects etc. The framework was developed within the Unreal Engine (Epic Games 2020) Blueprint visual programming language. For an excerpt of the Blueprint code, see chapter 8.11.

DYNAMIC LIGHTING

We apply custom code for the incremental upgrading of luminaires and the response of the luminaire in the form of sensors when, for example, pedestrians pass such a sensor and turn the light on.

DYNAMIC DENSIFICATION PROCESSES

In terms of experiencing the growth of a settlement, the user can navigate through the years by pressing a dedicated keyboard or controller button when using, for example, VR. The respective year that we expose the user to is displayed on the virtual "cockpit", the graphical user interface (GUI). The whole virtual environment is updated according to the chosen year, including correct light and shadows.

DYNAMIC MATERIALISATION LOADER

Materials are applied randomly to the building form within the virtual imaginary. The user can nevertheless specify if, in a particular year, a material change occurred. We link the functionality of this feature to the "dynamic densification process".

DYNAMIC URBAN TRANSFORMATION PROCESSES

The "dynamic urban transformation processes" feature is classified into scenario-thinking, focusing on the built environment, including the materialisation, street network, public spaces, vegetation and satellite imagery. For the initial state of an urban environment, we derive this information from geo-located data. For future anticipated or imagined scenarios existing data can be manipulated or completely new sets of data need to be generated with, for example, custom-code in Q-GIS (QGIS Development Team 2017), Grasshopper3D (Robert McNeel &

Associates 2017b) or Unreal Engine/C++ (Epic Games 2020). One scenario could be, for example, the percentual distribution of the share in gated communities in a city.

The respective scenario that we expose the user to is displayed on the virtual "cockpit", the graphical user interface (GUI). The whole virtual environment is updated according to the chosen scenario, including correct light and shadows.

DYNAMIC METEOROLOGICAL DATA

Custom code, using the "MAT file I/O" C++ library allows access to MATLAB files in order to read wind data for specific locations. We translate this wind data into "real" wind which, for example, causes clouds to move or trees shake.

4.1.3. TOOLS

To be able to engage with a variety of citizens and receive perception-related feedback (see figure 21), it was necessary to develop a three-dimensional graphical user interface (3D-GUI) which can include a survey and questionnaire framework within the game engine and the medium of VR (see figure 26).

SURVEYS/CITIZENS PREFERENCES

Each participant always received the survey questions both before the visualisation/communication experience as well as directly afterwards. This method allows quantitative measurement of the impact that the visualisation/communication had on the perception of the participants. It is important mentioning that the content shown and the survey questions were always unrelated to the research question of changing perception so as not to bias any response. To elicit preferences, the participants had to choose between two scenarios repeatedly. We can define the number of scenarios depending on the number of different solutions. If nine solutions exist, and we want to compare each with the others, this would result in 36 choices with 72 images in total. Mathematically, we can calculate this with the formula of permutations: $P(n,r)$; where "n" represents the number of scenarios and "r" the comparison sample, or in other words, how many scenarios to compare at a time. The equation would produce the total of images, which is divided by two to produce the number of choices made by each participant: $P(n,r)/2$.

$$P(n,r) = \frac{n!}{(n-r)!}$$

{a, b}{a, c}{a, d}{a, e}{a, f}{a, g}{a, h}{a, i}
 {b, a}{b, c}{b, d}{b, e}{b, f}{b, g}{b, h}{b, i}
 {c, a}{c, b}{c, d}{c, e}{c, f}{c, g}{c, h}{c, i}
 {d, a}{d, b}{d, c}{d, e}{d, f}{d, g}{d, h}{d, i}
 {e, a}{e, b}{e, c}{e, d}{e, f}{e, g}{e, h}{e, i}
 {f, a}{f, b}{f, c}{f, d}{f, e}{f, g}{f, h}{f, i}
 {g, a}{g, b}{g, c}{g, d}{g, e}{g, f}{g, h}{g, i}
 {h, a}{h, b}{h, c}{h, d}{h, e}{h, f}{h, g}{h, i}
 {i, a}{i, b}{i, c}{i, d}{i, e}{i, f}{i, g}{i, h}

Figure 25: CSV raw data generated from the preference survey. Source: Michael Walczak (2020)



Figure 26: A 3D graphical user interface to display widgets such as texts in VR. Source: Michael Walczak (2020)

Custom code saves the choice per participant as an XML file (see figure 25), including the time elapsed for each decision made. See chapter 4.6. for the application of this method.

QUESTIONNAIRES

From a more qualitative perspective, questions in the form of a common interview format were asked and answered directly after the visualisation/communication experience (see figure 27). See chapter 4.6.

OPEN WORLD/PREDEFINED PATH

We can experience the visualisation either on the basis of a fixed or predefined path or an open-world. The predefined path is similar to the “dynamic pedestrians” visualisation framework as a geo-located spline needs to be input along which we can guide the user and manage the speed of movement or walking. In case of an open-world setting, the user can navigate either with a standard gaming setting (“WASD” or arrows) or with, for example, the Oculus Joysticks (Oculus Touch), while using VR. See chapter 4.6.

CUSTOM OBJECT TRACKING

Either the camera can follow the input of the user (open-world) as previously described, or we need to define a path. Custom code also allows any objects such as vehicles to be tracked from a first-person or third-person perspective. The specific camera distance, angle, and position can be user-defined (see video 02 and figure 45 - 48).

4.1.4. USERS/MEDIUM/INTERFACE

On the one hand, we have the participants who use or are exposed to the visualisation/communication technology. On the other hand, we have the medium/output of how we communicate the visualisation. This is done either in the form of a print medium (such as posters, flyers, banners), Virtual Reality (VR), front-of-screen (meaning simple monitors), videos, images, or an interactive graphical user interface with free navigation and manipulation features. Mindful of Hito Steyerl's (2020) thesis “images are power”, particular emphasis is directed towards the importance of the medium.

VIRTUAL REALITY

We can use any high and low-tech VR goggles as an immersive medium. In this case, we opted for the Oculus Rift and Oculus Rift S goggles. The strength of VR is that we can expose any stakeholder and/or policymaker to any environment without actually being there, especially where settlements are not accessible, too dangerous, or are subject to travel restrictions invoked by a pandemic crisis. The digital, and with it VR, has gained a new plausibility as a result of the COVID-19 pandemic.

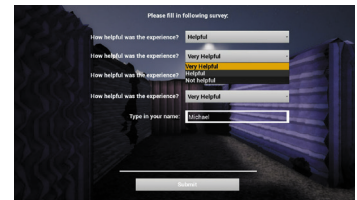


Figure 27: Survey interface within the graphical user interface (GUI) of the visualisation framework.

Source: Michael Walczak (2020)



Video 02: Real-time delivery vehicle visualisation using “GEMSim” and Zurich 3D data within Unreal Engine. Source: Michael Walczak; <https://www.youtube.com/watch?v=eaXMmB4CAAdI>; accessed 15.12.2020

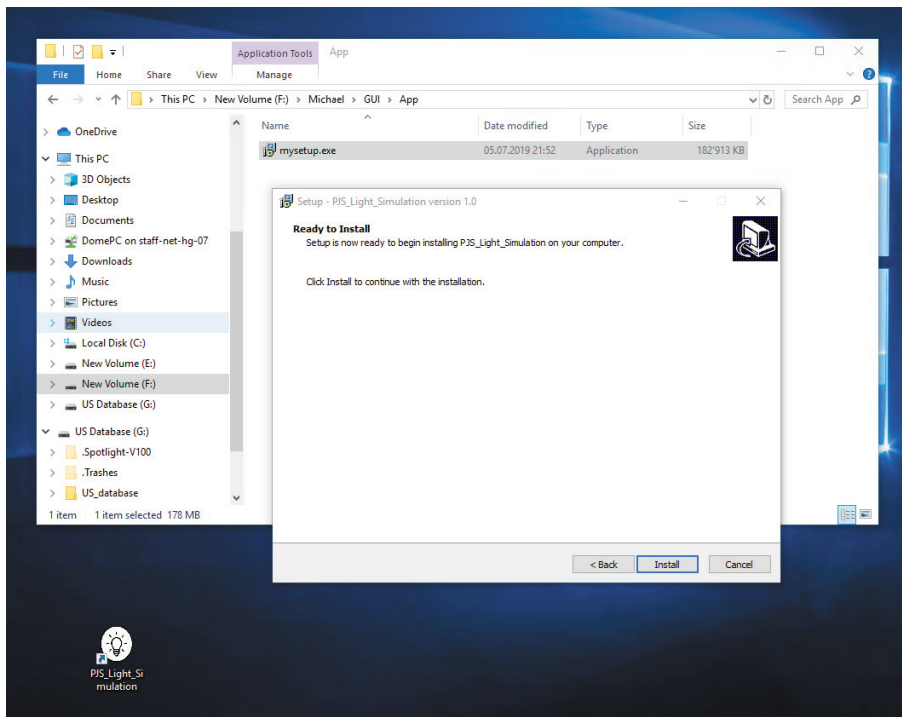


Figure 28: Standalone software to install on any computer running Windows operating system. The standalone software includes all the elements described in the chapter 4.1. of this dissertation. Source: Michael Walczak (2020)

FRONT-OF-SCREEN

Commonly used screens can serve as a medium to output the visualisation. To mimic immersion, commonly used monitor hoods enable the masking of screen surroundings. Such monitor hoods permit solely the virtual image to be viewed as opposed to the additional context of the viewing device. In this way, the observer is more strongly disconnected from the real world.

VIDEOS

We can record predefined paths with predefined walking speed and the predefined viewing angle as a common video format output. At the same time, there is also the option to not predefine the viewing angle and let the user rotate around the predefined path, see the "stereo- and monoscopic 360-degree video and image recording" feature below.

IMAGES

As an alternative medium to the more interactive formats, it is also possible to output high-resolution images for purposes of printing or still images.

GRAPHICAL USER INTERFACE (GUI)

The dynamic visualisation and survey/questionnaire features in particular, require the user to be able to interact with/manipulate the visualisation in the form of a graphical user interface (GUI) (see figure 29). For example, the year/time in which the user is navigating can be changed, as can the navigation



Figure 29: Custom graphical user interface in the Unreal Game Engine for user-generated parameter input. Source: Michael Walczak (2018)

mode between walking, running, and flying, the selection of elements visualised, launching of dynamic objects such as traffic and pedestrian motion, and/or participating in the survey/questionnaire.

We have to translate the graphical elements into a 3D GUI to display such widgets in VR. This requires the allocation of any interactive graphic feature into a 3D location within the virtual environment. Widgets include, for example, an orientation map, questionnaire forms, survey checkboxes, text elements.

STEREO- AND MONOSCOPIC 360-DEGREE VIDEO AND IMAGE RECORDING

In the context of pandemics and the resulting inaccessibility of countries, VR can offer significant support in the communication of urban transformation processes to remote stakeholders and policymakers. Since VR requires computational power, the pre-recording and re-rendering of such immersive environments can be advantageous since we can share them via commonly used online video and image platforms such as YouTube. We use the Unreal Engine version 28 (Epic Games 2020) to be able to record 360-degree, three-dimensional videos. The Unreal Engine (Epic Games 2020) has a built-in panoramic-capture framework that allows mono- and stereoscopic 360-degree VR images to be executed via console commands (see figure 30). Monoscopic 360-degree imagery consists of a single flat image, projected on to a sphere around the viewer (see figure 43 and 44). Monoscopic VR is intended for 360-degree videos for which we do not necessarily require a VR headset. Nevertheless, the standard format is to display stereoscopic imagery, often in the top/bottom 3D format. The top image is the left-eye view; the bottom image, the right-eye view. Such visualisation requires a VR headset, which may be as low-tech as "Google Cardboard"²⁰. To be able to record video footage, a predefined motion path with speed, start and endpoint, or moving objects is required. We have to set the fixed timestamp depending on the selected number of frames per second (fps). Through custom code and the "Panoramic Capture" framework, the image resolution, viewing direction, specific number of images, and precise moment of recording can all be set. The framework outputs single images depending on the fps chosen. Each image requires a calculation time of approximately 120 seconds on multiple (six) CPU cores (9th Generation Intel(R) Core i7(R) CPU 9750H clocked at 2.6 GHz.) with 32GB of RAM, a single NVIDIA RTX 2070 with Max-Q Design, and with 8GB RAM. A movie clip of 60 seconds with an fps of 60 would result in 3600 single images and would require a rendering time of 120 hours.

The "FFMPEG"²¹ framework allows such images with predefined parameters such as the fps to be assembled into commonly used video formats. "FFMPEG" is accessible through "Windows Command" or "MacOS Terminal".

Before being able to upload the footage to a video web platform, the "Spatial Media Metadata Injector"²² needs to be run to add metadata to the video file. The web platform can then directly identify the correct specifications such as stereoscopic top/bottom image or the 360-degree feature.



Figure 30: Stereoscopic visualisation to experience VR in low-tech cardboard goggles with a smartphone.
Source: Michael Walczak (2020)

²⁰ <https://arvr.google.com/cardboard/>; accessed 09.02.2021

²¹ <https://ffmpeg.org/>; accessed 09.02.2021

²² <https://github.com/google/spatial-media/releases>; accessed 09.02.2021

4.2. CHAPTER 2: EVALUATION OF TECHNOLOGICAL FRAMEWORK

We chose several techniques to evaluate the technological framework developed within this dissertation:

- (4.2.1.) a pixel comparison using real photography against the simulated virtual world;
- (4.2.2.) a visualisation speed improvement using binary data structures; and
- (4.2.3.) a paradigm shift from CPU- to GPU-based architecture enabling real-time ray-tracing techniques.

The computational specifications described in chapter 4.1.1. were compared against multiple (six) CPU cores (Intel(R) Core i7(R) CPU 4960X clocked at 3.6 GHz) with 32GB of RAM, and a single NVIDIA GTX TITAN BLACK 2070 with 6GB RAM.

4.2.1. PIXEL AND VISUAL COMPARISON

This research compared the VR scenes to photographs taken during the night in the location of the case studies to measure the accuracy of the images produced. How to capture reality as neutrally as possible and how to align the perspective distortion to align with the perspective chosen in the VR scene are questions in themselves. This approximation is chosen in order to understand whether the visual direction and representation of the VR scenes are meaningful. It is determining whether the data-driven positioning of the, for example, high mast lights is approximate to reality.

With a ten percent tolerance of the pixel colour in RGB (red, green, and blue) code, i.e. a red ratio of 185 would be tolerance from 175.75 to 194.25, the difference between the photography of reality and the simulated VR scene is 25 percent. If the research primarily focuses on the emitted light and its position, the simulation reaches a high accuracy. The mismatch between reality and simulation is often due to the uneven ground surface, differences in building façade textures, temporary objects like a trash container, and the accuracy between the light position and the building footprints (see figure 32).

4.2.2. FROM XML TO BINARY

To improve the overall computational efficiency, in particular, to import data related to traffic simulations, a custom C++ event parser is allowed to read, and a custom C++ event handler is allowed to store, cross-reference, and visualise binary data structures. This lowers the necessary RAM storage capacity and speeds up the process of data import, storage, cross-referencing and visualisation compared to commonly used XML data structures. Since the necessary storage space is reduced, the visualisation time-frame of, for example, daily traffic can be extended. Compared to a common XML parser, improvements per 1,000, 20,000 and 40,000 events (for example, one event

corresponds to a simulated moving vehicle) can be summarised as follows. One thousand events require 2 gigabytes (GB) of random-access memory (RAM) using an XML data structure, compared to 0.1 GB of RAM usage as a binary structure. The binary data structure is also improving the time necessary to process by a factor of 10. Looking at 20,000 events, RAM's storage required for the XML data structure requires 23 GB while the binary data structure is needing 2 GB. A similar time improvement by a factor of 10 is visible. If we loaded 40,000 events, the XML data parser could not load the data with the computational specifications used, compared to the binary parser which needed 8 GB of RAM and 40 minutes of processing time for this task. The comparison in both storage usage and time is suggesting an exponential growth (see figure 33).

4.2.3. REAL-TIME RAY TRACING

The advantage of real-time ray tracing techniques compared to commonly used pre-computed visualisations is the instant visualisation and simulation of virtual environments, including the simulation of light and material specifications such as reflections (see figure 31). One key condition is the paradigm shift from CPU- to GPU-based simulation and architecture. A visual inspection of the same scene while using real-time ray tracing in comparison to pre-computed ray tracing can unveil particular visual improvements in regard to the image sharpness, lighting, and shadow quality (see figure 34 - 37).

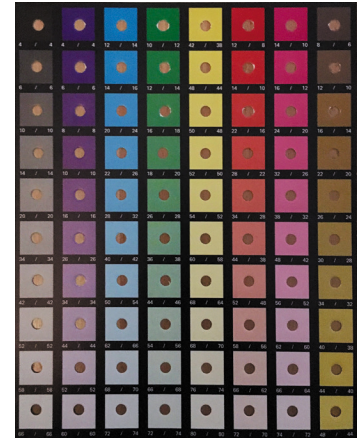


Figure 31: Analogue reflectance values from the Zumtobel Lighting Manual. Source: Zumtobel (2020)



Figure 32: From left to right, actual photograph of the current light condition in Khayelitsha, Cape Town; simulated light conditions; and pixel comparison in red showing the difference between actual reality and simulated reality. Source: Photograph on the left, Stephanie Briers (2019); center and right images, Michael Walczak (2019)

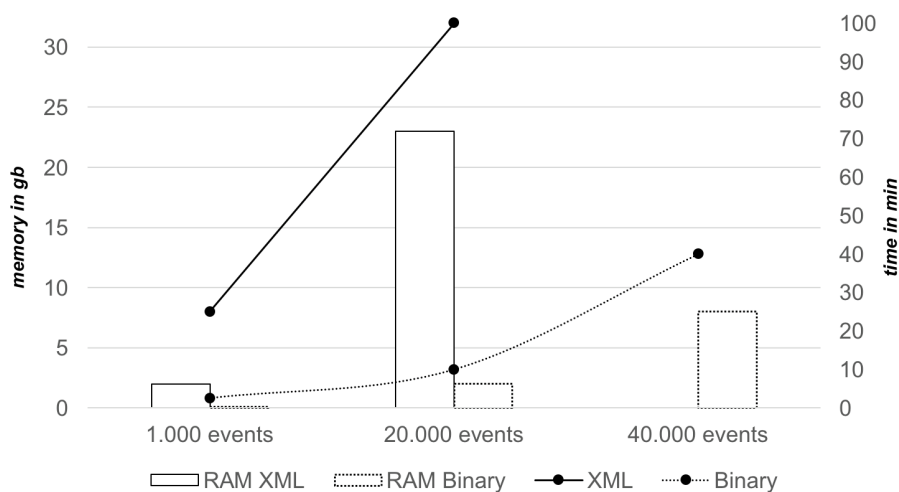


Figure 33: As an example, for 20,000 events: binary: ~10min and ~2GB RAM (loading network, loading events, parsing for GUI output). XML: ~100min and ~23GB RAM (loading network, loading events, parsing for GUI output). Source: Michael Walczak (2019)

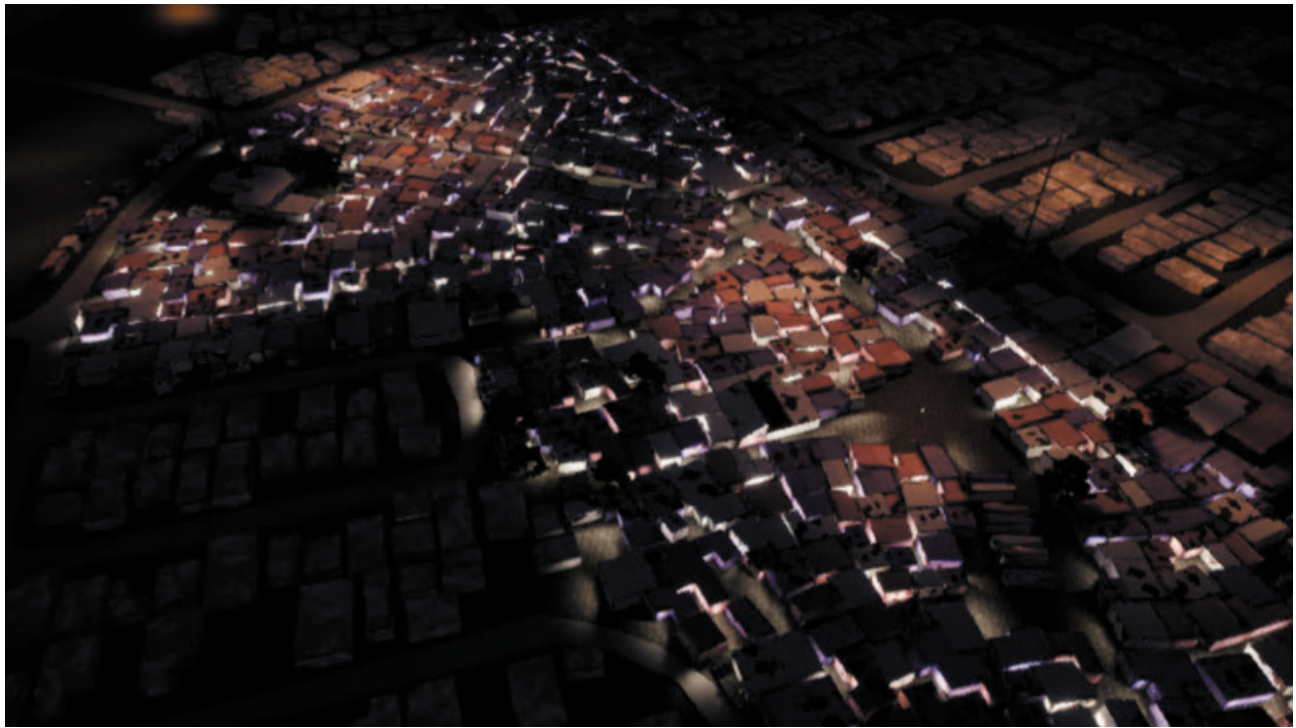


Figure 34 and 35: Top image shows pre-computed ray tracing while the bottom image shows the real-time ray tracing visualisation technique. Source: Michael Walczak (2019)

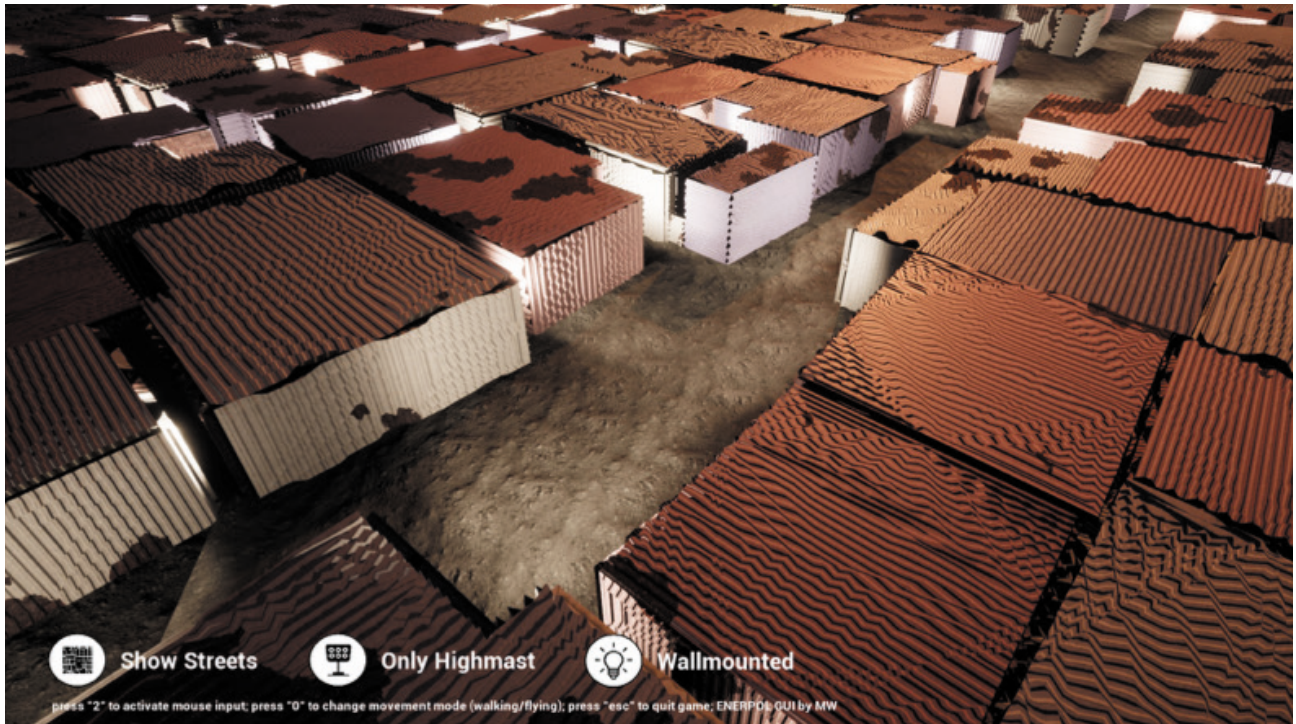
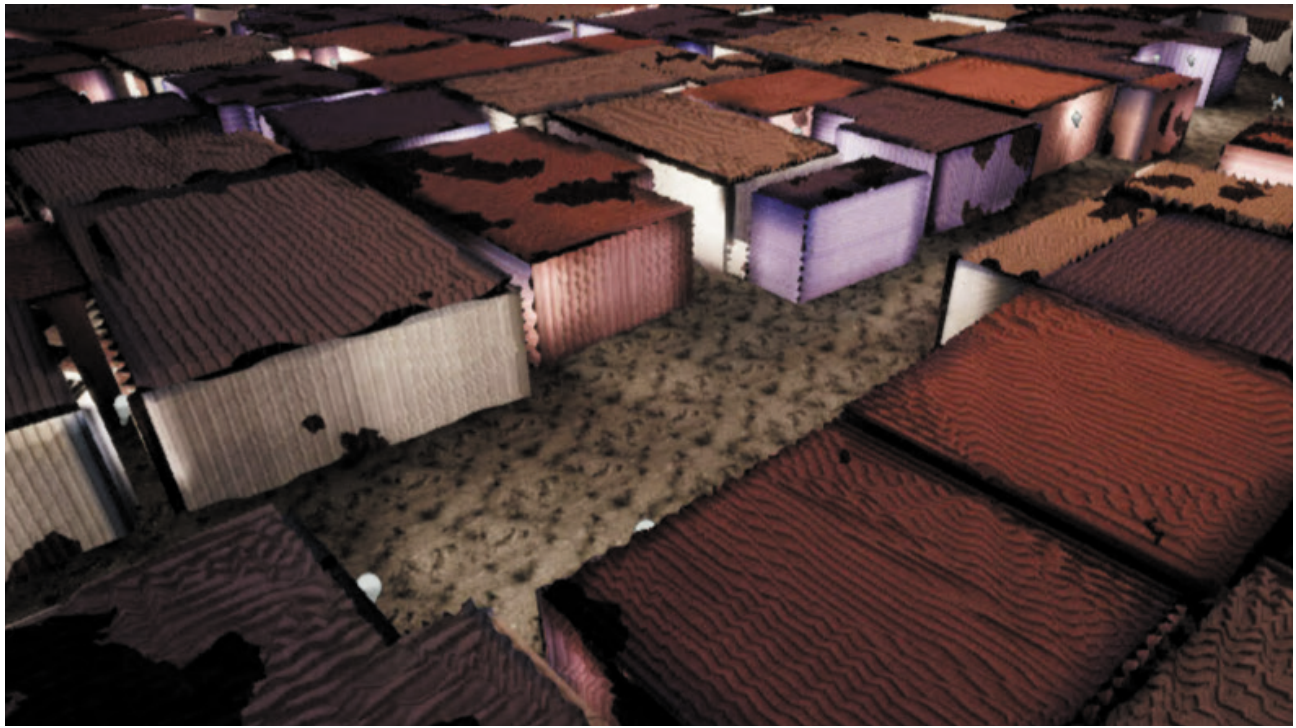


Figure 36 and 37: Top image shows pre-computed ray tracing while the bottom image shows the real-time ray tracing visualisation technique. Source: Michael Walczak (2019)

```

void AimportMobility::readGemSim()
{
    //*****NETWORK*****

    auto networkreader = new gemsim::data::io::NetworkReader();
    networkreader->read(„C:/GUI/Vienna/network_AT.xml.gz“);
    networkreader->waitForFinished();
    UE_LOG(LogTemp, Warning, TEXT(„GemSimNetwork_Loaded“));

    auto networklinks = networkreader->getNetwork();
    UE_LOG(LogTemp, Warning, TEXT(„Got_Network“));

    //*****CLIPPER*****

    for (int i = 0; i < networklinks->getLinkCount(); i++)
    {
        float getxfrom = networklinks->getLink(networklinks->getLinkId(i))->getFromNode()->getLocation().x();
        float getyfrom = networklinks->getLink(networklinks->getLinkId(i))->getFromNode()->getLocation().y();

        float getxto = networklinks->getLink(networklinks->getLinkId(i))->getToNode()->getLocation().x();
        float getyto = networklinks->getLink(networklinks->getLinkId(i))->getToNode()->getLocation().y();

        const QPoint p1(getxfrom, getyfrom);
        const QPoint p2(getxto, getyto);
        const QPoint topleft(624486, 484509);
        const QPoint topright(628685, 481957);
        const QRect rect(topleft, topright);

        if (gemsim::core::GeometryUtils::isLineSegmentClipped(p1, p2, rect) == true)
        {
            UE_LOG(LogTemp, Warning, TEXT(„WE FOUND A MATCH WITH CLIPPER“));
            clippedNetwork.insert((networklinks->getLink(networklinks->getLinkId(i))->getId()), 1);
        }
    }

    UE_LOG(LogTemp, Warning, TEXT(„HashValue %i“), clippedNetwork.key(1));

    //*****SUBNETWORK*****

    foreach(QSharedPointer<gemsim::data::NetworkLink> link, networklinks->getLinks())
    {
        if (clippedNetwork.contains(link->getId()))
        {
            QSharedPointer<gemsim::data::NetworkLink> newLink = netFactory->cloneLink(link);
            QSharedPointer<gemsim::data::NetworkNode> fromNode = subNetwork->getNode(link->getFromNode()->getId());

            UE_LOG(LogTemp, Error, TEXT(„CLIPPER AND ID MATCH“));

            if (fromNode.isNull())
            {
                fromNode = netFactory->cloneNode(link->getFromNode());
                subNetwork->addNode(fromNode);
            }

            QSharedPointer<gemsim::data::NetworkNode> toNode = subNetwork->getNode(link->getToNode()->getId());
        }
    }
}

```

```

        if (toNode.isNull())
        {
            toNode = netFactory->cloneNode(link->getToNode());
            subNetwork->addNode(toNode);
        }

        newLink->setFromNode(fromNode);
        newLink->setToNode(toNode);

        fromNode->addOutLink(newLink);
        toNode->addInLink(newLink);

        subNetwork->addLink(newLink);
    }
}

//*****EVENTS*****

QVector<double> eventsvector;

auto gemsimimport = new gemsim::events::EventManager();

gemsimimport->addHandler(gemsimhandler);

gemsimimport->read(„D:/GUI/Vienna/events.bin.gz“);

gemsimimport->waitForFinished();

//*****FILTER_EVENTS_TO_CLIPPER*****

UE_LOG(LogTemp, Warning, TEXT(„Is it empty: %i“), gemsimhandler->eventtime.size());
UE_LOG(LogTemp, Warning, TEXT(„Is it empty: %i“), gemsimhandler->linkid.size());
UE_LOG(LogTemp, Warning, TEXT(„Is it empty: %i“), gemsimhandler->personid.size());

for (int i = 400; i < 500; i++)
{
    if (clippedNetwork.contains(gemsimhandler->linkid[i]))
    {
        eventtimeclipped.append(gemsimhandler->eventtime[i]);
        linkidclipped.append(gemsimhandler->linkid[i]);
        personidclipped.append(gemsimhandler->personid[i]);
        pseudoMatch.append(gemsimhandler->linkid[i] + gemsimhandler->personid[i]);
    }
}

for (int j = 400; j < 500; j++)
{
    if (clippedNetwork.contains(gemsimhandler->linkidLeave[j]))
    {
        eventtimeclippedLeave.append(gemsimhandler->eventtimeLeave[j]);
        linkidclippedLeave.append(gemsimhandler->linkidLeave[j]);
        personidclippedLeave.append(gemsimhandler->personidLeave[j]);
        pseudoMatchLeave.append(gemsimhandler->linkidLeave[j] + gemsimhandler->personidLeave[j]);
    }
}

//*****DELETE_OLD_EVENTS*****

gemsimhandler->eventtime.clear();
gemsimhandler->linkid.clear();
gemsimhandler->personid.clear();
gemsimhandler->traveltimeNEW.clear();

gemsimhandler->eventtimeLeave.clear();
gemsimhandler->linkidLeave.clear();
gemsimhandler->personidLeave.clear();

```

```

//*****VEHICLES TRAVELTIME DETERMINATION*****

for (int k = 0; k < eventtimeclipped.length(); k++)
{
    for (int l = 0; l < eventtimeclippedLeave.length(); l++)
    {
        if (pseudoMatch[k] == pseudoMatchLeave[l])
        {
            eventtimeFinal.append(eventtimeclipped[k]);
            linkidFinal.append(linkidclipped[k]);
            personidFinal.append(personidclipped[k]);
            speedFinal.append(eventtimeclippedLeave[l] - eventtimeclipped[k]);
        }
    }
}

//*****DELETE_OLD_EVENTS*****

eventtimeclipped.clear();
linkidclipped.clear();
personidclipped.clear();

eventtimeclippedLeave.clear();
linkidclippedLeave.clear();
personidclippedLeave.clear();

pseudoMatch.clear();
pseudoMatchLeave.clear();

//*****EVENTS COORDINATES DETERMINATION*****

for (int i = 0; i < eventtimeclipped.length(); i++)
{
    for (int j = 0; j < subNetwork->getLinkCount(); j++)
    {
        if (linkidclipped[i] == subNetwork->getLinkId(j))
        {
            UE_LOG(LogTemp, Warning, TEXT(„WE GOT THE LINK“));

            int time = eventtimeclipped[i];
            int person = personidclipped[i];

            float getxfrom = subNetwork->getLink(subNetwork->getLinkId(-j))->getFromNode()->getLocation().x();
            float getyfrom = subNetwork->getLink(subNetwork->getLinkId(-j))->getFromNode()->getLocation().y();

            float getxto = subNetwork->getLink(subNetwork->getLinkId(-j))->getToNode()->getLocation().x();
            float getyto = subNetwork->getLink(subNetwork->getLinkId(-j))->getToNode()->getLocation().y();

            LocationStart = FVector(getxfrom, getyfrom, 0.0f);
            LocationEnd = FVector(getxto, getyto, 0.0f);

            double distance = subNetwork->getLink(subNetwork->getLinkId(-j))->getLength();

            UE_LOG(LogTemp, Warning, TEXT(„eventtime %i“), time);
            UE_LOG(LogTemp, Warning, TEXT(„personid %i“), person);
            UE_LOG(LogTemp, Warning, TEXT(„length %f“), distance);
        }
    }
}

```

```

//*****VEHICLES TRAVELTIME DETERMINATION*****

    for (int k = 0; k < eventtimeclipped.length(); k++)
    {
        for (int l = 0; l < subNetwork->getLinkCount(); l++)
        {
            if (subNetwork->getLink(subNetwork->getLinkId(j))->getNode()->getLocation().x() ==
                subNetwork->getLink(subNetwork->getLinkId(l))->getNode()->getLocation().x() && personidclipped[i]
                == personidclipped[k])
            {
                int traveltimelocked = eventtimeclipped[k] - eventtimeclipped[i];
            }
        }
    }
}

```

Figure 38: C++ code excerpt to import and cross-reference "GEMSim" public and private traffic simulation data into the visualisation framework.
Source: Michael Walczak (2020)

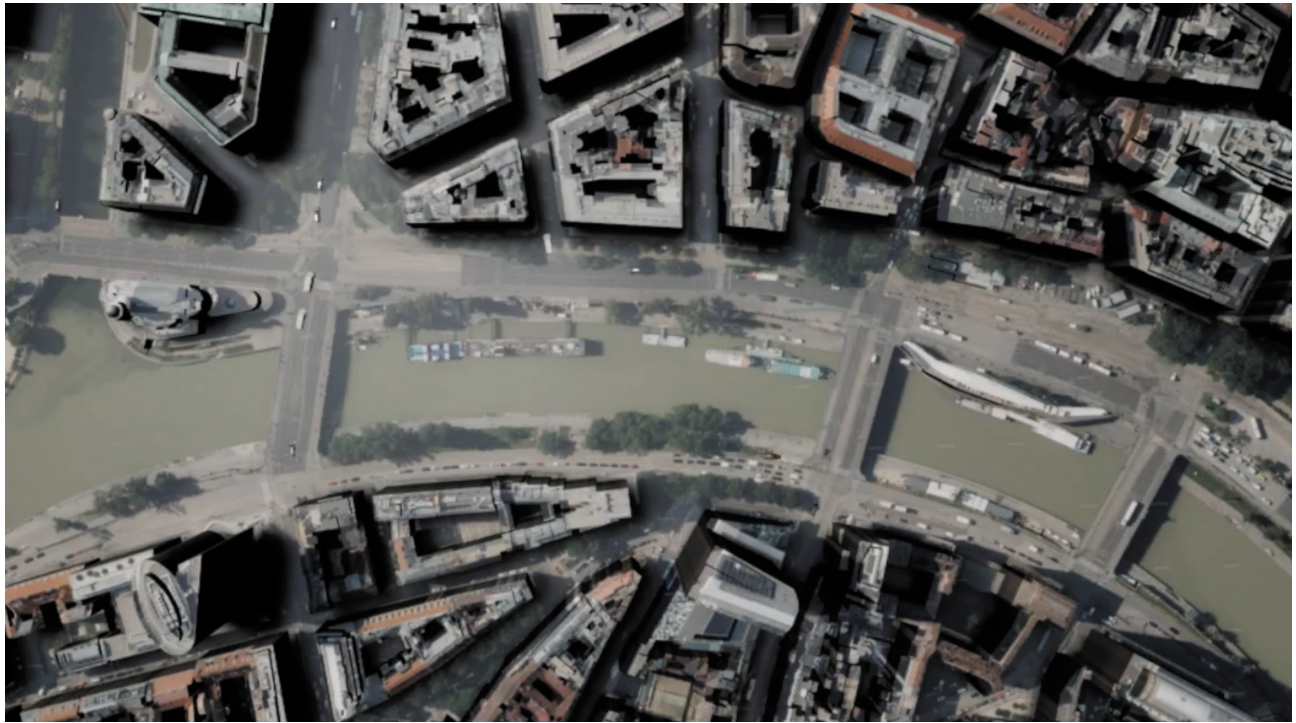


Figure 39 and 40: Two exemplarily snippets on different moments of the day using the custom visualisation framework for Vienna's context. The *DIGITAL URBAN IMAGINARY* is including "GEMSim" public and private traffic simulation, daylight simulation, satellite imagery and the build and natural environment.
Source: Michael Walczak (2020)



Figure 41 and 42: Two exemplarily snippets on different moments of the day using the custom visualisation framework for Vienna's context. The *DIGITAL URBAN IMAGINARY* is including "GEMSim" public and private traffic simulation, daylight simulation, satellite imagery and the build and natural environment.
Source: Michael Walczak (2020)



Figure 43: Left-eye 360° *DIGITAL URBAN IMAGINARY* of Caracoli neighbourhood in Bogotá including pedestrian motion visualisation, lighting simulation, the detailed environment and densifying buildings signaled by the graphical text component displaying the current year of the imaginary. We can use such images to experience through virtual reality goggles.

Source: Michael Walczak (2020)



Figure 44: Right-eye 360° *DIGITAL URBAN IMAGINARY* of Caracoli neighbourhood in Bogotá including pedestrian motion visualisation, lighting simulation, the detailed environment and densifying buildings signaled by the graphical text component displaying the current year of the imaginary. We can use such images to experience through virtual reality goggles.

Source: Michael Walczak (2020)



Figure 45 and 46: Two exemplarily snippets on different moments of the day using the custom visualisation framework for Zurich's context. The *DIGITAL URBAN IMAGINARY* includes a delivery vehicle followed by the camera, "GEMSim" public and private traffic simulation, satellite imagery, daylight simulation and the build and natural environment. Source: Michael Walczak (2020)

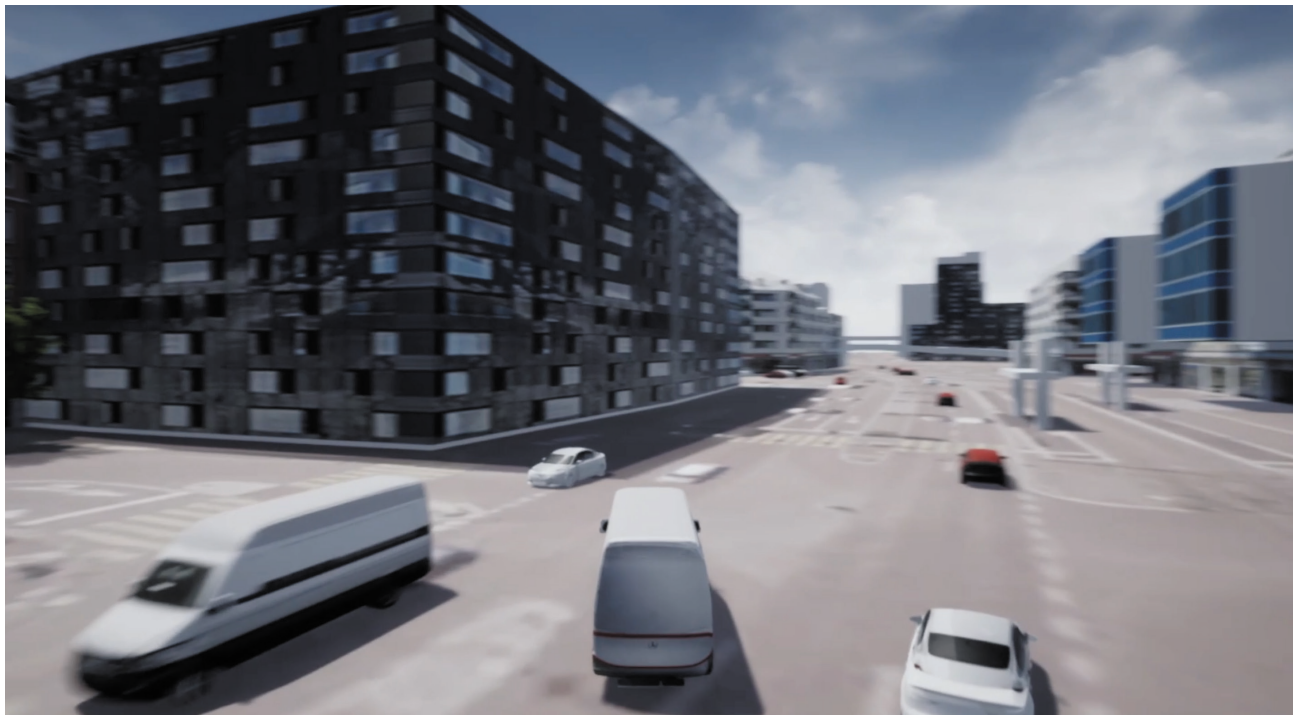
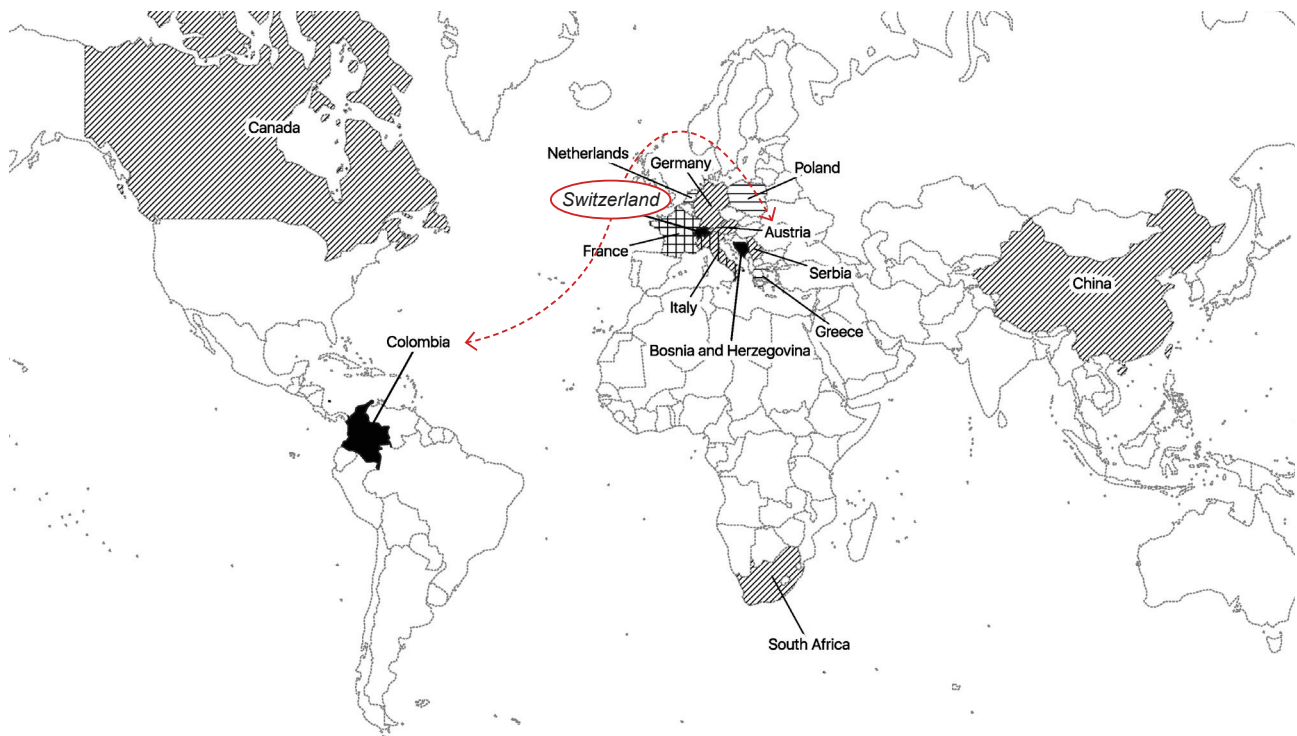


Figure 47 and 48: Two exemplarily snippets on different moments of the day using the custom visualisation framework for Zurich's context. The *DIGITAL URBAN IMAGINARY* includes a delivery vehicle followed by the camera, "GEMSim" public and private traffic simulation, satellite imagery, daylight simulation and the build and natural environment. Source: Michael Walczak (2020)

4.3. Chapter 3: Step 1, Collection (i)



The first step mainly focuses on the collection of new sets of data. Such data is raw, not processed, and does not yet supply any evidence. Existing, newly generated, or projected data collection is the foundational stone to create *DIGITAL URBAN IMAGINARIES*. In our case of urban transformation processes, the baseline of the static and dynamic environment is crucial. Exemplarily, we illustrate this step with the case studies of Lausanne’s agglomeration, the City of Sarajevo and Caracoli, a neighbourhood in Bogotá. We collected:

- (4.3.1.) for the Spatial Policy Model (SPM) in the agglomeration of Lausanne data on the built environment and its regulatory boundary conditions;
- (4.3.2.) for the City of Sarajevo climatic data such as wind speed and wind direction, and theoretically correlated to other locations; and
- (4.3.3.) for Caracoli, a neighbourhood in Bogotá, data on pedestrian motion and densification processes.

This step can be scaled and transferred to other contexts such as Colombia and Austria due to the *DIGITAL URBAN IMAGINARIES* methodology (see figure 49).

Figure 49: Location and transferability matrix, see chapter 3.2. Source: Michael Walczak (2021)

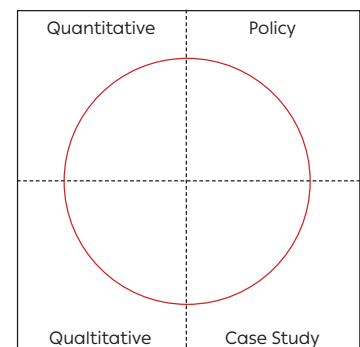


Figure 50: Stakeholder matrix, see chapter 3.3. Source: Michael Walczak (2021)

4.3.1. AGGLOMERATION OF LAUSANNE ²³

In the following section, we describe the data sources required to perform the Spatial Policy Model (SPM) (see chapter 4.1.2.):

(1) Cadastral data includes the precise geo-located geometry (poly curve) of each of the building lots and if applicable, its respective building footprint geometry in the Lausanne agglomeration.

(2) Zoning regulation includes the precise geo-located geometry (poly curve) of each of the different building zones with its specification such as residential area (high, medium and low density), industrial area, historical centre, intermediate area, peripheral area, etc. Each of the different zones has a respective building regulation requirement that differs in each of the municipalities of the agglomeration of Lausanne.

(3) Building regulations are very complex, as shown and visualised by Grams (2015). In the case of Switzerland, building regulations are not homogenised, which means that each municipality has its own data format. Most of the data is not yet digitised or is merely provided as text and/or graphic descriptions in the form of a PDF file (see figure 51). Building regulations include information about the minimum distances from the lot border, maximum building heights, roof geometries, minimum building distances, building programme, maximum building length, maximum building footprint, floor area ratio (square metres of all floors of the particular building divided by the corresponding building lot), distribution of residential surface area in mixed-use areas, etc. To be able to use this information in an automated manner, the data had to be manually converted and homogenised into a machine-readable format (see table 02). A table with columns distinguishing all building regulatory requirements and corresponding rows with all communes and their zones was developed. Not all zones have the same specifications, in which case the cell is left empty.

(4) Since the output of the SPM is in 3D, it enables a detailed comparison of the current built environment with the potential future built environment provided by the SPM (see figure 52). The current building stock is represented using the building, and apartments register from the Swiss Federal Office for Statistics (2015a) dataset. This dataset includes the current number of floors for each building footprint and its roof geometry. With this information, it is possible to derive the potential growth in cubic metres of building volume in the current building regulation in comparison to the existing building volume in cubic metres. Nevertheless, it is important to maintain that the square-metre indicator is as important as the cubic metres, especially when speaking about densification in residential and mixed-use areas. People measure living space in square metres rather than cubic metres, and some buildings have, for example, a rather high volume in cubic metres but low surface area in square metres because of high ceiling heights. Industrial areas might benefit from cubic metre measurements, for example, due to storage areas, etc.

²³ Modified excerpt from:

Michael Walczak, Single-Authored, published as part of this dissertation in: SAGE Journal "Environment and Planning B: Urban Analytics and City Science."

First published 21.01.2021, <https://doi.org/10.1177%2F2399808320985854>; accessed 21.01.2021

4.3.2. CITY OF SARAJEVO

On the one hand, due to vast open-source accessibility to climatic data including current air quality index (see figure 53 and 56), daylight-hours, wind-speeds, climate classifications, modal split, population health ratios, and population and building densities, we could collect and compare the case of Sarajevo to other locations such as Zurich, Stuttgart, Medellin, Milano, Paris, Vienna and Katowice (see table 03). The health ratio is the number of deaths from ambient air pollution for the whole respective country for 2010. All other values are on a city-scale. We divided the absolute available data for 2010 through its respective country's population size in this particular year. See all data sources in table 03.

On the other hand, a mobile laboratory was used to conduct wind measurements during two weeks in May 2019 in 15 locations within the basin of Sarajevo boundaries (see figure 54), to understand the current environmental conditions of the City of Sarajevo. Suitable sites were identified together with local authorities from the Regional Planning Institute, Regional Institute for Public Health, and the Federal Hydro-Meteorological Institute. Key locations included the former Olympic site in Sarajevo as one of the two sub valleys, the river "Miljacka" and the white bastion as the second sub valley, "Skenderija" as the hinge of both sub valleys, "Marijin Dvor" as the bottleneck, the airport area as the end of the main valley and ten more locations in between. Compared to conventional wind measurement systems, which measure at one specific location (not mobile) and altitude, mostly near to the ground (+/- 5m), it is essential in valley conditions to understand in a vertical wind profile what wind conditions can be observed, for example, above the inversion weather phenomenon and the topographical mountain range.

To do so, "a Galion LIDAR system (Long Range Inland model) is used to measure the line-of-sight component (LOS) of wind speed. The measurement of the LOS component of wind speed is based on the Doppler shift of backscattered laser from aerosols in the atmosphere. (...) The LIDAR has a 3D scanning head that allows for volumetric scanning (...). The LIDAR system is installed in a mobile laboratory, "windRover" (see figure 55). During measurements, the LIDAR's laser head is raised through an opening in the roof of "windRover" by an elevator. A 5kW generator and a battery bank provide electric power for the laboratory's on-board systems" (Zendeabad et al. 2015). The output of these on-site wind measurements in Sarajevo includes data for wind direction and wind speed in the form of a vertical profile, and turbulence measurements for the 15 different sites (see figure 57 - 59).

4.3.3. CARACOLI NEIGHBOURHOOD IN BOGOTÁ²⁴

A multi-method case study was conducted in a 183-metre-long pedestrian street in Bogotá's Caracolí settlement during January and February 2019. This included night-time street observations, spatial measurements, a household survey, a lighting audit, and illuminance measurements using a Konica Minolta CL-200 A. 88 metres of the street were lit by four high-pressure sodium street

²⁴ Modified excerpt from:

Michael Walczak, Co-Authored with David Michael Kretzer, published as part of this dissertation in: Athens Journal of Architecture. Volume 6, pp. 1-29 [online pre-version, fully available in 2021: volume 7 (2)].

Available online, 22 July 2020, <https://www.athensjournals.gr/architecture/2020-3677-AJA-PLA-Kretzer-Walczak-04.pdf>; accessed 07.02.2021

lights (referred to as "formal" lighting), with the remaining 95 metres lit by nine self-built luminaires installed by the residents (referred to as "informal" lighting). The street begins at an altitude of 2,720 metres and ends at an altitude of 2,770 metres, resulting in a very steep incline of over 35% (see figure 76). The majority of the dwellings are regarded as illegal, having been built on land classified as high risk due to the threat of landslides.

Since informal settlements are characterised by permanent physical transformation, spatial measurements were conducted using a drone, a 360° camera, a measuring wheel, a laser distance meter, and a measuring tape in order to document the neighbourhood. Both "formal" and "informal" self-built luminaires were analysed in terms of their geometrical and lighting characteristics. The luminaires' height, the lamp types and wattages as well as the horizontal illuminance directly beneath each luminaire were recorded. Furthermore, the horizontal illuminance along the entire informally lit part of the street was measured. One informal luminaire was shipped to Europe in order to measure and digitise its photometry in a goniophotometer (see figure 60).

The purpose of observing the street was to analyse residents' night-time activities by mapping the number, type, and location of activities as well as to record people's age and gender. Such information can be expected to have an impact on how people evaluate fear of crime under certain lighting conditions. Observations were conducted during both a weekday and a weekend day. During the hours of participant observation, we were able to overlook both the formally and informally lit part of the street simultaneously, standing at the threshold of both parts of the street. Walking was the main activity. Furthermore, other outdoor activities such as talking, playing, smoking, smartphone use, and cooking were observed.

The household survey was used to collect the construction data from 36 out of 52 dwellings (see figure 61). The main questions were in what year each of the dwelling storeys had been built and what materials had been used. The data was compared with Google Earth satellite images and corrected if necessary. For the 26 dwellings for which no survey was available, the construction dates of the first storey were estimated using satellite imagery or the data of neighbouring dwellings. The average duration until additional storeys (second and third storey respectively) had been constructed was used for the 26 dwellings without survey data, as well as for the storeys that will be constructed after 2019.

**CHAPITRE 4 - ZONE D'HABITATION MOYENNE DENSITE
(LOCATIFS)**

Article 24 - Destination

Cette zone est destinée à l'habitation collective.

La Municipalité peut autoriser des magasins, petits commerces, locaux administratifs et autres activités tertiaires, dont l'exploitation n'incommodé pas le voisinage (bruits, odeurs, fumées, trafic, etc.).

Article 25 - Ordre

L'ordre non contigu est obligatoire.

Article 26 - Surface bâtie

Les bâtiments d'habitation auront une surface bâtie minimum de 200 m², la surface de la parcelle étant de 1250 m² au minimum.

Article 27 - Coefficient d'occupation du sol

Le coefficient d'occupation du sol est de 0.16 au maximum.

Article 28 - Coefficient d'utilisation du sol

Le coefficient d'utilisation du sol est de 0.64 au maximum.

Article 29 - Distances aux limites

La distance minimum "d" entre les façades et la limite de la propriété voisine ou du domaine public, s'il n'y a pas de plan fixant la limite des constructions, est en fonction de sa plus grande dimension en plan "L":

- si "L" est inférieur à 24.00 m. : "d" = 10.00 m.
- si "L" est supérieur à 24.00 m. : "d" = 10.00 m. + $\frac{L-24}{5}$

Entre bâtiments sis sur une même propriété, ces distances sont additionnées.

Pour les bâtiments de plus de 30.00 m. de longueur, un décrochement (retrait) de 2.00 m. au minimum est exigé.

Figure 51: Sample page of building regulations from the Swiss municipality of Ecublens (VD) showing the regulatory requirements for the medium-density residential area provided in form of a PDF document.
Source: <https://www.ecublens.ch/images/stories/reglements/rpga.pdf>; accessed 13.02.2021

ZIP code	1024	1024	1024
Municipality	Ecublens (VD)	Ecublens (VD)	Ecublens (VD)
Zone	Village	Medium-density residential area	Low-density residential area
Floor-area ratio	0.48	0.64	0.42
Attached/ detached buildings	Attached & detached	Detached	Detached
Max. footprint	0.16	0.16	0.14
Max. full floors	3	4	3
Max. building length (m)	30	30	25
Max. façade height (m)	7	12.5	5.5
Max. pitched roof height (m)	10.5		9
Attica setback (m)	2		
Distance lot boarder (m) (Building length (bl))	3 (detached)	bl<24=10 bl>24=10+bl-24/5	6

Table 02: Sample table (machine readable conversion) of the building regulations from the Swiss commune of Ecublens (VD). The column in grey shows a sample of the translation from the original building regulatory document provided by the commune in form of a PDF file, on figure 51.
Source: Michael Walczak (2020)

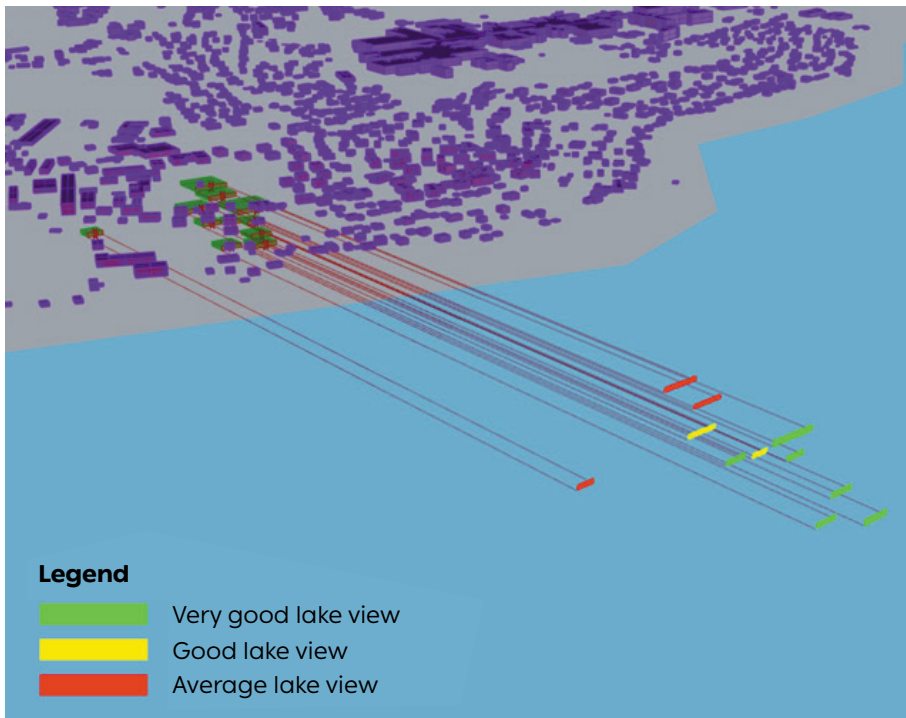


Figure 52: Top image: Qualitative visualisation of building regulation in the agglomeration of Lausanne. Green roofs represent the reassessed buildings including its attic roof. Buildings with red roofs symbolise the existing building stock within the context. Bottom image: Quantitative visualisation of an exemplary selection of 11 building units and their view analysis in the direction of the lake, embedded within the Lausanne area. This analysis considers whether the view is obscured by any other building, topography, or vegetative element.
Source: Michael Walczak (2020)

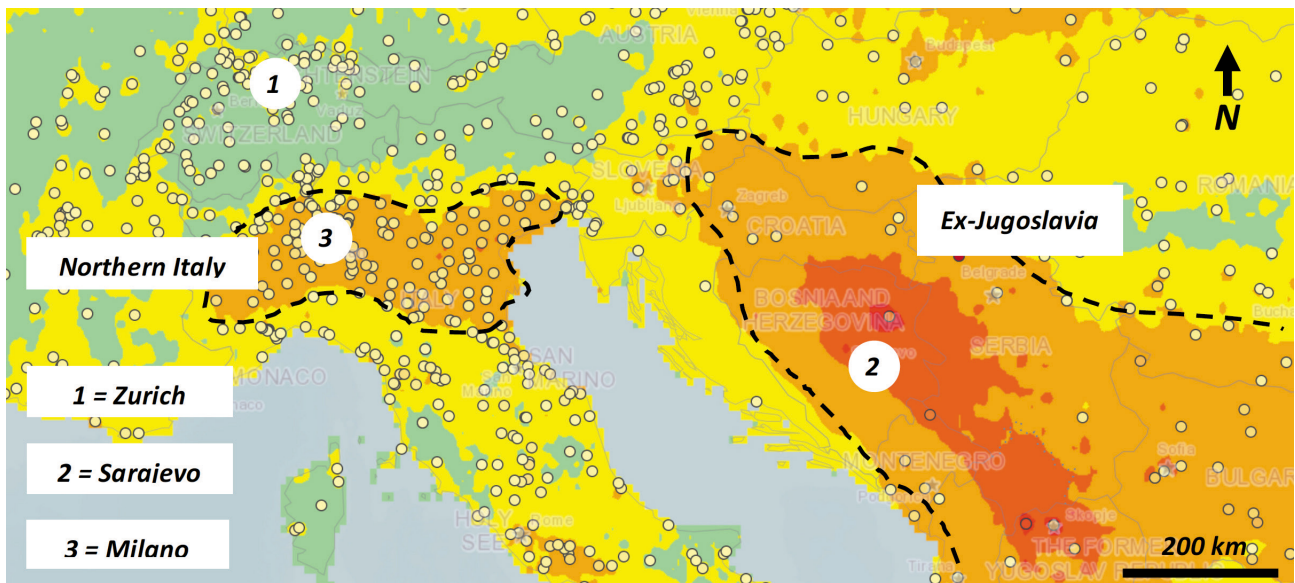


Figure 53: Screenshot of real-time air quality index map. Colour code showing the concentration of $PM_{2.5}$ from green less than $10 \mu m^3$ to dark red more than $70 \mu m^3$, Northern Italy and Ex-Yugoslavia are the areas within Europe with the highest air pollution density. Source: <http://maps.who.int/airpollution/>; accessed 10.12.2019; with adaptations by Michael Walczak (2019)

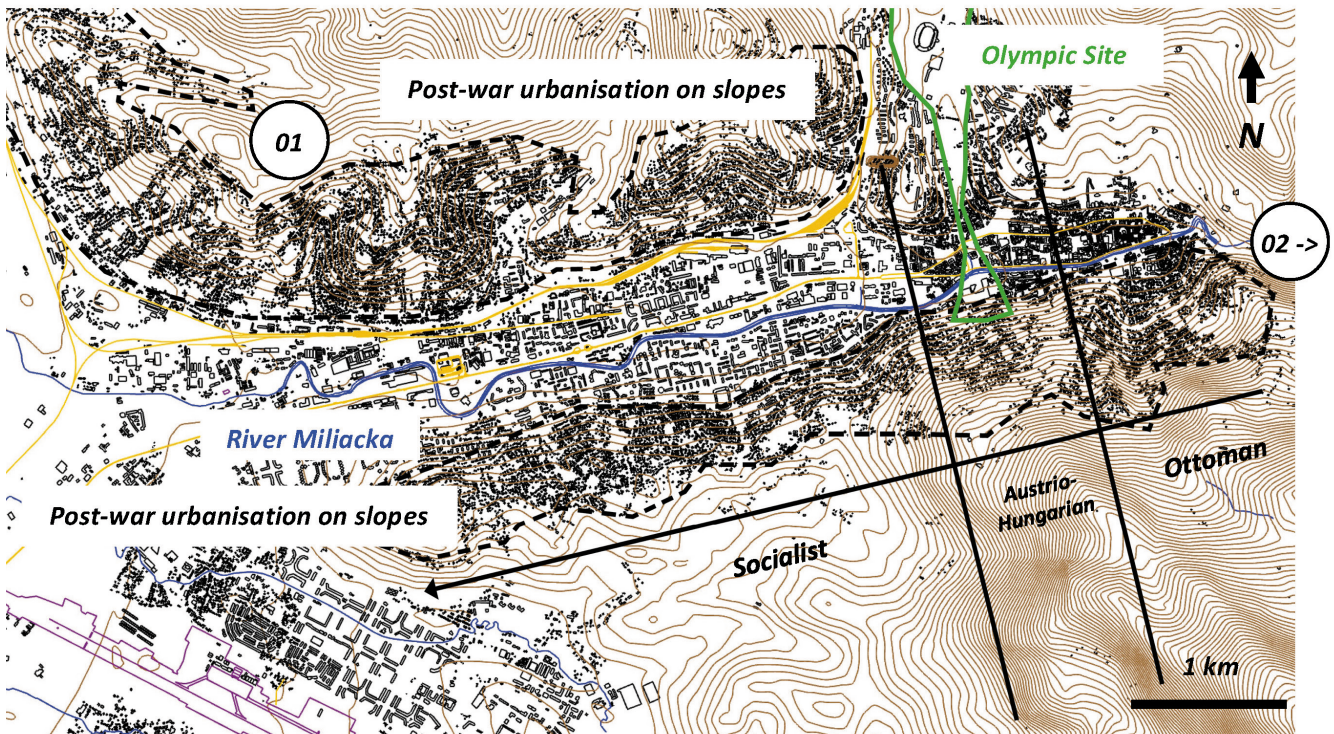


Figure 54: Sarajevo map through time, north-oriented, in yellow railway and tram network, in blue the river, in brown the topography, in purple the airport and in black the buildings. Urbanisation on the slopes of Sarajevo was resumed after the Bosnian War (1992–1995) in areas with steep slope gradients. This was a consequence of the impossibility or unwillingness of those internally displaced, sheltered in Sarajevo during the conflict, to return to pre-war homes (Martín-Díaz et al. 2018). Waste and garbage landfill (01) (Calò et al. 2009). Mine (02). Source: Michael Walczak (2019)

Case Studies	Air quality index (AQI)	Daylight (h/year)	Density		Wind speed (m/s)	Topo- graphy	Climate according to Köppen-Geiger	Mobility (Public %, private %, others % (walking, biking))	Health per 10.000 inhabitants
			Scale (km ²)	People (people/km ²)					
Zurich (CH)	20	~1600	90	4200	4	basin	Cold, no dry season, warm summer (CNW)	34, 36, 30	3
Stuttgart (GER)	20	~1600	210	3100	5	basin	CNW	24, 45, 31	5
Medellin (COL)	30	~1900	380	6700	4	basin	Tropical, rainforest	51, 19, 30	3
Sarajevo (BiH)	100	~1700	140	2100	3	basin	CNW	25, 40, 35	14
Milano (I)	30	~1900	180	7700	3	flat	Temperate, no dry season, hot summer	56, 30, 14	6
Paris (FR)	20	~1700	100	21500	5	elevations	CNW	61, 25, 14	3
Vienna (AT)	30	~1800	410	4400	6	elevations	CNW	39, 27, 34	4
Katowice (PL)	40	~1400	160	1900	6	elevations	CNW	NA	7
Case Studies	Air quality index (AQI)	Daylight (h/year)	Density		Wind speed (m/s)	Topo- graphy	Climate according to Köppen-Geiger	Mobility (Public %, private %, others % (walking, biking))	Health per 10.000 inhabitants
Zurich (CH)	20	~1600	90	4200	4	basin	CNW	34, 36, 30	3
Stuttgart (GER)	20	~1600	210	3100	5	basin	CNW	24, 45, 31	5
Paris (FR)	20	~1700	100	21500	5	elevations	Temperate, no dry season, warm summer	61, 25, 14	3
Vienna (AT)	30	~1800	410	4400	6	elevations	CNW	39, 27, 34	4
Milano (I)	30	~1900	180	7700	3	flat	Temperate, no dry season, hot summer	56, 30, 14	6
Medellin (COL)	30	~1900	380	6700	4	basin	Tropical, rainforest	51, 19, 30	3
Katowice (PL)	40	~1400	160	1900	6	elevations	CNW	NA	7
Sarajevo (BiH)	100	~1700	140	2100	3	basin	CNW	25, 40, 35	14
Case Studies	Air quality index (AQI)	Daylight (h/year)	Density		Wind speed (m/s)	Topo- graphy	Climate according to Köppen-Geiger	Mobility (Public %, private %, others % (walking, biking))	Health per 10.000 inhabitants
Sarajevo (BiH)	100	~1700	140	2100	3	basin	CNW	25, 40, 35	14
Milano (I)	30	~1900	180	7700	3	flat	Temperate, no dry season, hot summer	56, 30, 14	6
Medellin (COL)	30	~1900	380	6700	4	basin	Tropical, rainforest	51, 19, 30	3
Zurich (CH)	20	~1600	90	4200	4	basin	CNW	34, 36, 30	3
Stuttgart (GER)	20	~1600	210	3100	5	basin	CNW	24, 45, 31	5
Paris (FR)	20	~1700	100	21500	5	elevations	Temperate, no dry season, warm summer	61, 25, 14	3
Vienna (AT)	30	~1800	410	4400	6	elevations	CNW	39, 27, 34	4
Katowice (PL)	40	~1400	160	1900	6	elevations	CNW	NA	7

Table 03: The above table is sorted according to the air quality index, the wind speed and the topography. For the air quality index, the lower the number, the better the air quality. The city summaries (density in scale, density in population, and modal split) are based on data from the urban stories lectures by the ETHZ Chair of Architecture and Urban Design, AQI annual average from plumelabs.com; accessed 22.02.2020, annual wind data from <https://globalwindatlas.info>; accessed 22.02.2020, Köppen-Geiger climate classification (Beck et al. 2018), daylight data from <https://commons.wikimedia.org/wiki/File:Sol-Europa-Sunshine.png>; accessed 10.02.2021, topography data from <https://portal.opentopography.org/raster?opentopoID=OTSRTM.082015.4326.1>; accessed 10.01.2021, health ratios (death from ambient air pollution on a country-scale) with some adaptations from https://read.oecd-ilibrary.org/environment/the-cost-of-air-pollution_9789264210448-en#page48; accessed 10.02.2021. Source: Michael Walczak (2020)



Figure 55: "windRover" measurements in Sarajevo, here the location of "Groblje Alifakovac", a collaboration between ETHZ D-MAVT Laboratory for Energy Conversion and ETHZ D-ARCH Chair of Architecture and Urban Design.
 Source: Michael Walczak (2019)

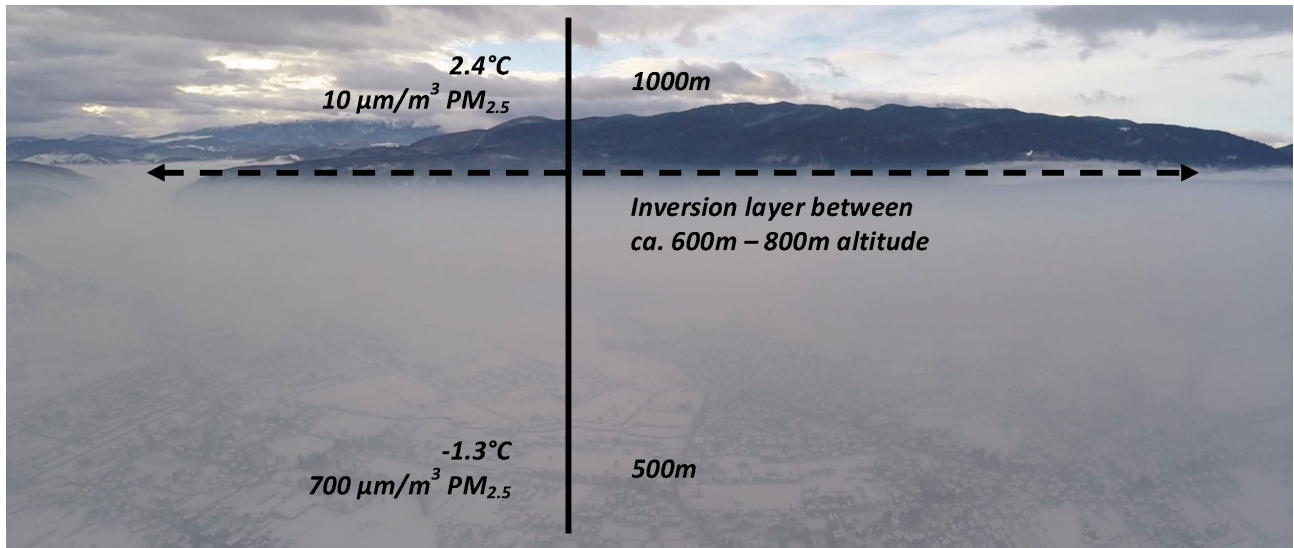
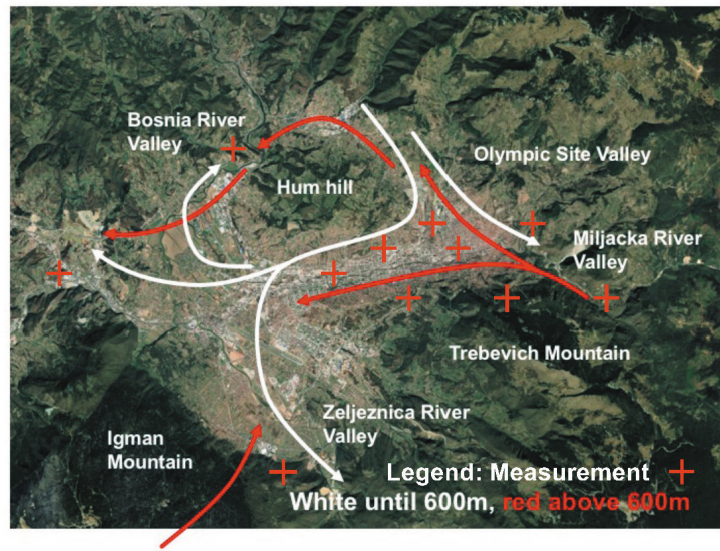


Figure 56: Aerial view on an exemplarily winter-day of the basin of Sarajevo showing the thick inversion weather phenomenon recorded from a drone flight around the Sarajevo airport area. In this specific case, the temperature at an altitude of 1000m is at 2.4°C and particulate matter at ten $\mu\text{m}^3 \text{PM}_{2.5}$ compared to the ground temperature of -1.3°C and particulate matter at $700 \mu\text{m}^3 \text{PM}_{2.5}$, which shows almost a three °C difference and 70 times less concentration of particulate matter. The lower the number, the better the air quality.
 Source and measurements: University of Sarajevo, Faculty of Mechanical Engineering, Prof. Dr. Adnan Mašić, with additions by Michael Walczak (2019)

Sarajevo's wind condition's specificity is the change in wind speed and wind direction above 400 - 600m.



Wind speed and direction changes at 200m and 800m.

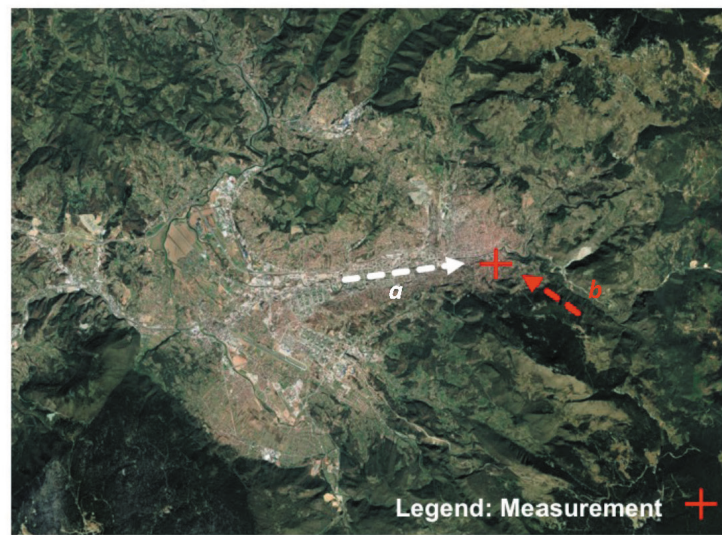
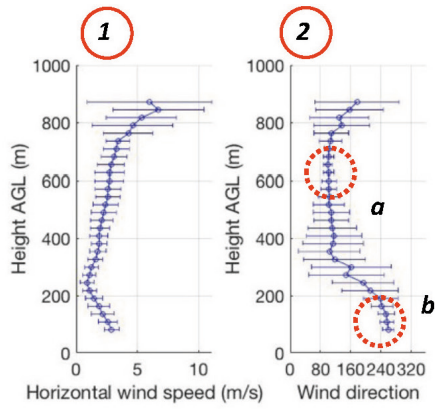
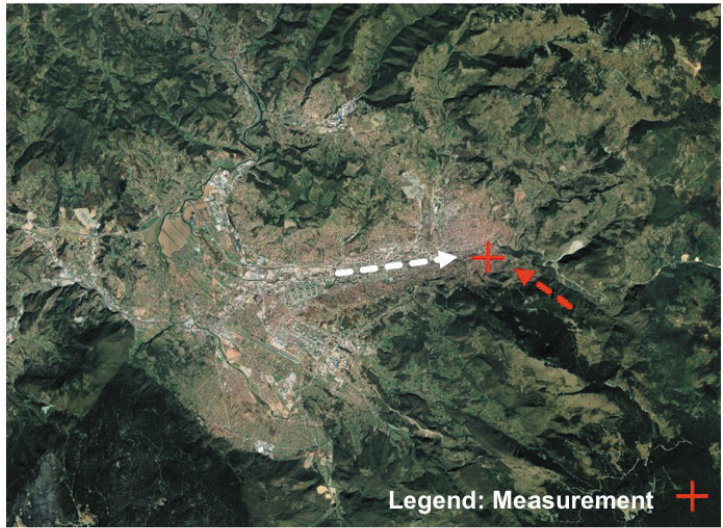
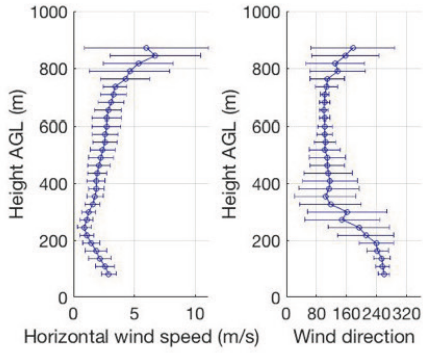
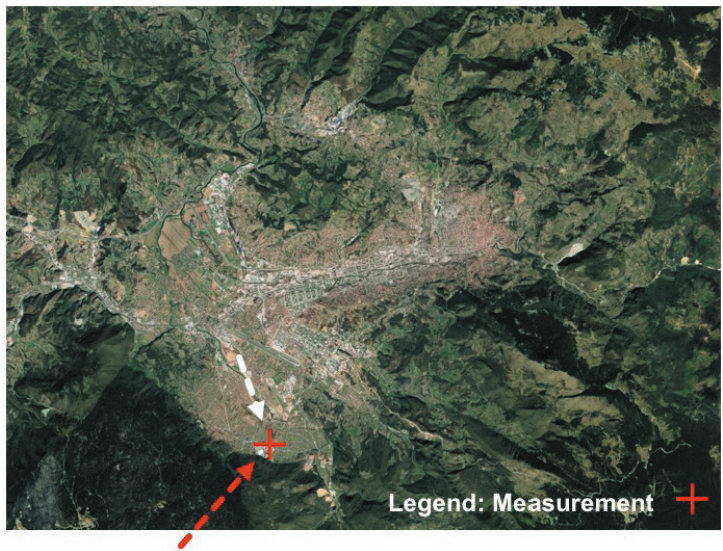
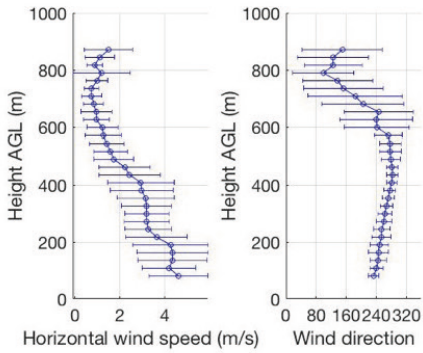


Figure 57: Top map with Sarajevo measurement locations and consolidated predominant wind directions in different elevations. Bottom chart and graphic show exemplarily results in Sarajevo (here measurements in the "Ottoman" district), red arrows symbolise wind below 400-600m and white arrows symbolise wind above 400-600m. The first line-chart shows a vertical profile of different wind speeds in different heights. Red circles in the second vertical profile represent the wind direction change in different heights. Source: Michael Walczak (2019)

Wind speed and direction changes at 200m and 800m.



Wind speed and direction changes above 600m.



Wind speed and direction changes above 400m - 600m.

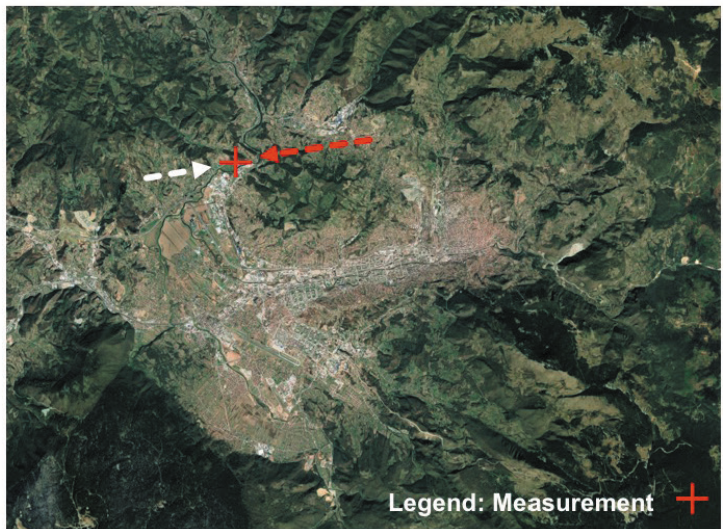
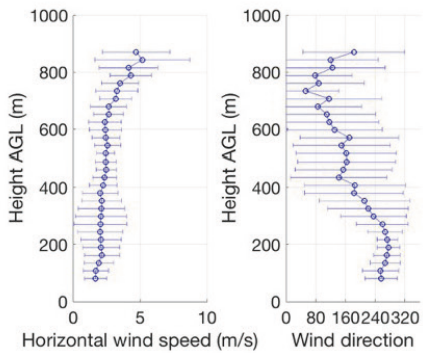
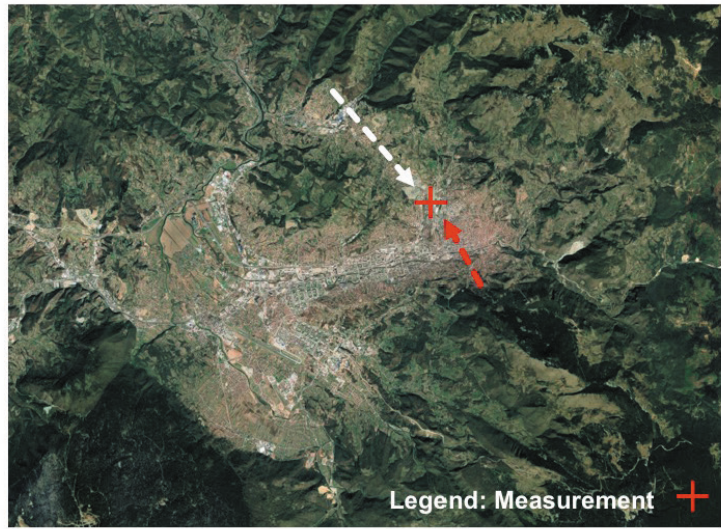
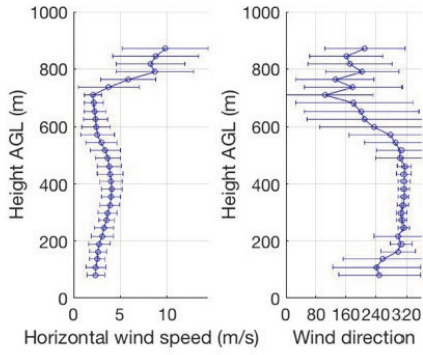
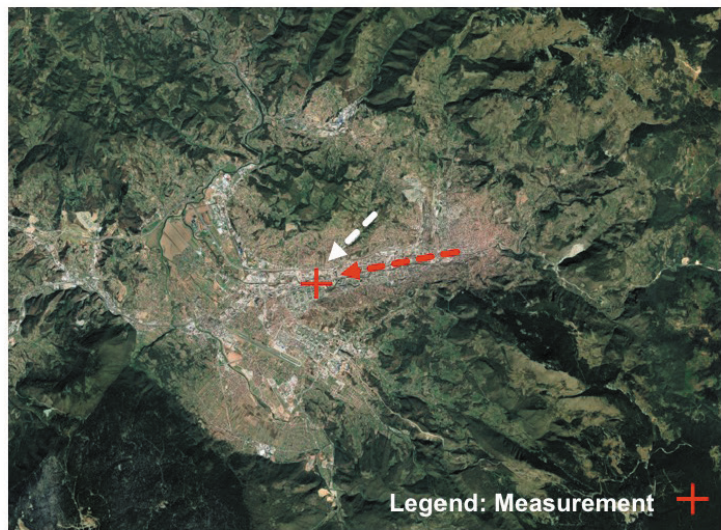
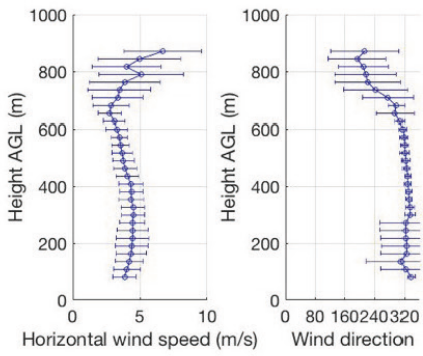


Figure 58: Maps and graphics show exemplary results measured in different locations in Sarajevo, red arrows symbolise wind below 400-600m and white arrows illustrate wind above 400-600m. The first line chart shows the vertical profile of different wind speeds in different altitudes. The second vertical profile symbolises the wind direction change in different heights.
Source: Michael Walczak (2019)

Wind speed and direction changes above 700m.



Wind speed and direction changes above 600m.



Wind speed and direction changes above 600m.

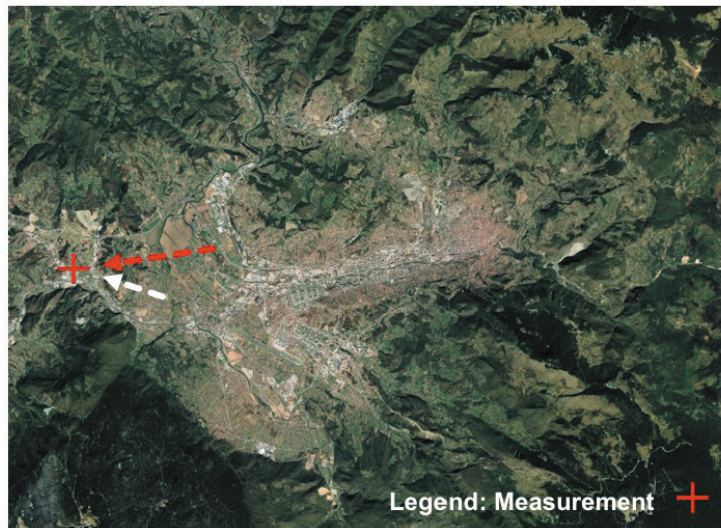
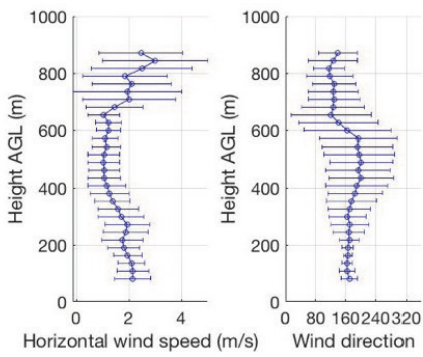


Figure 59: Maps and graphics show exemplary results measured in different locations in Sarajevo, red arrows symbolise wind below 400-600m and white arrows illustrate wind above 400-600m. The first line chart shows the vertical profile of different wind speeds in different altitudes. The second vertical profile symbolises the wind direction change in different heights.
Source: Michael Walczak (2019)



Figure 60: Digitisation process of informal luminaires including physical and photometric information.
Source: David Michael Kretzer & Michael Walczak (2020)

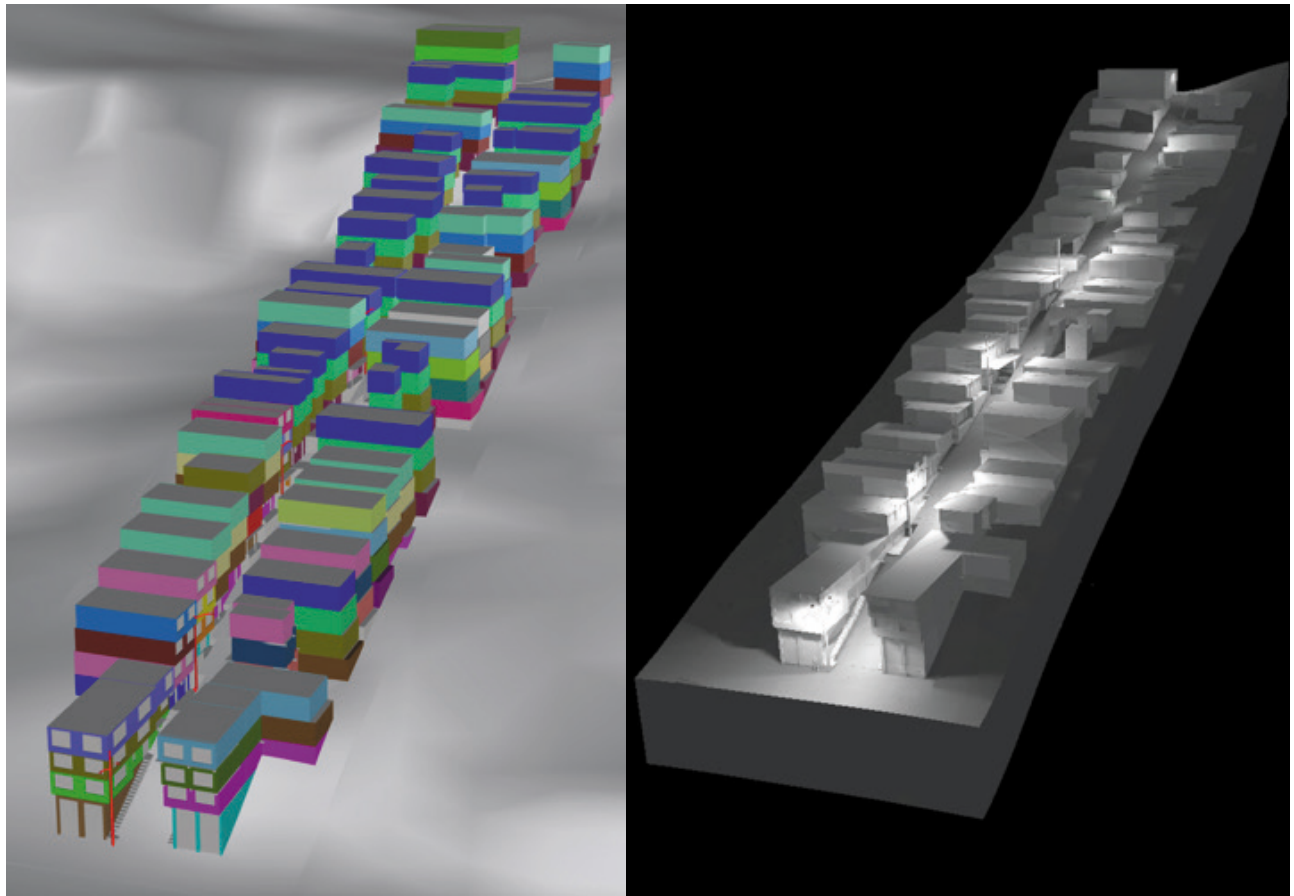
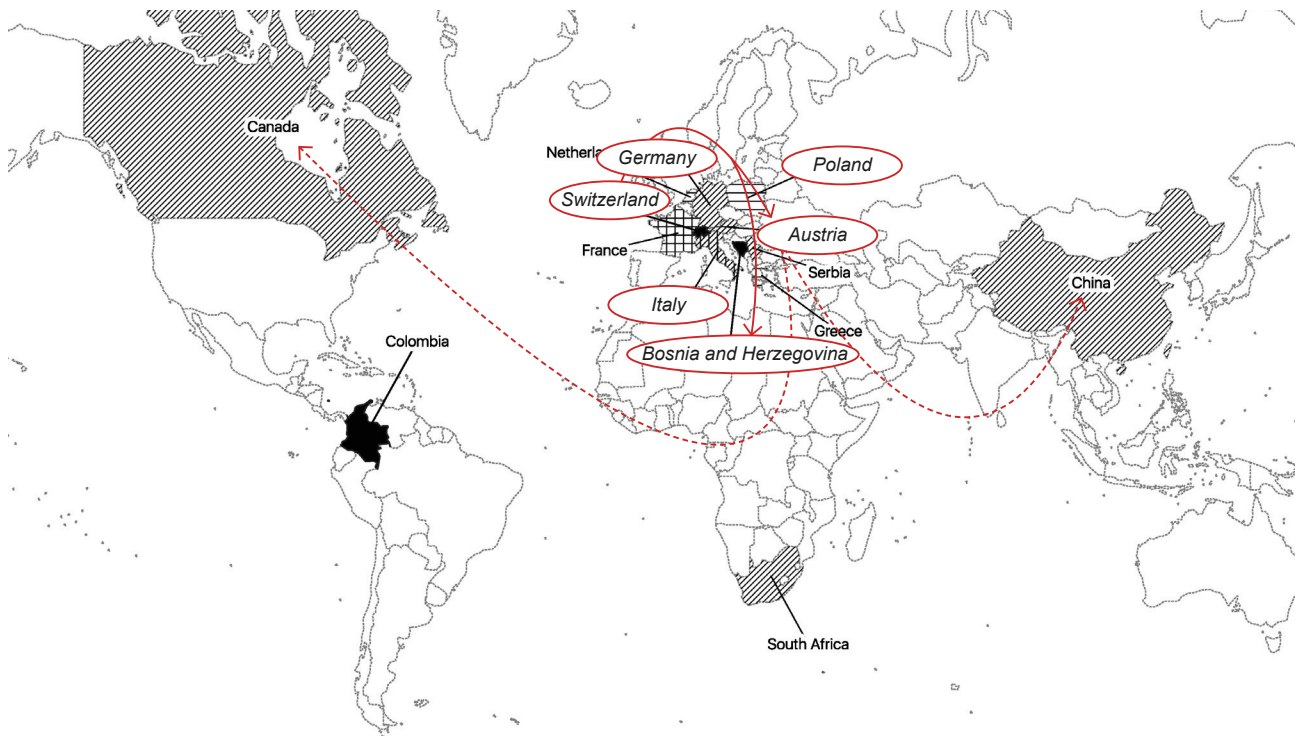


Figure 61: The 3D model of the four-storey case-study street including color-coded construction years (created in Rhinoceros3D (left-hand side)) and the lighting of the formally and informally lit parts of the case-study street in 2019 (reconstructed in the Dialux lighting software (right-hand side))

Source: 3D model: Michael Walczak (2019); lighting reconstruction: David Michael Kretzer (2019-2020).

4.4. Chapter 4: Step 2, Processing (ii)



The second step focuses on the processing and merging of data such as the data generated in step 1, to be able to scale and extrapolate collected data points to the whole of a neighbourhood, city or country. Our case of urban transformation processes mainly involves processing dynamic and time-related data into *DIGITAL URBAN IMAGINARIES*. Exemplarily, we illustrate this step with the case studies of Lausanne’s agglomeration, the City of Sarajevo and Caracoli, a neighbourhood in Bogotá. We processed:

- (4.4.1.) with the spatial policy model (SPM) for the agglomeration of Lausanne the current building regulation policies into a three-dimensional representation;
- (4.4.2.) with computational fluid dynamics (CFD) simulations the evidence collected on-site and scaled to the whole City of Sarajevo; and
- (4.4.3.) with custom C++ and Unreal Engine (Epic Games 2020) Blueprint code the dynamic data for Caracoli, a neighbourhood in Bogotá.

This step can be scaled and transferred to other contexts such as Toronto and Shanghai due to the *DIGITAL URBAN IMAGINARIES* methodology (see figure 62).

Figure 62: Location and transferability matrix, see chapter 3.2. Source: Michael Walczak (2021)

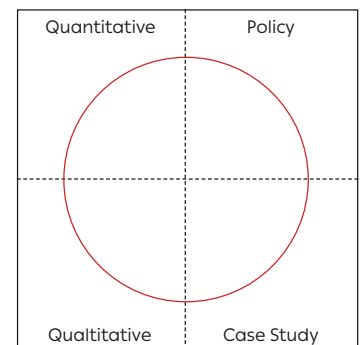


Figure 63: Stakeholder matrix, see chapter 3.3. Source: Michael Walczak (2021)

4.4.1. AGGLOMERATION OF LAUSANNE ²⁵

This research implementation step 2 developed a "definition" within the object-oriented programming and parametric software "Grasshopper3D" (Robert McNeel & Associates 2017a; 2017b) for "Rhinoceros3D" (Robert McNeel & Associates 2017c) since it allows for large-scale geometric data analysis and geometric calculation. The advantage of this framework is the automation, scalability, and replicability of such analyses to other locations in contexts that provide the necessary data mentioned above and the direct application into architectural and urban planning frameworks. Since each commune has a variety of different zones that consider different building policies and regulations, the first step entails the matching and superimposition process. Before being able to compute the maximum building surface area according to the building regulation, each building lot is assessed within the zoning and commune boundaries in which this specific lot is allocated and cross-referenced with the respective building policy, which for instance the method of Schaller (2018) did not take into account. This method enhances the ability to use this framework for any kind of context with the same data availability.

As soon as the correct building regulation for the building lot is identified, the model proceeds with the actual geometrical calculations. We need to bear in mind that the calculation of the final geometric solution for the specific lot (**see step 1 in figure 65**) is designed in an iterative loop since many of the policy requirements are interlinked. Small changes in the building geometry can affect all policy requirements and so forth.

The initial stage is to determine the correct lot border distances, *bd* (**see step 2 in figure 65**). Most of the building regulations distinguish between several values for the border distance. The first is the identification of the "long-distance" border. The "long-distance" border in most cases is determined on the one hand by the most southerly area of the lot, to provide high-quality outdoor spaces for the residents and to not cast shadow on neighbouring buildings (which also points to the necessity for a 3D representation of the building regulations). Depending on the building regulation, "long-distance" border can also be determined using the longest edge in comparison to all the other building lot edges. In this case, it is important to measure each edge of the building lot to automatically assign the correct lot border. The "long-distance" border is distinguished from the "short-distance" border in that it is normally 1/3 longer than the "short distance" border. Conversely, the "short-distance" border is used for all other lot edges excluding where the "long-distance" border was identified. The second significant factor for the border calculation depends on the maximum length, *ml*, of the building, which is normally specified in the building regulations. If not, it depends on the geometry of the building lot and its border distance calculation. The following two equations can be produced for the initial stage:

$$\begin{aligned} ml < \text{building length} &= bd \\ ml > \text{building length} &= bd + \frac{ml - \text{building length}}{\text{border extension}} \end{aligned}$$

²⁵ Modified excerpt from:

Michael Walczak, Single-Authored, published as part of this dissertation in: SAGE Journal "Environment and Planning B: Urban Analytics and City Science."

First published 21.01.2021, <https://doi.org/10.1177%2F2399808320985854>; accessed 21.01.2021

The second stage involves the calculation of the maximum building footprint, which must stay within the boundaries of the previously calculated lot borders (see step 3 in figure 65). If the building regulations specify the floor area ratio²⁶, az , then we need to take the amount of full floors, ff , into consideration (excluding underground floors and roof/attic surfaces). This will allow us to calculate the maximum footprint, mf , with which we can determine the length, l , of a potential volume:

²⁶ Floor area ratio is translated into English from the German "Ausnutzungsziffer". The coefficient is the maximum building surface divided by the lot surface

$$l = \sqrt{\text{lot sqm} * \frac{az}{ff}}$$

We can use the value l for an iterative comparison with the maximum building length value ml (see step 4 in figure 65). If this value exceeds the value in the building regulation, the building length needs to be adjusted. Either the length needs to be decreased, or the building mass needs to be subdivided into smaller building units (see step 5 in figure 65). In the case of subdivision, the regulation requires a specific minimum distance between the buildings (see step 6 in figure 65). Again, the smaller building units would need to stay within the boundaries of the computed lot borders. To extrude the buildings into the Z axis, the building regulation offers the maximum building height, bh , and the maximum building floors, f , which will determine the floor height, fh (see step 7 in figure 65):

$$fh = \frac{bh}{f}$$

The French-speaking part of Switzerland includes a unique parameter called "Ordre contigu" (see "a" in figure 65) and "Ordre non-contigu" (see "b" in figure 65), which literally means "attached" and "detached" buildings. The "attached" buildings policy allows existing buildings to be adhered to without considering the lot border distances. This case is especially apparent in zones of historic areas or city centres.

There are two options to consider with respect to the roof implantation: the attic or the pitched roof. The building regulation provides a setback value of the building footprint geometry for the attic roof. The regulation stipulates the roof ridge height and the maximum façade height for the pitched roof. These two values and an additional curve parallel to the long-sided edge of the building footprint – which is being extruded to the roof ridge height – can be used to compute the pitched roof geometry.

4.4.2. CITY OF SARAJEVO

Using custom "Matlab²⁷" code allows processing the "windRover" data collected in research implementation step 1 into three-dimensional representations. Matlab is a software framework to process, solve and visualise mathematical problem statements.

²⁷ <https://ch.mathworks.com/de/products/matlab.html>; accessed 10.12.2019

To understand and visualise the microscopic dynamics and dimensions of the impact of building volumes on wind behaviour in a trans-scalar method, computational fluid dynamics (CFD) simulations were applied. This method also allows the extrapolation, replicability and scalability of the on-site wind measurements collected in research implementation step 1 to inform the CFD simulations in terms of wind direction and wind speed. "Butterfly" (Roudsari 2019a) is a python library to create and execute "OpenFOAM" (blueCFD-Core 2017) cases and is running within the "Rhinoceros3D" (Robert McNeel & Associates 2017c) and "Grasshopper3D" (Robert McNeel & Associates 2017b) environment. "OpenFOAM" is an open-source CFD software and has an extensive range of features to solve among others complex fluid flows and turbulences made accessible through the "blueCFD-Core" (blueCFD-Core 2017) project. "Grasshopper3D" (Robert McNeel & Associates 2017b) is an object-oriented programming and parametric software environment whereas all the results are displayed within "Rhinoceros3D" (Robert McNeel & Associates 2017c) which is a computer-aided 3D modelling and computer-aided design software. This method simulates the current state of building conditions (framework developed in research implementation step 1) and projected future developments and their impact on wind behaviour.

Wind data collection can contribute to a better understanding of urban phenomena's and act as one layer to inform potential policy recommendations of future development for strategic plans such as, for example, the 2040 general urban plan for Sarajevo (GUP). Most current wind measurement devices are located on one specific height, in most cases very close to the ground surface. Regarding valley conditions and tall buildings, it is inevitable to measure wind conditions, such as in research implementation step 1, in different elevations. As an example, this research was able to identify main wind corridors within the City of Sarajevo. The measurement campaign took place from May 6, 2020 to May 10, 2020, and from May 16, 2020 to May 19, 2020. The former winter Olympic development strip - rectangular to the central longitudinal valley - including the Olympic stadium and indoor sports hall supplies the city centre of "Skenderija" with ten m/s wind from south to north. "Skenderija" is a convergence point of two smaller sub valleys continuing into the university campus's central valley corridor, located in "Marijin Dvor" and directing wind from east to west. The second sub valley - an extension of the central valley - and its wind stream is formed by the river "Miljacka" and oriented from east to the west. We allocated the main wind exit points of the Sarajevo valley in the valley of the Željeznica river and the mouth of the Željeznica river and the Bosna river, where multiple streams of wind join.

The Sarajevo case shows that the wind speed and the wind direction are changing at different heights. We observed mostly one wind condition until 400 - 600m, including wind speed until 5m/s and an utterly another state above 400 - 600m, including wind speed from 5m/s and more. These different wind conditions in different altitudes show a correlation with the inverse weather phenomenon, completely disappearing above 250m altitudes. We can, therefore summarise that winds below and above the inversion differ. Winds below the inversion are very calm, around five m/s and support high values

of particulate matter (PM₁₀²⁸). Winds above the inversion are stronger, ten m/s and more and lower the values of PM₁₀²⁸. The observed shift of the wind speed in higher altitude is, among other factors, due to tall miss oriented buildings in the city fabric since measurements in the windward entry points of the two sub valleys of the leading wind corridor showed stronger wind in lower altitude compared to leeward measurements after the city centre with its tall buildings. As the main conclusion, this research shows that building form and setting has a significant impact on air quality due to the effect on wind behaviour.

CFD (Computational Fluid Dynamics) simulations confirm the findings of the on-site measurements in the City of Sarajevo (see figure 66). The wind condition located windward, the entry point into the longitudinal valley, is much higher than leeward, right after a tall building section (Marijin Dvor). The wind is also reoriented and dispersed into other directions. In several conditions, the wind is also "locked" into the built environment's constellation and keeps pollutants within its perimeter. In the CFD simulation, the "bottlenecks" are also clearly visible, that buildings which are oriented transversally in relation to the longitudinal basin, in other words, against the natural wind direction, are creating a blockage wall with little porosity, and support the creation of windless pockets within the city fabric. In comparison, the river stream "Miljacka" or the main street corridor "Zmaja od Bosne" are providing an undisturbed wind corridor to the City of Sarajevo, as well as porous, low or longitudinally oriented buildings.

4.4.3. CARACOLI NEIGHBOURHOOD IN BOGOTÁ²⁹

Transforming the data gathered by drone and 360° filming as well as distance measurements into a 3D model was a complex iterative process. The drone footage was the basis for establishing information about the plan view, combined with information provided by Google Earth satellite imagery and digital elevation maps from the NASA shuttle mission. The 360° footage provided the vertical information for the model with regards to the number of building storeys as well as the location of windows, doors and stairs, the roof geometry, overhangs, terraces, materialisation, topography, and vegetation. The static elements visualised within the VE/VR visualisation framework comprise the topography, buildings, vegetation as well as specific objects such as luminaires, fences, and tyres. Each of these elements is further explained in the following section.

As regards the static topography visualisation, the Geotiff raw data for Bogotá is accessed through the NASA shuttle mission. Within Q-GIS Version 3.4.8-Madeira (QGIS Development Team 2018), the QGis2Threejs plugin is used to convert Geotiff Data into gltf format. Aspose.3D Conversion³⁰ is used for the translation from gltf to stl format, allowing the topography to be opened in Rhinoceros3D (Robert McNeel & Associates 2017c) and the format to be translated to Unreal Engine (Epic Games 2020) readable format (fbx). Additional elements such as trees, bushes, and significant objects are added and materialised manually through the Rhinoceros3D (Robert McNeel & Associates 2017c) and Unreal Engine

²⁸ Particulate matter (PM): air quality is measured, next to NO₂ (nitrogen dioxide) and SO₂ (sulphur dioxide), in PM which was introduced in 1987 as National Air Quality-Standard. After PM₁₀, also known as suspended dust, is a mixture of minute particles less than one-hundredth of a millimetre in diameter (10 µm), PM_{2.5} is added with a much higher resolution and lower scale, below 2.5 µm. Particulate matter is a mixture of diesel soot, oil and wood combustion particulates, tires and pavement debris. It also contains sediment and particulate matter from illegal waste incineration and natural mineral content (Official Journal of the European Union 2016). The smaller the particles are, the more harmful the impacts are.

²⁹ Modified excerpt from:

Michael Walczak, Co-Authored with David Michael Kretzer, published as part of this dissertation in: Athens Journal of Architecture. Volume 6, pp. 1-29 [online pre-version, fully available in 2021: volume 7 (2)].

Available online, 22 July 2020, <https://www.athensjournals.gr/architecture/2020-3677-AJA-PLA-Kretzer-Walczak-04.pdf>; accessed 07.02.2021

³⁰ <https://products.aspose.app/3d/conversion/gltf-to-stl>; accessed 19.03.2020

(Epic Games 2020) workflow.

Regarding the static building visualisation, the Unreal Engine (Epic Games 2020) is extended with custom C++ code. GDAL library is used for loading all geo-located building footprints and their respective numeric building storeys provided by "Mapas Bogotá"³¹. If no spatial building measurements could be taken the following method is applied: according to aggregated field observations, the building footprints are extruded by the multiplication of a 2.4-metre building height for the ground floor and 2.6 metres for all the subsequent floors, which have additional height for the ceiling compared to the ground floor which has its ground plate below ground level. Another observed specificity is that the first floor (i.e. the second storey) on average overhangs the streetscape by approximately 0.6 metres. Each consecutive floor, starting from the second floor, was found to overhang the streetscape by an average of around 0.2 metres. Custom code relocates the buildings by their altitude to their respective position in accordance with the topography by finding their intersection point. The buildings are materialised and UV-mapped automatically with a selection of common materials in the settlement, including bricks, corrugated steel, glass, and wood. Windows, doors, railings, specific roof geometries, and terraces are added and materialised manually through the Rhinoceros3D (Robert McNeel & Associates 2017c) workflow and Unreal Engine (Epic Games 2020) framework.

³¹ <https://mapas.bogota.gov.co>; accessed 14.02.2021

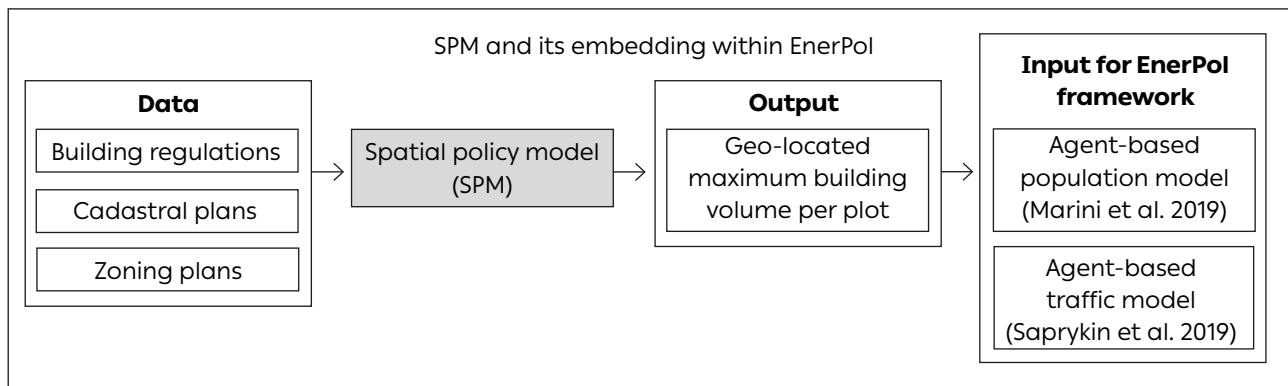


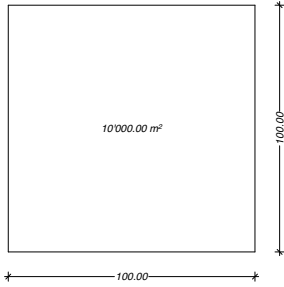
Figure 64: Schematic of the dynamic spatial policy model that is integrated into the EnerPol framework.
Source: Michael Walczak (2020)

	Proposed SPM methodology	Comparison to classical GIS approach
Cost	Rhinoceros3D (Robert McNeel & Associates 2017c) and Grasshopper3D (Robert McNeel & Associates 2017a; 2017b) require a licence, Unreal Engine (Epic Games 2019) has an open source-code	Depending which tool is used, QGIS (QGIS 2017; 2018) is, for example, open-source
Benefit	Allows for real-time 3D visualisation including materialisation and lighting	Allows for 2.5D (without specific roof geometry, just extrusion of building footprint) visualisation without materialisation and lighting
	Automated	Manual work
	12 hours' computation time for the task of this research implementation step	Approx. 1,200 hours for the same task
	3D comparison with existing building stock including all correct roof geometries such as pitched roofs	2.5D comparison with aggregated and extruded building stock resulting in less accuracy
	2D and 3D output in form of data which can be read by conventional CAD tools or game engines	2D output in form of data which can be read by conventional CAD tools
	Adequate communication through 3D-visualisation (including materialisation and lighting) in laymen terms	Communication through 2D maps or plots
	Compatibility with further 3D analyses, such as views and sunlight hours	Manual workaround is required to prepare files for 3D analyses such as views and sunlight hours
	Instant visual and 3D feedback to changes in input parameters	No instant visual and 2.5D feedback to changes in input parameters
	Embedded within broader simulation framework "EnerPol"	Stand-alone framework

Table 04: Cost-benefit analysis between the proposed methodology of the SPM and a more classical approach using GIS (Geographical Information System) tools such as Q-GIS (QGIS Development Team 2018).
Source: Michael Walczak (2020)

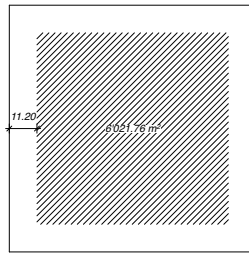
a "Ordre non-contigu" = no "attached" buildings

STEP 01
Initial lot



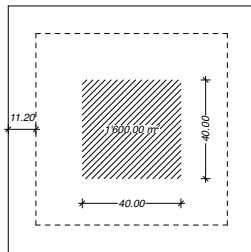
STEP 02
Lot border distance

max. length (L) = 30m
 $L < 24m = 10m$
 $L > 24m = 10m + ((L - 24) / 5)$
 $10m + ((30m - 24) / 5) = 11.2m$



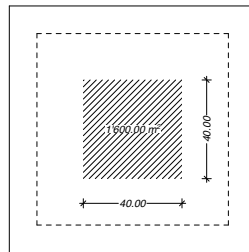
STEP 03
Maximum building footprint

max. AZ = 0.64
 max. full floors = 4
 $0.64 / 4 = 0.16$ max. footprint
 $10,000m² \times 0.16 = 1,600m²$
 $\sqrt{1,600m²} = 40m$



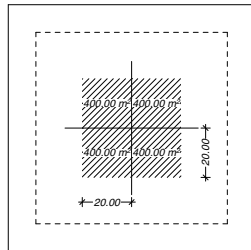
STEP 04
Maximum building length

40m exceeding length limit of 30m (see step 2)
 max. footprint = 0.16
 $10,000m² \times 0.16 = 1,600m²$
 $\sqrt{1,600m²} = 40m$



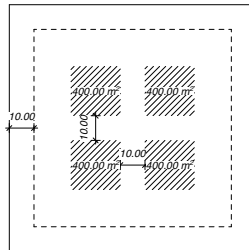
STEP 05
Building subdivision

subdivision until length limit is fulfilled
 $40m / 2 = 20m$



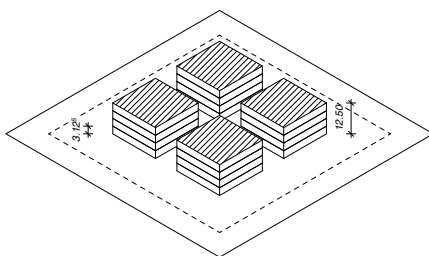
STEP 06

"Ordre non-contigu" = no "attached" buildings
 if value between building is not specified the lot distance is applied. Since length is reduced to 20m, the reduced value of 10m for the lot distance will be applied and reduced accordingly (see step 2).



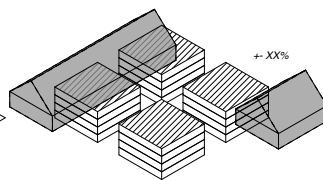
STEP 07
Building 3D extrusion

max building height = 12.5m
 max. building floors = 4
 max floor height: $12.5m / 4 = 3.125m$



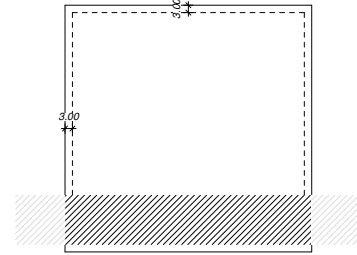
STEP 08

3D comparison with existing buildings
 in grey existing buildings
 existing buildings - new buildings = potential building surplus



b "Ordre contigu" = "attached" buildings

"Ordre contigu" = "attached" buildings
 connect new building to existing buildings for row continuity



Building 3D extrusion

max pitched roof height = 10.5m
 max. facade height = 7m
 max. full floors = 3
 max floor height: $7m / 3 = 2.33m$ (too little floor height, reduced to 2 floors with 3.5m floor height)

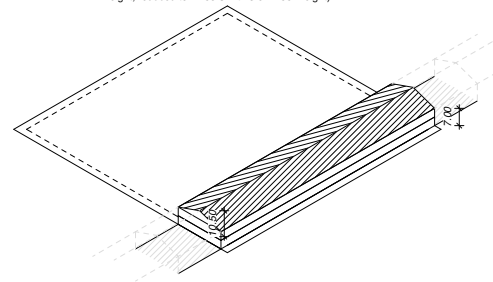


Figure 65: Building regulations from the Swiss commune of Ecublens (VD): this specific example shows schematically the "Zone d'habitation moyenne densité" (Medium density housing area) on the left and the "Zone du village" (Historical centre area) on the right and how the spatial policy model interprets this.
 Source: Michael Walczak (2020)

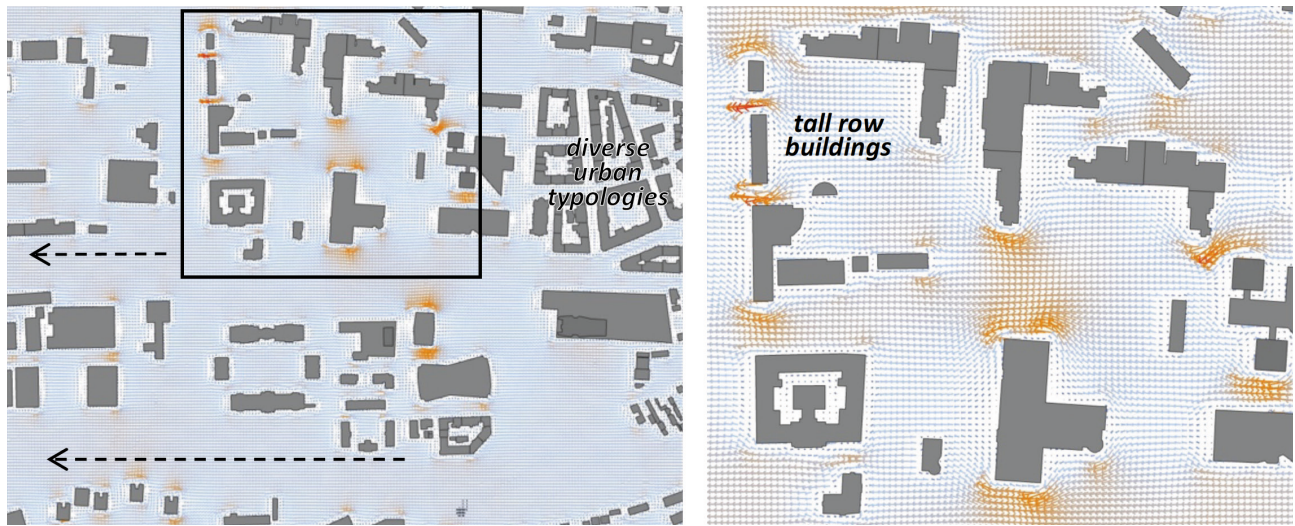


Figure 66: Using results of the LIDAR onsite measurements to inform CFD simulations showing the turbulences and blockages/bottlenecks of leeward natural wind flow, right after tall buildings with arrow colour gradient from orange to red, blue arrows show undisturbed airflow. The left image is showing a black frame in which the right image is zoomed in. Both figures show exemplarily one horizontal section plane on human eye level in the Marijin Dvor Area in Sarajevo. Black arrows on the left image are showing the two main wind corridors through the City of Sarajevo including the River "Miljacka" and the Street "Zmaja od Bosne".

Source: Michael Walczak (2019)



Figure 67: Framework to process dynamic data such as pedestrian motion. User setup for spline, speed, start- and end-time, and location. Automatised recognition of topography in relation to spline path. Source: Michael Walczak (2020)

4.5. Chapter 5: Step 3, Communication (iii)

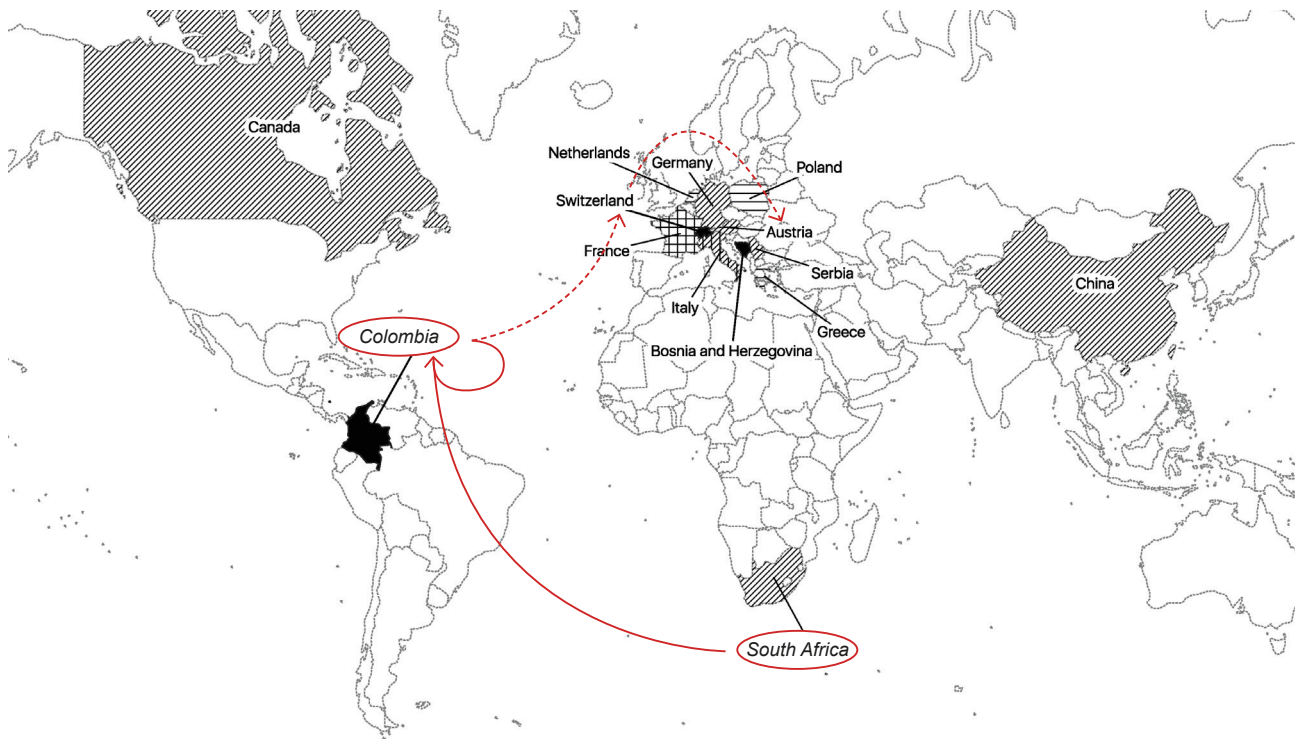


Figure 68: Location and transferability matrix, see chapter 3.2.
Source: Michael Walczak (2021)

The third step focuses mainly on citizen-centred design processes and the communication of data generated in step 1 and evidence and results processed in step 2. This visual representation shall result in the making of more well-founded decisions. We developed novel immersive, dynamic and interactive visualisation techniques at the intersection of citizens, actors and stakeholders from urban transformation processes (see figure 69). Exemplarily, we illustrate this step with the case studies of Lausanne’s agglomeration, the City of Sarajevo and Caracoli, a neighbourhood in Bogotá. We communicated:

- (4.5.1.) with quantitative tables, plots and maps identified evidence for the agglomeration of Lausanne;
- (4.5.2.) with three-dimensional digital models simulated results for the City of Sarajevo; and
- (4.5.3.) with customised game engine frameworks various scenarios in qualitative four-dimensions for Caracoli, a neighbourhood in Bogotá.

This step can be scaled and transferred to other contexts such as the 2nd district in Vienna due to the *DIGITAL URBAN IMAGINARIES* methodology (see figure 68).

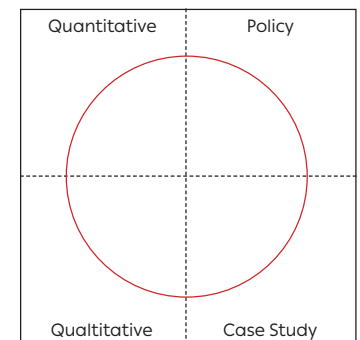


Figure 69: Stakeholder matrix, see chapter 3.3.
Source: Michael Walczak (2021)

4.5.1. AGGLOMERATION OF LAUSANNE ³²

A total of 29,914 parcels in 30 municipalities within the whole agglomeration of Lausanne were processed by the Spatial Policy Model (SPM) (see chapter 4.1.2.). A total of 7,945 building parcels were identified within residential and mixed-use zones, with a sum of approx. 600 hectares (6,095,368 m²) of potentially developed building surface (see figure 70), in order to identify and filter 256 reasonable and meaningful building lots for future development (see figure 70). Filtering, in this case, meant considering the aspect of feasibility in architectural terms, i.e. very narrow building lot and/or building volume is exactly the same or less than the current building volume on this specific building lot. This results in an additional densification of 381,034 m² in urban densification (i) and 933,114 m² in brownfield redevelopment (ii) (see table 05). The additional densification is calculated by subtracting the current existing buildings from the maximum building surface within the building regulations identified by the SPM. The current building regulations for the whole agglomeration of Lausanne mean the acquisition of between one to a maximum of five floors. Nevertheless, the potential of additional densification of ~38 hectares in (i) urban densification of existing buildings is still significant. In case of political decisions not to take greenfield or brownfield redevelopment into consideration, the potential is still significant.

The City of Lausanne is already close to its maximum capacity. Almost no more new surfaces for development and/or densification can be built on under the current building policies in the absence of either re-zoning or conversion of industrial buildings – excluding refurbishment and/or optimisation of current residential layouts. The impact and potential for densification is more pronounced in the periphery of the agglomeration than in the city centre, which brings the agglomeration of Lausanne into the development spotlight. Exemplarily, 59 potential building lots were identified in the municipality of Morges that could be developed either for (i) or (ii). Eleven potential building lots were identified in the municipality of Pully. In contrast, a densification coefficient (ratio of the current existing buildings to the maximum surface that could be build on within the current regulatory framework: current state in m² divided by the maximum m² permitted under building regulations) of just 0.12 (see table 06) was measured in Morges, whereas a higher densification ratio of 0.14 (see table 06) was assessed in Pully. This is due to the re-assessment of the building regulations of the municipality of Pully, which accounts for the need to accommodate the population increase in the coming years.

In any type of Swiss building development, each architect/planner is obliged to stay within the rules of the building regulations excluding the strategy (iii). This requires the careful study of these policies and a translation into a three-dimensional geometrical representation of these regulations, similar to step 7 in figure 65. Such a three-dimensional representation (see figure 71) allows the planner to compare the desired design with the requirements and to assess whether it matches. Exceptions from the regulatory framework can be made in rare cases, but in the case of Switzerland local communities and neighbours need to be engaged in to be approved. Such a process of translating the

³² Modified excerpt from:

Michael Walczak, Single-Authored, published as part of this dissertation in: SAGE Journal "Environment and Planning B: Urban Analytics and City Science."

First published 21.01.2021, <https://doi.org/10.1177%2F2399808320985854>; accessed 21.01.2021

building regulations into a three-dimensional geometrical representation takes approximately ten minutes for each building lot, depending on the size and complexity of the policy. If this time approximation were to be scaled up to the amount of building parcels analysed in this study, this would mean a total of approx. 1,200 hours compared to approx. twelve hours for the method presented here (**see table 04**): The automated framework yields computation that is up to two orders of magnitude faster.

4.5.2. CITY OF SARAJEVO

The power of data to inform urban policy, mainly when aggregated and evaluated across municipalities (Avrami 2019) is inevitable. In this case, the method of “evidence-based policy evaluation” (Avrami 2019) is the mentioned collected and processed evidence from on-site measurements and observations, correlated to other fields such as densification (research implementation step 1) or daylight, then being translated into policy recommendations. Nevertheless, we even used the “windRover” measurement vehicle itself as a medium/tool of communication in the City of Sarajevo (**see figure 73**). We engaged and sensitised local authorities and universities to show the vehicle’s functionalities in real-time and resulting evidence during the city’s measurements. As policy recommendations, we can conclude that each city needs to identify prevailing wind corridors (**see figure 74**), and patterns including process/scenarios of the built densification, building geometries, building heights, green and water passages. These patterns and streams need to be visualised in a three-dimensional or four-dimensional (time) *DIGITAL URBAN IMAGINARY*. The municipalities’ regulatory zoning frameworks need to adapt dynamically, especially in terms of the building heights, building orientation, and porosity, to prevent the described mismatch between the built and natural environments such as climate and daylight. The zoning framework could identify potential existing water streams that could be uncovered or preserved as well as green corridors could be extended. Such policies should be accompanied by a primer or manual, including all glossaries and planning recommendations. Also, the digital content shall be in the form of geo-located data of such climatic conditions such as wind measurements and radiation analysis, densification and zoning scenarios; since we are already used to such inventories as in the field of heritage with lists of historic monuments more than two centuries ago (Avrami 2019). These datasets and recommendations have to be considered very dynamically and never absolute or finished. It has to have a constant iterative re-evaluation, re-assessment, and re-design built-in—a never-ending process—due to our current climate conditions’ very disruptive nature.

We have to create a culture of climate on a trans-scalar urban scale, a *DIGITAL URBAN IMAGINARY*. A culture of climate responsiveness can only exist if we collect knowledge and imaginations, similarly to the example, that the culture of TV and radio can only exist as long as shows are collected and recorded (Debray 2003).

4.5.3. CARACOLI NEIGHBOURHOOD IN BOGOTÁ³³

A dynamic real-time visualisation framework was developed. The simulations and visualisations were run on multiple (six) CPU cores (9th Generation Intel(R) Core i7(R) CPU 9750H clocked at 2.6 GHz) with 32GB of RAM. The GPU-accelerated visualisation model runs on a single NVIDIA RTX 2070 with Max-Q Design and 8GB of RAM. The Unreal Engine version 28 (Epic Games 2020) is used as the elemental visualisation framework.

The dynamic elements visualised within the visualisation framework comprise the buildings, pedestrians/footfall, luminaire geometries, and photometric characteristics. Each of these elements is further explained in the following section.

In terms of the dynamic building visualisation, the time component in the form of the historical growth (as documented in the household survey in the research implementation step 1) and anticipated densification process (extrapolation of historical data into future) of the settlement were translated into the visualisation framework by tagging each building with its respective years of storey construction and characteristics such as material or luminaire types. The respective buildings with all their characteristics are visualised for the specific year in which the user is navigating or is located.

Regarding the dynamic footfall visualisation, custom code allows for automated adaptation of pedestrian paths to the topography through an extrusion of multiple spline knots up to the moment of intersection with the topography surface. These intersected spline points are then again connected together and form the walking path of the footfall visualisation.

In input terms, it was necessary to import a geo-located spline as the path of each individual "agent" (which in this case constitutes data in the form of a detailed night-time participant observation sequence of five minutes) (**see figure 67**), to set the pedestrian walking speed, and to set a start time. The "agent" appears at the start time and disappears as soon as the sequence is finished. The visualisation time-frame, in this case, 30 seconds, can randomly start within the five-minute scenario sequence. The animated 3D characters, including character geometry in the form of meshes and virtual skeleton of bones, are from Adobe Mixamo.

The built-in Unreal Engine (Epic Games 2020) framework is applied to visualise the physical and photometric lighting characteristics within the dynamic environment, which allows for the use of three-dimensional photometric data in the form of IES files for each luminaire. Nvidia RTX graphics card and Nvidia CUDA technology enable real-time ray tracing to be used and more adequate lighting and reflection results to be achieved. Custom code is applied for the incremental upgrading of luminaires and the response of the luminaire in the form of motion sensors.

The interactive visualisation (**see figure 107**) can be experienced through either front-of-screen or virtual reality in the form of Oculus Rift/Rift S goggles. The visualisation can be experienced either on a fixed/predefined path or open-world. Where a predefined path is the input, it is necessary to provide a geo-located spline on which the user can be guided and also enter the movement/walking speed, as with the footfall visualisation framework. For an open-world

³³ Modified excerpt from:

Michael Walczak, Co-Authored with David Michael Kretzer, published as part of this dissertation in: Athens Journal of Architecture. Volume 6, pp. 1-29 [online pre-version, fully available in 2021: volume 7 (2)].

Available online, 22 July 2020, <https://www.athensjournals.gr/architecture/2020-3677-AJA-PLA-Kretzer-Walczak-04.pdf>; accessed 07.02.2021

setting, the user can navigate either with a standard gaming setting ("WASD" or arrow keys) or with the Oculus joysticks (Oculus Touch). To experience the growth of the settlement, the user can navigate through years by pressing a dedicated keyboard or Oculus controller button. The respective year to which the user is exposed is displayed on the virtual "cockpit", graphical user interface (GUI).

Regarding the VE/VR framework, this study shows the feasibility of (1) a method presented for the spatial and temporal documentation of rapidly changing informal environments in VE, (2) the medium for visualising such data in VR, and (3) the ability to generate lighting-specific features in multiple future scenarios in VE/VR (see figure 77 - 83).

(1) Custom code enables state-of-the-art game-engine technology to be enhanced with the capability to use temporal large-scale quantitative as well as empirical data sets in an automated manner. This is primarily a matter of visualising the historical as well as the projected future incremental development of architectural structures and their changes in materialisation terms. The output in the form of common planning documents such as sections and plans can be further used in planning processes. The visualisation of motion patterns of pedestrians in the form of animated human skeletons is a further key concern.

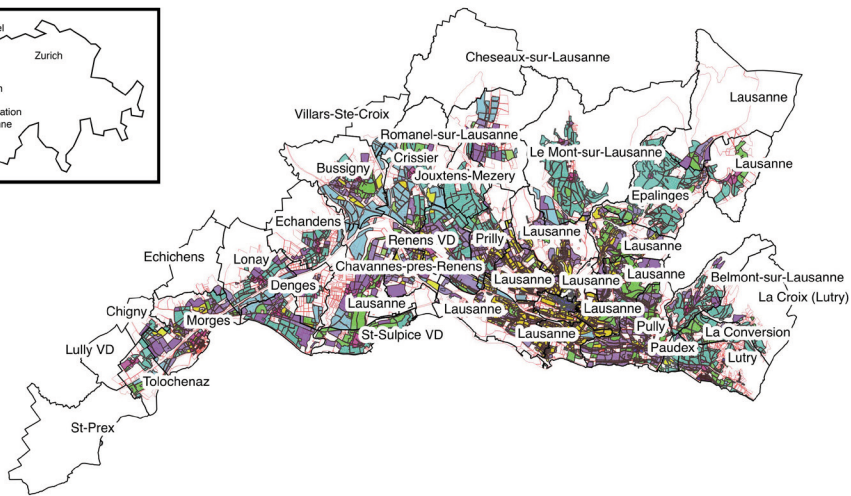
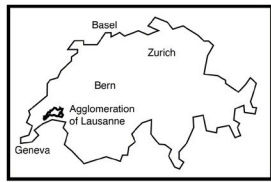
(2) A custom graphical user interface (GUI) helps navigate the virtual environment by displaying in text form the current year that is being visualised or the tasks/functionalities that the user can access.

Based on state-of-the-art game-engine technology, a range of media can be deployed to create visualisation output: in this case, VR. Since the output is a visual one, the viewer can use this medium for a visual inspection of the content displayed, for example, any types of pole and overhang collisions or lighting non-uniformities. If the framework is documented, this presented workflow can be used for future studies, scaled, and transferred to other contexts.

(3) Custom code allows the expansion of state-of-the-art game-engine technology to accommodate dynamic incremental changes in luminaire types and their geometries. Custom code allows for a dynamic response to user behaviour in the form of additional lighting attributes such as motion sensors. Since all of these parameters and attributes can be changed dynamically in the form of a custom graphical user interface (GUI), the tool is particularly useful for iterative design processes and scenario planning.

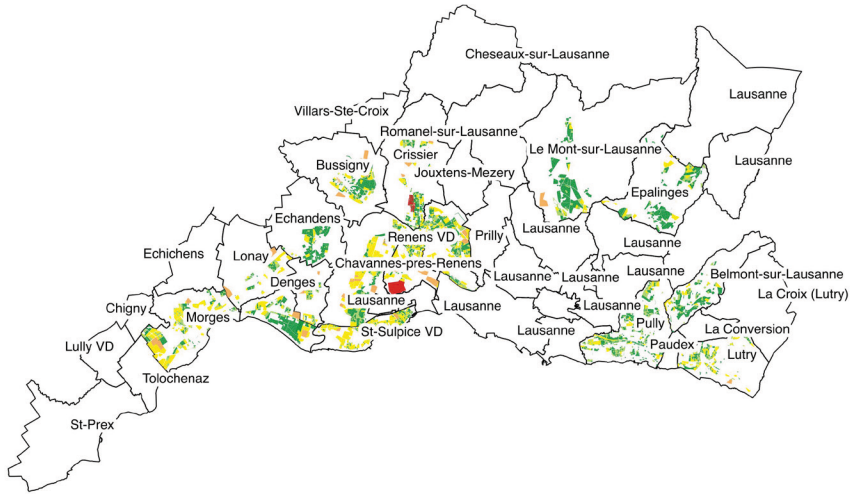
Figure 70: Top: All communes, lots, and selected zones in the whole agglomeration of Lausanne (data provided by Administration cantonale vaudoise (2017)). Each individual lot has to be superimposed on the 30 different communes each with nine different zones to identify the correct building regulation. Center: All 7,945 identified building parcels and their respective size of development in m² in residential and mixed use zones. Bottom: Filter of 256 reasonable and meaningful building parcels, their respective size of development in m², and development type (i) and (ii) in residential and mixed-use zones. The inset shows the location of the focus area in relation to Switzerland's cities.

Source: Michael Walczak (2020)



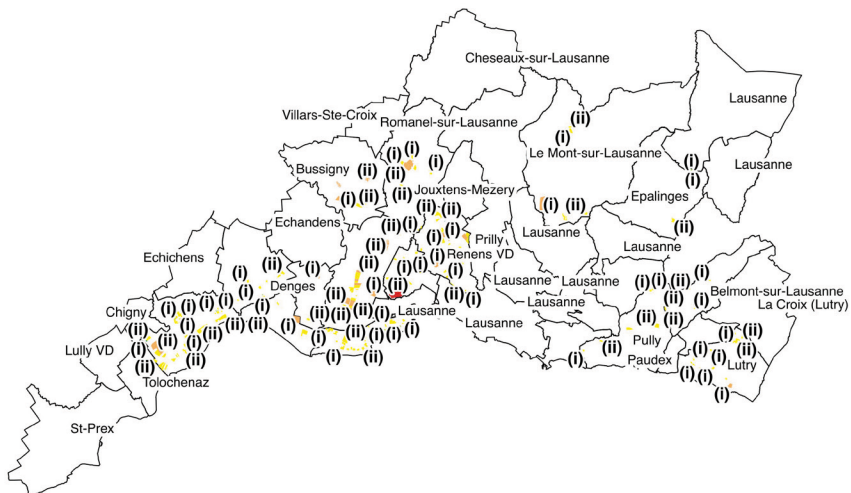
LEGEND

- | | | |
|---------------------------------|-------------------------------|-------------------|
| Zoning plan | Very low density housing zone | Industrial zone |
| Low density housing zone | Village zone | Intermediate zone |
| High density residential zone | Historic centre zone | Lots |
| Medium density residential zone | Commercial zone | Communes |



LEGEND

- | | | | |
|-----------------------|----------------|-------------------|----------|
| New Building Surfaces | 500 - 1000 | 10.000 - 100.000 | Communes |
| 1 - 500 | 1.000 - 10.000 | 100.000 - 250.000 | |



LEGEND

- | | | | |
|-----------------------|----------------|-------------------|----------|
| New Building Surfaces | 500 - 1000 | 10.000 - 100.000 | Communes |
| 1 - 500 | 1.000 - 10.000 | 100.000 - 250.000 | |

	Maximum building m² within building regulations	Current existing buildings in m²	Additional densification in m²
(i) Urban densification	536,162	155,128	381,034
(ii) Brownfield redevelopment	933,114	0	933,114
Total	1,469,276	155,128	1,314,148

Table 05: Summary of processed building lots according to current building regulations in the agglomeration of Lausanne. Results compared with the actual building volume in order to identify the additional densification potential in residential and mixed use zones.
Source: Michael Walczak (2020)

	Maximum building surface area within building regulations in m²	Current existing buildings in m²	Additional densification in m²	Densification coefficient
Morges	154,847	17,885	136,962	0.12
Pully	31,596	4,421	27,175	0.14

Table 06: Comparison between the maximum building volume under the current building regulations and the current state of buildings for the Swiss municipalities of Morges and Pully in residential and mixed use zones.
Source: Michael Walczak (2020)



Figure 71: Further qualitative visualisation of different building regulations in varying contexts and municipalities in the agglomeration of Lausanne. Green roofs represent the reassessed buildings. Buildings with red roofs symbolise the existing building stock within the context.
Source: Michael Walczak (2020)

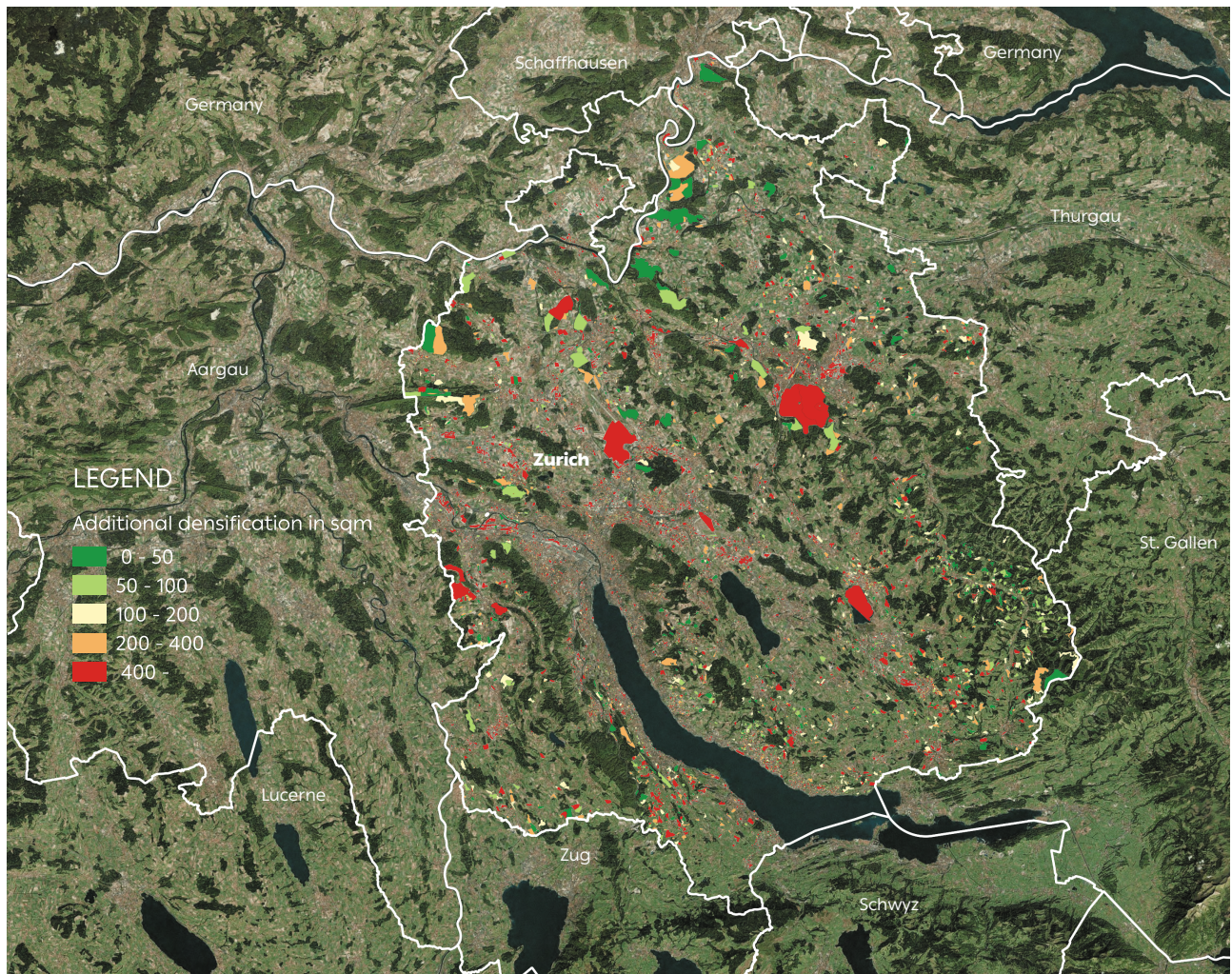


Figure 72: Transferability and scalability of the developed SPM method from Lausanne's agglomeration to the whole canton of Zurich. The map shows potential additional densification in sqm within the current regulatory framework of the canton of Zurich. The white line is showing the borderlines of the Swiss cantons and to Germany. The method was also applied successfully to the whole canton of St. Gallen. This figure is not part of the published journal paper ³². Source: Michael Walczak (2020)



Figure 73: "windRover" vehicle as the medium of communication and engagement with local authorities and universities within Sarajevo. Presenting the "windRover" to the Swiss ambassador in Sarajevo, the rector of the University of Sarajevo and the local team involved in the project.

Source: ETH Zurich, Chair of Architecture and Urban Design, Prof. Hubert Klumpner, University of Sarajevo (2019); <https://www.unsa.ba/en/novosti/cooperation-between-eth-zurich-and-university-sarajevo-urban-transformation-project>; accessed 18.12.2020

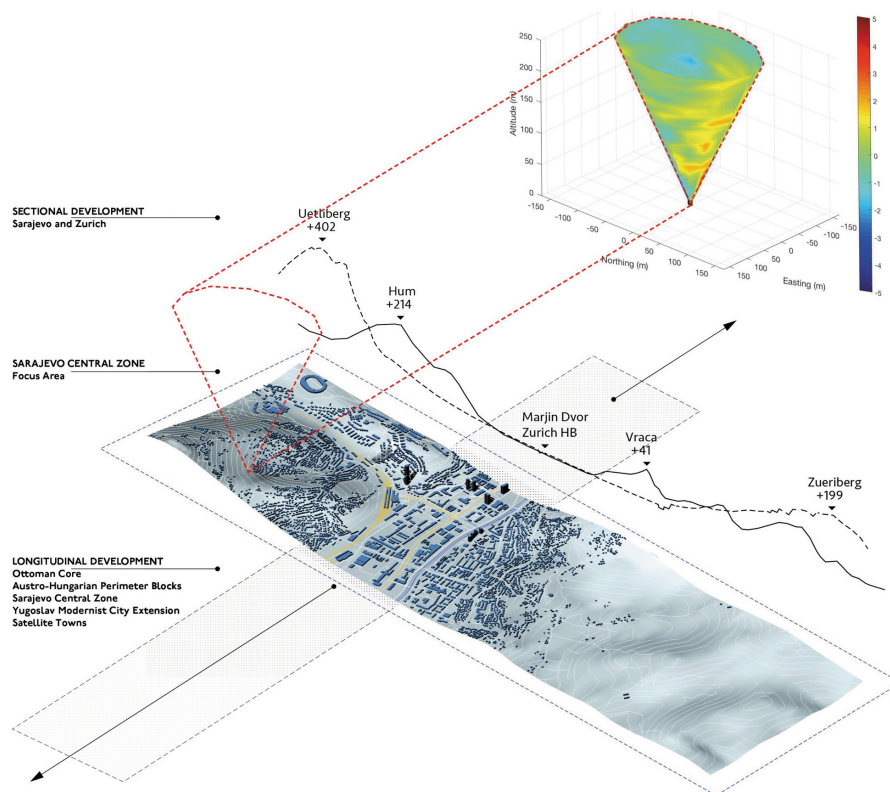


Figure 74: 3D graphic of the exemplary location of three dimensional LIDAR wind measurement within the City of Sarajevo boundaries, topographical height comparison with the City of Zurich and different zoning explanations.

Source: ETH Zurich, Chair of Architecture and Urban Design, Prof. Hubert Klumpner, Melanie Fessel and Michael Walczak (2019)



Figure 75: Digital projection on a physical model during the Cartagena Winterschool at ETH Zurich Chair of Architecture and Urban Design, Prof. Hubert Klumpner.
Source: Clearhos Papanicolaou (2018)

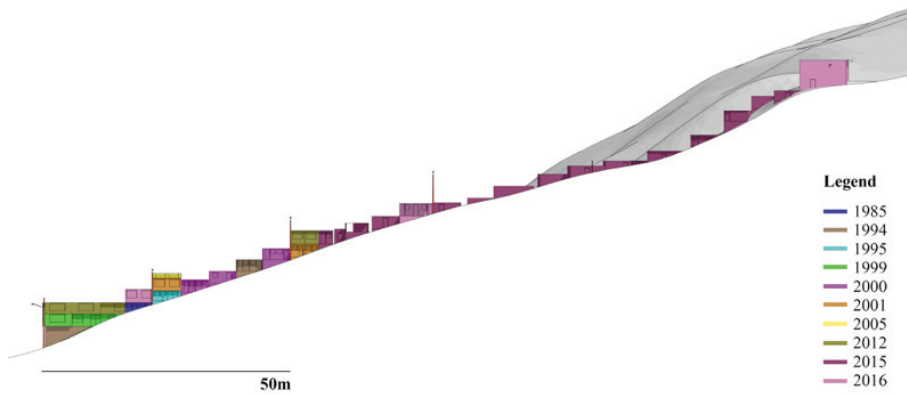


Figure 76: Section of the case-study street documented in 2019 showing the topography, buildings with their respective color-coded construction years, and the location of formal lighting. This planning document was produced via automated means using the Unreal Engine and the Rhinoceros3D framework.
Source: Michael Walczak (2019)

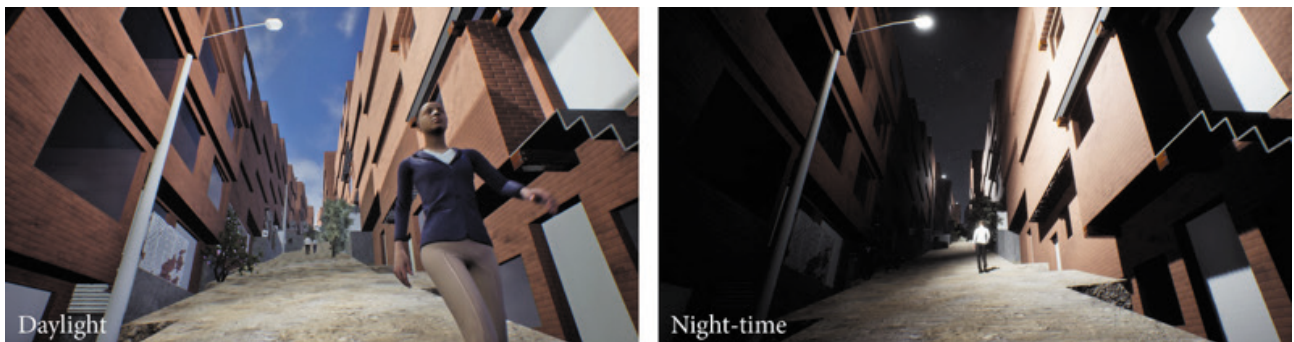


Figure 77: The Unreal Engine framework allows daylight simulation in comparison to the night-time lighting conditions.
Source: Michael Walczak (2020)



Figure 78, 79 and 80: Sample situations from the real-time VE simulation over time displaying the environment, the vertical building densification, and the footfall. The "2012" image, for example, clearly illustrates the delay of formal luminaire provision in the upper part of the settlement that had been already covered with informal dwellings in 2010.
Source: Michael Walczak (2020)



Current lighting policy



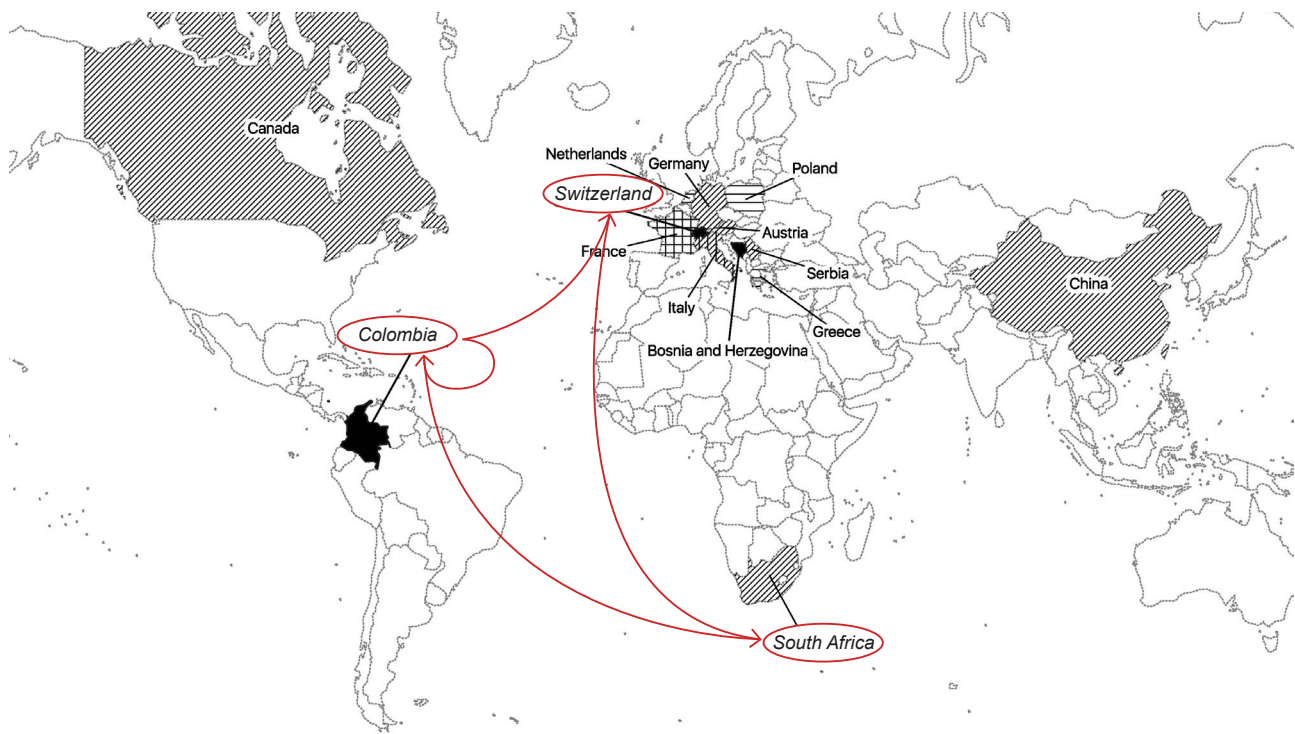
Alternative lighting policy phase 1



Alternative lighting policy phase 2

Figure 81, 82 and 83: Scenario-based decisionmaking visualisation for a multitude of different options, in this case the current lighting approach in the case-study street as a "seven-metre-wide street with four storeys scenario", versus the two-phase alternative lighting approach. All of the scenarios include temporal data such as densification and footfall. Visual inspection illustrates not only the lighting effect, but also enables detection of how the light column collides with the fourth storey (see figure on "current lighting policy").
Source: Michael Walczak (2020)

4.6. Chapter 6: Step 4, Measuring (iv)



To assess the impact of the developed technology and all its methodology on the citizen-centred design processes engagement metrics, we chose several techniques to measure the shifting baseline in human percept using *DIGITAL URBAN IMAGINARIES*:

Figure 84: Location and transferability matrix, see chapter 3.2.
Source: Michael Walczak (2021)

- (4.6.1.) a citizen engagements platform; and
- (4.6.2.) the ratio in perception change of subjects for the case of Bogotá and Cape Town.

4.6.1. MEDIATING: CITIZEN MAPPING

One of the methods used in this dissertation is exchange and engagement with a multitude of different actors and citizens from different fields and professions, including engineering, social science, design, architecture, urban planning, and private and public institutions (see figure 84). We embedded this research within four various institutions including the Department for Special Topics in Architecture Design at the University of Applied Arts Vienna (STARCH), the Urban Research Incubator (URI) at the Institute of Science, Technology and Policy at the Swiss Federal Institute of Technology in Zurich (ISTP), the Chair for Architecture and Urban Design at the Swiss Federal Institute of Technology in Zurich (LUS), and the Laboratory for Energy Conversion at the Swiss Federal Institute of Technology in Zurich (LEC).

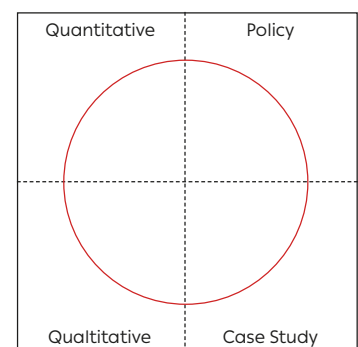


Figure 85: Stakeholder matrix, see chapter 3.3.
Source: Michael Walczak (2021)

Each of the four different institutions mentioned has a particular role, such as STARCH for the leading role in this doctoral research as well as the qualitative part of art and media theory, LEC for the quantitative role of technology development, LUS for the provision of case studies and their locations, and ISTP for the role of a stakeholder network from governmental bodies and their part in policymaking. Although some positions are repeated in the other affiliations, each has a particular focus as discussed. One way to cooperate and communicate between such a diverse group of actors was the medium of the digital model and visualisations (see figure 75). Visualisations "help to address collaborations across different actors" (Sirianni and Girourd 2012) (see figure 86) and also help to better understand interests, opinions, aspirations and to frame policy issues by visualising different scenarios, trying ideas, and easily changing them (von Heland et al., 2016).

All of the actors related to this dissertation (see figure 85 and 87), as well as survey participants, are spread, conflated, and interlinked throughout those four institutions, or hold external or affiliated positions. The main driver behind this extensive stakeholder engagement is, "[...] Nietzsche's account of how knowledge emerges by moving something from the domain of the unknown or stranger into that of the known or familiar (Bottazzi 2020)". Such "moving" – in Nietzsche's terms – from one domain to another requires the role of the mediator. The mediator takes on the part of a translator since he or she understands the different glossaries and the "professional" languages of the various actors. The language concept also includes the way in which the appropriate medium for communicating between actors is selected. The medium can be either a visual or non-visual form of communication such as qualitative images, film, and graphics or quantitative texts, numbers, and plots. Scenarios with a set of boundary conditions and parameters that can be tweaked and manipulated by "both" parties can be compelling and goal-oriented. We can perform a multitude of such scenarios iteratively and assess and evaluate their performance. New knowledge is created and emerges at this "in-between" position of the mediator – a sort of hybrid of both worlds, which is also represented by this dissertation. The mediator has a potent "tool" in their hands since they can change the perception of "both" sides and facilitate decisionmaking processes based on simulated evidence or knowledge. As a result, this improves the cost and time efficiency of the process.

The "digital model" methodology presented within this dissertation allowed us to effectively communicate with 73 individuals from six broad disciplines embedded within four institutions on a daily basis as well as more than 30 policy stakeholders and more than 300 survey and interview participants from three different continents. Depending on the content and location, the group of stakeholders was dynamically changing.



Figure 86: The core team with the Swiss ambassador in Colombia during the exhibition opening ceremony. The exhibition took place for 44 days from 29.08. until 11.10.2019. It was part of the show "ciudad isla" and located in the Museum of Architecture "Leopoldo Rother" at the National University of Colombia Campus in Bogotá. Source: National University of Colombia (2019)

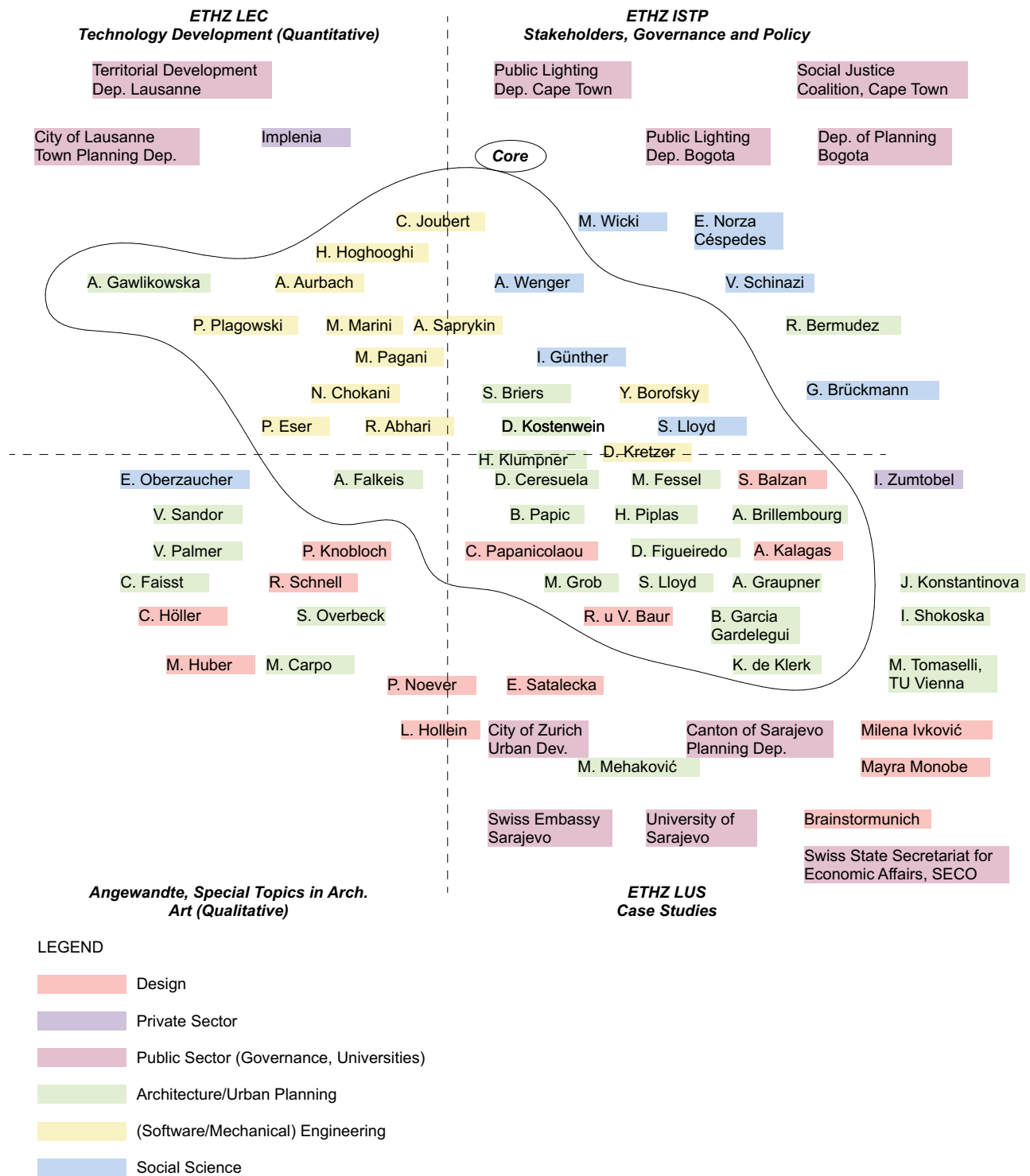


Figure 87: The graphic is showing all close/relevant actors and stakeholders during the dissertation. We grouped the stakeholders within the four involved institutions and colour coded between various disciplines. The central core is further distinguished.
Source: Michael Walczak (2020)

4.6.2. SHIFTING BASELINE

In the following chapters, we measure in the location of Cape Town and Bogotá if *DIGITAL URBAN IMAGINARIES* impact the opinion made by citizens and how it affects their current baseline. We will apply our methodology of “immersion elicitation”. This technique will stimulate discussion or reflection in interviews and elicit responses from study participants using *DIGITAL URBAN IMAGINARIES* with the medium of VR.

4.6.2.1. CAPE TOWN: GENERAL AUDIENCE³⁴

At Cape Town location (see figure 88), we established whether it is possible to elicit lighting preferences from the local population in the informal settlement using the technique of *DIGITAL URBAN IMAGINARIES* advanced in the dissertation. We undertook this research in collaboration with Stephanie Briers. The study took place in Cape Town, South Africa, in March 2019. A total of 90 participants from the second largest township in South Africa, Khayelitsha in Cape Town,³⁵ participated in this study. The study location was the office of the non-governmental organisation “Social Justice Coalition” (SJC) located in Khayelitsha. SJC assisted in the recruitment of all of the participants since local trust by the community leaders of each neighbourhood was required. SJC selected participants spread well across all different areas within Khayelitsha. The study demographics consisted of 36 percent male and 64 percent female participants subdivided into age groups of 18 to 24 (41 percent), 25 to 34 (18 percent), 35 to 44 (27 percent), 45 to 54 (7 percent) and 55 to 64 (7 percent).

Half of the participants completed the image-based survey; and the other half, the VR-based survey. None of the participants participated in both studies. The process conducted for the study was similar for both groups of participants – image-based and VR-based. To start with, a training workshop (see figure 89) introduced the participants to the research topic and the necessary technical skills. Second, the survey phase was performed as a baseline on a tablet interface, as explained below. The third step saw the participants complete the actual image or VR choice experiment, as described below. Compared to the image-based survey, the VR included six test scenes, meaning three options, to introduce each participant to the features of VR. This scene required the participant to identify when a cube geometry was visible so as not to prime the participants with results from the test scenes. Last, the participants redid the tablet survey with some additional questions to observe if any perception change was visible.

The first – pre-experiment – tablet survey determined the participant’s current perception, behaviour, and attitudes towards the night-time situation and corresponding lighting. The second questionnaire asked the participants if they would prefer high mast lights, pole-mounted lights, or street lights. Towards the end of the second questionnaire, we asked participants about the drivers for their decisionmaking regarding safety, night-time activities, or vandalism. In between the two surveys, we asked the participants to proceed with the choice

³⁴ Partly presented during the “Interuniversitarian PhD Colloquium” at Kunstuniversität Linz on the 18.10.2019; see chapter 8.7.

³⁵ <http://www.sikhulasonke.org.za/about-khayelitsha.html>; accessed 01.04.2019



Figure 88: Site selection identification and emphasis through the engagement of the Empower Shack project in Khayelitsha, Cape Town. Source: Urban-Think Tank, Alfredo Brillembourg & Hubert Klumpner, <http://u-tt.com/project/empower-shack/>; accessed 13.02.2021



Figure 89: Introduction of the survey to participants at the venue in Khayelitsha, Cape Town. Source: Michael Walczak (2019)

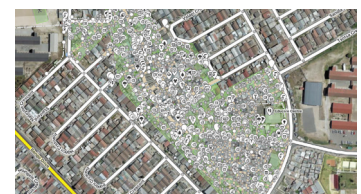


Figure 90: Opensource data from OpenStreetMap for Khayelitsha, Cape Town. Source: [openstreetmap.org](https://www.openstreetmap.org/); accessed 15.12.2020



Figure 91: Graphical User Interface (GUI) for Khayelitsha, Cape Town.
Source: Michael Walczak (2019)



Figure 92: Survey venue in Khayelitsha, Cape Town with VR survey participants experiencing the GUI.
Source: Michael Walczak (2019)

experiment, requiring them to walk virtually along the informal settlement, either with VR or via an image consisting of the same path redesigned with different types of light infrastructure as explained in the following chapter.

In the second survey directly following the VR/image-based experience, we used a post-experiment tablet survey to ask respondents the same questions as at the beginning to understand whether any perception change had occurred or to deduce what they retained from the experience. Additional items were asked, such as how the usage of VR added to their experience of making decisions regarding lighting or if any learning process regarding lighting had taken place.

The whole choice experiment consisted of 72 images/VR clips, resulting in 36 choices (see figure 93) to be made by each participant: three different light types (high mast light, pole-mounted light, and wall-mounted light) each consisting of three different light temperatures (2000 kelvin warm light, 4000 kelvin neutral light, and 6000 kelvin cold light) resulted in nine different light scenarios.

Game engine technology was used for this research design to visualise each lighting condition as accurately as possible. In this particular case, we used the Unreal Engine (Epic Games 2020) because of its capacities for much more accurate visualisation of light and shadows, including high-end graphics, as compared to other game engines like "Unity".³⁶ We had to generate many light solutions and scenarios for both the VR and the image-based scenario. Game engines were predestined to be used because of their real-time computation of visualisations and GPU technology use. We extended the default game engine capabilities to allow for the import of geo-referenced data (see figure 90) so we could accurately construct the informal settlement environment in 3D with the precise location of the existing high-mast lights (see figure 91). We defined the location of the wall-mounted lights by the location of the entrance door to each housing unit. Policy and regulations from the Public Lighting Department of the City of Cape Town were applied to the pole-mounted light solution.

Photometric data (".ies" files) needed to be collected and imported into the game engine environment to visualise each different light type accurately. Photometric data includes the exact spatial light distribution and light intensity of the specific light. As Maheshwari et al. (2016) describe, VR helps to address in particular the missing eye-level perspective in traditional 3D models and design drawings such as plans and sections, which produces a better understanding and communication for the subjects/participants.

The image survey was set up on nine tablets (see figure 94 and 95). The subjects observed two images simultaneously and had to choose which one they would prefer by clicking on the image. Each participant received a random order of images to level out factors such as tiredness throughout the survey. None of the scenarios shown was further described or labelled with the current lighting situation so as not to bias the observer/subject. The same procedure was applied to the VR-based survey.

The physical set up of the VR experiment (see figure 92 and 98) involved two VR trainers, two head-mounted units (Oculus Rift), two PCs, and two display

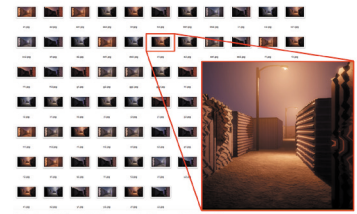


Figure 93: Selection of different lighting scenarios.
Source: Michael Walczak (2019)

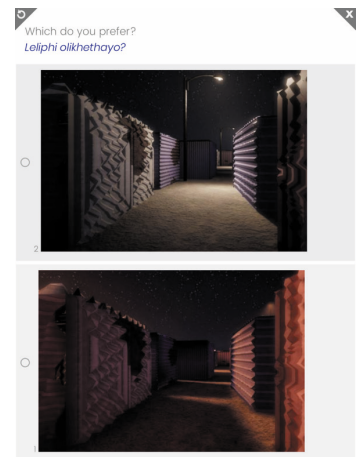


Figure 94: Exemplarily tablet page of the image survey comparing two images.
Source: Michael Walczak (2019)

³⁶ <https://sundaysundae.co/unity-vs-unreal/>; accessed 03.04.2019

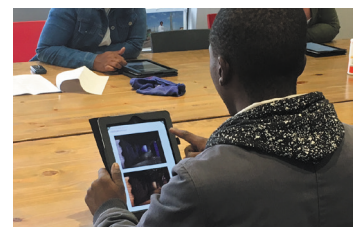


Figure 95: Survey venue in Khayelitsha, Cape Town with participant experiencing the image survey.
Source: Michael Walczak (2019)

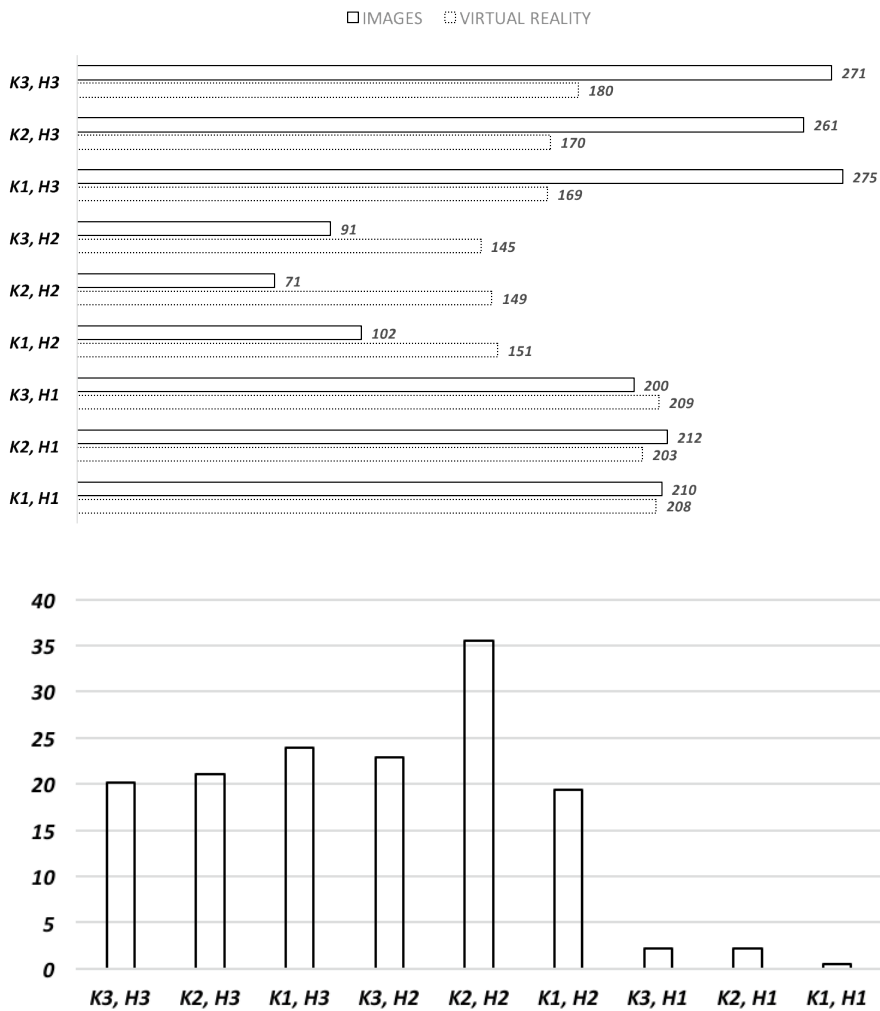


Figure 96: Chart showing the comparison between choices made in the Image experiment vs the VR experiment, in absolute numbers.

Figure 97: Chart showing the difference in percent between choices made in the Image experiment vs the VR experiment.

K3, H3 = 6000 Kelvin, Cool light, Pole mounted lights.
 K2, H3 = 4000 Kelvin, Neutral light, Pole mounted lights.
 K1, H3 = 2000 Kelvin, Warm light, Pole mounted lights.

K3, H2 = 6000 Kelvin, Cool light, High mast lights.
 K2, H2 = 4000 Kelvin, Neutral light, High mast lights.
 K1, H2 = 2000 Kelvin, Warm light, High mast lights.

K3, H1 = 6000 Kelvin, Cool light, Wall-mounted lights.
 K2, H1 = 4000 Kelvin, Neutral light, Wall-mounted lights.
 K1, H1 = 2000 Kelvin, Warm light, Wall-mounted lights.

Source: Michael Walczak (2019)

monitors for viewing the videos as we guided the participants through the township (see figure 99). We rented the two stationary PCs in Cape Town, which included a powerful enough GPU to run VR. We installed the necessary visualisation framework that we developed in the frame of the dissertation. The VR experience was set up as a 360-degree video with no steering, walking, or movement control. Each clip had a length of 18 seconds along a path of 15 meters, which takes into account the three seconds before the "walk" starts; the actual route is 15 seconds long based on a natural walking movement of one metre per second. 18 seconds in 72 clips adds up to a total of 21.6 minutes, without adding the time needed for each participant to make a decision. A similar approach to survey design in terms of the set of choices and the sample size was used by Valencia-Romero et al. (2017), which served as a reference for this study, as not many VR experiments have been performed or published, especially not in informal urban conditions. The small sample size results from the difficulty in obtaining subjects from the context of informal settlements and/or townships.

Nevertheless, Patterson et al. (2016) describe the increased effectiveness, significance, and better-focused attention from respondents using the VR technology, which justifies the evaluation of such technology in informal urban conditions. VR has made its way into the research-method toolbox (Kuliga et al. 2015), albeit not in informal urban situations and with participants from township neighbourhoods. This research gap opened up a huge opportunity to experiment with research of this type. At the same time, it is also a step towards understanding whether VR is a compelling means of communication that impacts public perception.

Images result in much more extreme preferences than with VR, and therefore preferences in the image survey do not match the preferences in VR survey.

Since images focus on one specific angle and viewpoint that we force the researcher to choose, it is not inevitable that the aspects that influenced the survey participants to make certain decisions can be identified. As a researcher, it is not easy to choose a meaningful viewpoint as compared to VR, where many conditions can be shown and observed. This is also apparent from the results of this study, where images offer much more extreme preferences than with VR. As an example, in the images, we showed the pole-mounted light solution that depicted an appropriate light solution in this specific image frame, but looking at it in a spatial setting with VR revealed that the luminaire did not light some areas appropriately. The VR participants thus preferred the wall-mounted solution, which has a much more homogenous light distribution.

When comparing the results from the image-based survey to the VR-based study, we can observe a significant difference in the decision made by the participants, especially with the high-mast and pole-mounted lights (see figure 96 and 97). We can see three trends: the preference for the wall-mounted light solution remains the same; the high-mast receives a positive upward trend in VR, whereas the pole-mounted light was rated more negatively using VR. This phenomenon could be due to the lighting uniformity of the wall-mounted



Figure 98: Survey venue in Khayelitsha, Cape Town with VR survey participants.
Source: Michael Walczak (2019)



Figure 99: Pole mounted light with 2000K light temperature on top and high mast light with 4000K light temperature at the bottom.
Source: Michael Walczak (2019)

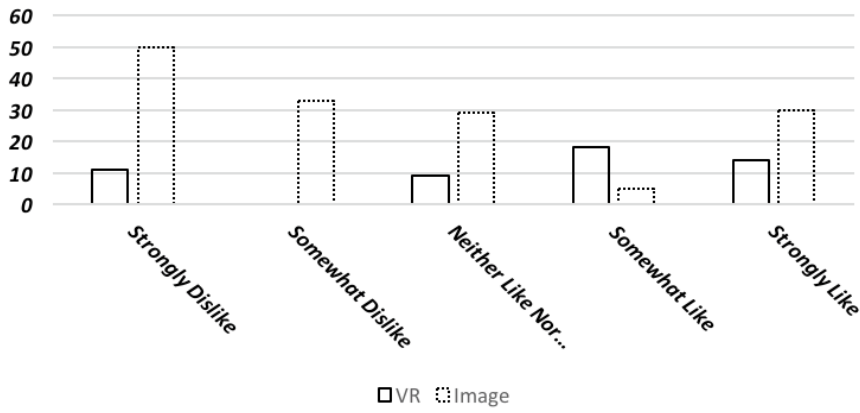


Figure 100: Opinion on pole-mounted lighting. Chart showing the difference in an opinion made before the VR or image choice experiment and directly afterwards, in percent, resulting from preference asked through survey questions.
Source: Michael Walczak (2019)

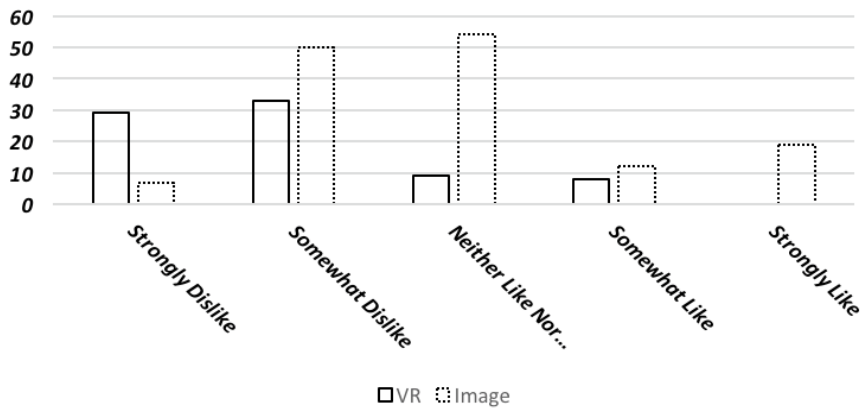


Figure 101: Opinion on high-mast lighting. Chart showing the difference in an opinion made before the VR or image choice experiment and directly afterwards, in percent, resulting from preference asked through survey questions.
Source: Michael Walczak (2019)

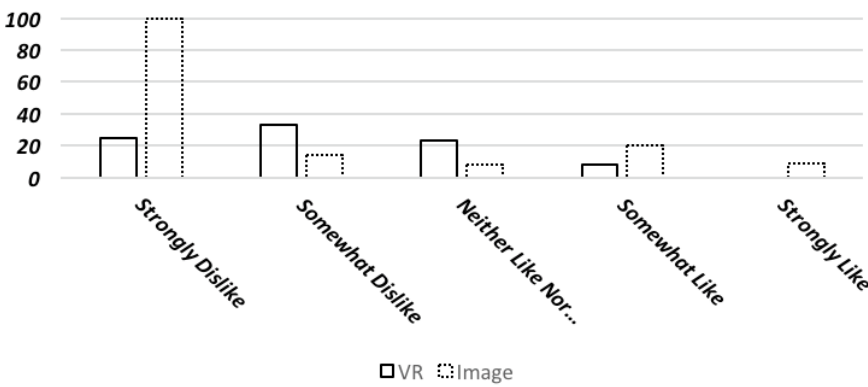


Figure 102: Opinion on wall-mounted lighting. Chart showing the difference in an opinion made before the VR or image choice experiment and directly afterwards, in percent, resulting from preference asked through survey questions.
Source: Michael Walczak (2019)

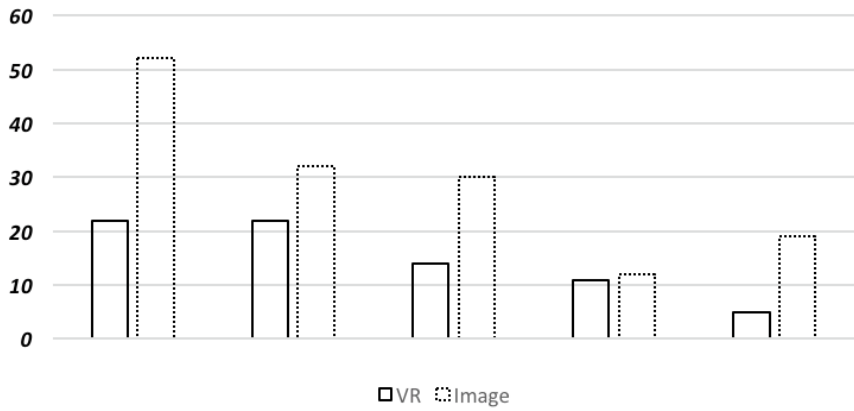


Figure 103: Average opinion on high-mast, wall- and pole-mounted lighting. Chart showing the difference in an opinion made before the VR or image choice experiment and directly afterwards, in percent, resulting from preference asked through survey questions. Source: Michael Walczak (2019)

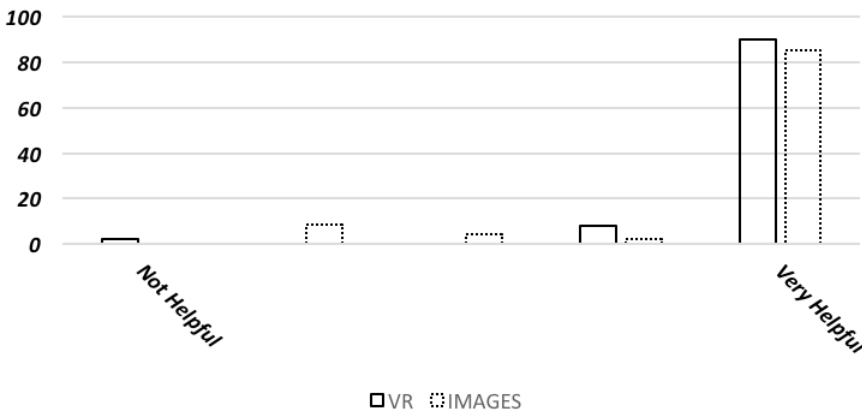


Figure 104: Participants evaluation of helpfulness and improvement of understanding using the DIGITAL URBAN IMAGINARY methodology, in percent. Source: Michael Walczak (2019)

solution, which was visible in both the image and VR based survey. The other solutions showed a significant visual difference, especially while looking into narrow side streets, which the images could not provide since they only point in one predefined direction.

Images result in a more significant perception change than with VR.

We can assume that a similar argumentation applies to the more significant perception change in images than in VR as we saw with the extreme preferences above. The VR experience visualises a much more natural and spatial experience and therefore matches participants' initial perception and understanding of the lighting. VR resulted in up to a 30 percent perception change compared to the subject's initial opinion. Light visualisation through one static image can result in perception distortion on the part of the participants. Images

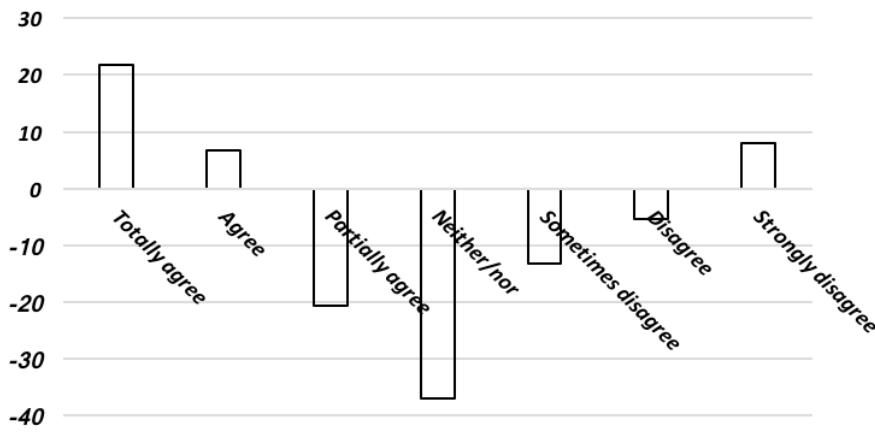


Figure 105: Evaluation of "BOGOTÁ: GENERAL AUDIENCE" study (see chapter 4.6.2.2.). The second category of the survey questions was focusing on the opinion of particular statements and if participants would "totally agree", "agree", "partially agree", "neither/nor", "sometimes disagree", "disagree" or "strongly disagree". The figure is showing the percentual change in responses after seeing VR compared to just before seeing VR.
Source: Michael Walczak (2020)

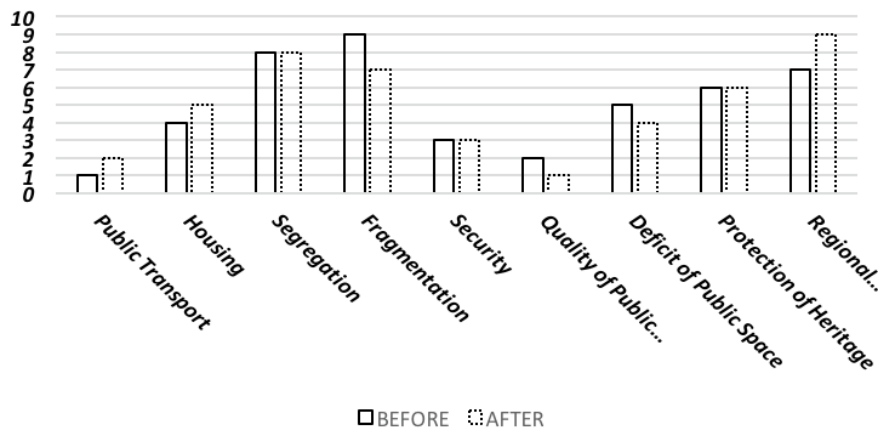


Figure 106: Evaluation of "BOGOTÁ: GENERAL AUDIENCE" study (see chapter 4.6.2.2.). The third category of the survey questions was focusing on currently relevant topics within the context of Bogotá, namely: public transport, housing, spatial segregation, urban fragmentation, security in public space, quality of public space, the deficit of public space, protection of heritage and regional development of the Bogotá metropolitan area. We asked the participant before and after the VR exposure to rank order (on a scale between 1 to 10) these topics according to their importance and relevance for the urban development of Bogotá in the next ten years.
Source: Michael Walczak (2020)

assume one specific light scenario – which can be either good or bad – but the viewer extrapolates that this particular view applies in any situation, which is not the case. The perception change for images resulted in up to 50 percent compared to the subject's previous perception (in one specific case even up to 100 percent, which is not entirely justifiable) (see figure 101 - 103). As with the VR, the visualisation dome (Gawlikowska et al. 2018) was evaluated in terms of the perception change of the individual subjects – in this case, the acceptance of offshore wind parks. Compared to VR, the visualisation dome had a very insignificant impact.



Figure 107: Real-time building geometries including pedestrian simulation, lighting and topography for Bogotá, Caracoli.
Source: Michael Walczak (2020)



Figure 108: *DIGITAL URBAN IMAGINARIES* as the initiator for a "citizen-centred design processes" exchange platform. Here, the virtual reality experience of the whole City of Bogotá, made accessible as part of the exhibition 'ciudad isla' and located in the Museum of Architecture 'Leopoldo Rother' at the National University of Colombia Campus in Bogotá with more than 200 citizens participating.
Source: Michael Walczak (2019)

In the comparison of VR and the image-based experience, both displayed a similar increase in understanding during the decisionmaking process and an increase in the learning factor.

For the participants, the exposure to either VR or images strongly supported them in making decisions in both cases, with up to 80 percents of participants (see figure 104). Both resulted in substantially more confidence and trust in the ultimate decision made. A similar trend is visible in the participants' self-evaluation of the learning factor.

Qualitative observations during VR and image experience

Observing 90 participants during their image or VR experience did show that images are not evoking any oral emotion or feelings during the decisionmaking process. In contrast, VR makes people comment and speak about their opinions and emotions. Participants were not asked to think aloud (Maheshwari et al. 2016), to instead focus on the scene and their decisions, but VR evoked naturally a "think aloud" behaviour. If any think-aloud behaviour occurred, it was noted and considered as a qualitative observation. Some examples of longer comments were: "I feel very safe now", "The light is very bright, I like it", "The light is very easy to reach and people would vandalise it", "I am in an informal settlement" and "I feel not so good now, I feel unsafe". This more significant focus is also visible in the much faster decisionmaking process during the image survey than during the VR survey. Nevertheless, nine females and four male VR participants experienced motion sickness and had to stop their experience and continue watching the study on the screen. During the image experience, there was no experience of any motion sickness or similar issues.

4.6.2.2. BOGOTÁ: GENERAL AUDIENCE

To evaluate the *DIGITAL URBAN IMAGINARIES* communication technique advanced in this this dissertation (see chapter 4.1.), which is informed by the method of collection and processing (see chapter 3.3.), the method of "immersion elicitation" was used along with quantitative survey techniques to measure percept change. We conducted this research in collaboration with David Kostenwein. The experiment took place during 44 days from August 29 to October 11, 2019. It was part of the "ciudad isla" exhibition and located in the "Leopoldo Rother" Museum of Architecture at the National University of Colombia Campus in Bogotá (see figure 108). A total of 203 participants took part in this study. The study demographics consisted of 62 percent male, 35 percent female and 3 percent other participants subdivided into age groups of under 18 (2 percent), 18 to 34 (87 percent), 35 to 54 (7 percent), and 55 to 84 (4 percent). 58 percent of the participants were students, 11 percent without occupation, 11 percent others, 10 percent private industry, 8 percent educational entities, and 2 percent governmental bodies.

Each participant experienced the interactive visualisation through virtual reality in the form of the Oculus Rift S Head-Mounted Display (HMD) (see figure 111). The

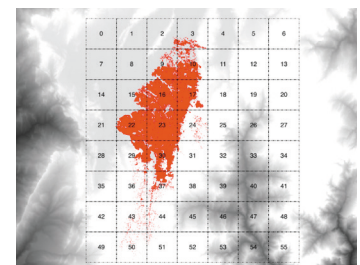


Figure 109: The data structure for the VR experience in Bogotá, including buildings (red) and topography (white to grey).
Source: Michael Walczak (2019)



Figure 110: Different scenarios of gated communities projections in Bogotá experienced in VR.
Source: Michael Walczak (2019)

experiment set included a screen to mirror the content of the user exposed to virtual reality. The participants experienced the visualisation through an open-world, in this case, the whole City of Bogotá (see figure 109). The user navigated (moved forwards, backwards, and sideways) using the Oculus Joysticks (Oculus Touch). Pitch, jaw, and roll are responsive to the head movement of the HMD. To be able to reach any place within the City of Bogotá within a reasonable amount of time, we introduced a "flying" function. Flying the user was much faster compared to the "eye-level" walking perspective mode. As long as the flying mode is activated, essential landmarks in the form of pins and text are displayed for orientation. When the participant reached their desired destination, we introduced the "landing" function, and the participant could explore the built environment from an eye-level perspective. Within this "eye-level" perspective, the participant could choose between multiple scenarios. We based the strategies on research around gated communities since Bogotá's share of such typology is about 40 percent of its city fabric (see figure 110). Kostenwein (2021) identified four central gated community typologies which we used for this case in the form of architectural form and shape. We manipulated the different shapes of each typology to fit different lot geometries. The participant could toggle through four scenarios by pressing a dedicated Oculus Controller button, these being 40 percent of the share of gated communities within the fabric of Bogotá (approximately the current state), 60 percent, 80 percent and 100 percent (the last three scenarios extrapolate the past development speed). The distribution of the gated communities in the extrapolated scenarios is generated randomly by custom code. The virtual "cockpit" displays the respective share of gated communities we expose the user to in the form of text.

We trained four research assistants (see figure 112) to maintain the experiment setting, introduce and assist the participants, and conduct the interviews. Each participant was required to undergo the same procedure. Each participant had to participate in a survey before and right after the VR experience. The survey questions were in Spanish. The exposure was not limited to the immersive experience itself since a qualitative interview was performed once the participant decided to stop the experience and concluded the survey.

The survey included three categories of questions. The first focused on more general and broad questions such as age, gender, place of habitation, socio-economic status, place of work as well as more specific questions such as:

- (1) Have you ever used virtual reality (104 answered with "yes" and 98 answered with "no")?
- (2) Have you ever used interactive virtual reality (where you can influence the virtual environment) (46 answered with "yes" and 54 answered with "no")?
- (3) Have you ever used a free-world virtual reality experience (where it is possible to go anywhere in the environment and not merely via a predefined route) (25 answered with "yes" and 79 answered with "no")?

The second category of the survey questions focused on the opinion of particular statements and if participants would "totally agree", "agree", "partially agree",



Figure 111: Exhibition visitors in Bogotá experience VR.
Source: Michael Walczak (2019)



Figure 112: Help assistants guiding in VR survey. Exhibition setting in collaboration with David Kostenwein from the Urban Research Incubator at the ETH Zurich Institute of Science, Technology and Policy. The exhibition took place during 44 days from 29.08. until the 11.10.2019. It was part of the show "ciudad isla" and located in the Museum of Architecture "Leopoldo Rother" at the National University of Colombia Campus in Bogotá.
Source: Michael Walczak (2019)

"neither/nor", "sometimes disagree", "disagree", or "strongly disagree". In order not to bias the participants, only questions about gated communities were asked and not about VR itself. We chose the topic of gated communities because currently 3,500 gated communities in Bogotá are home to close to 40 percent of Bogotá's population and have constituted the dominant form of (formal) housing provision since the year 2000. They shape the streets of the neighbourhoods with more than 1,360 km of fences and walls (or roughly the distance between Santiago de Chile and Montevideo, crossing the entire continent) (Kostenwein 2021). The survey statements were the following:

- (1) gated communities contribute to safe public spaces;
- (2) gated communities contribute to the segregation of the city;
- (3) gated communities help strengthen community ties;
- (4) gated communities contribute to urban fragmentation;
- (5) gated communities affect the use and quality of streets and public spaces in Bogotá;
- (6) gated communities change the way public space is controlled and managed;
- (7) gated communities contribute to the privatisation of public spaces;
- (8) gated communities present a great problem for the urban development of Bogotá;
- (9) Bogotá should seek to restrict the construction of gated communities through urban regulations and standards;
- (10) the market should decide how the city develops;
- (11) if residents want fences, they should be allowed to build them;
- (12) gated communities are at the moment the best solution to lack of security;
- (13) public spaces such as parks and platforms surrounded by fences and walls are uncomfortable;
- (14) public spaces are strongly influenced by the surrounding built environment;
- (15) public spaces should be open to all citizens;
- (16) public spaces should be free of informal business;
- (17) public areas around gated communities are safer; and
- (18) streets surrounded by gated communities are used differently than roads that are not.

As a result, it is particularly visible that participants have a much more pronounced opinion after being exposed to VR. Especially answers like "partially agree", "neither/nor" or "sometimes disagree" were reduced significantly by up to a factor of 3.5 (see figure 105). These answers create polarisation: an increase of the more pronounced responses such as "totally agree" or "strongly disagree". We might justify this polarisation phenomenon by clarifying the topic presented and due to the lack of understanding of how the research introduced the issue to date. We can make the following observations to the responses to such statements:

The participants have a more definitive decision after seeing VR. Approx. 36

percent fewer participants choose the “neither/nor” option. 20 percent fewer “partially agree” and 13 percent less “sometimes disagree” decisions, which results in a more substantial “totally agree” (22 percent), “agree” (7 percent), “disagree” (5 percent), and “strongly disagree” (8 percent) decisionmaking change compared to before viewing the VR.

The third category of the survey questions focused on currently relevant topics within the context of Bogotá, namely public transport, housing, spatial segregation, urban fragmentation, security in public space, quality of public space, the deficit of public space, protection of heritage, and regional development of the Bogotá metropolitan area. We asked the participants to rank these topics in order of their importance and relevance for the urban development of Bogotá over the next ten years. By looking at the evaluation of the response, we can observe that VR has a minor impact on the perception of prejudiced and biased opinion (see figure 106).

We can conclusively say that VR can impact perception, particularly while asking direct questions. If participants have to rank themes or topics, they tend to stick to their pre-existing point of view and are not influenced by external forces such as VR.

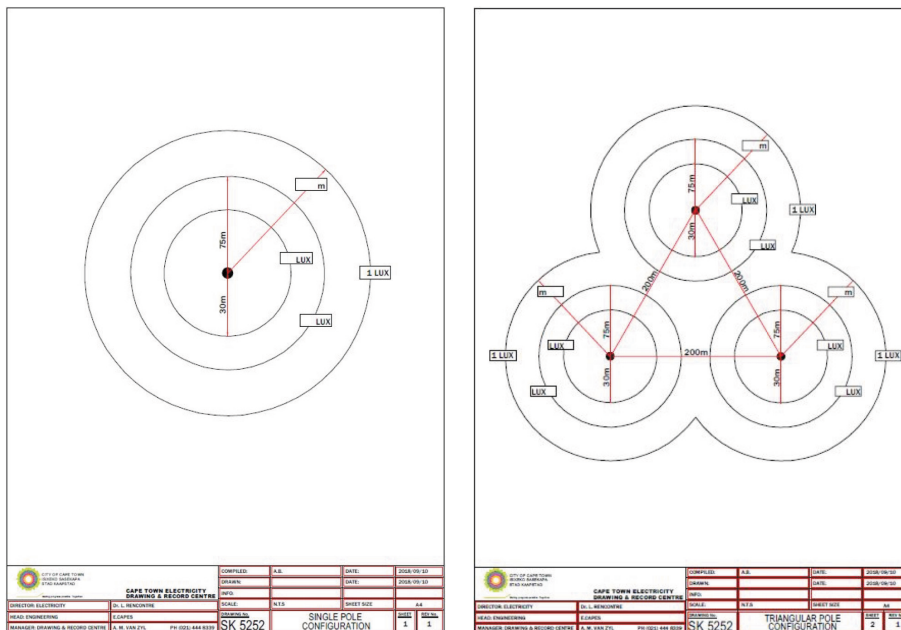


Figure 113 and 114: Current lighting policy for the City of Cape Town, in this case, for high-mast single- and triangular pole configuration. The policy is not considering any environmental context (buildings, topography or vegetation). Its initial situation is a plane surface. Source: City of Cape Town (2019)

4.7. Chapter 7: Policy Exploration

The seventh chapter is exploring the developed methodology's potential to be scaled and transferred to policymaking with specific use cases such as public lighting. We present a qualitative interview with local policymakers in Cape Town and in Bogotá, and a theoretical review of agendas such as the sustainable development goals. The “immersion elicitation” method is used to stimulating discussion or reflection in the following interviews of focus group situations.

4.7.1. CAPE TOWN: SPECIFIC AUDIENCE WITH POLICYMAKERS

We ran this workshop in collaboration with Stephanie Briers on March 19, 2019. Policymakers from the City of Cape Town's “Public Lighting Development” and “Transmission System Development” departments participated.

The workshop included a setup similar to that described in chapter 4.6.2.1. The policymakers were virtually exposed to the current night-time lighting conditions – consisting of high-mast lights – in the PJS settlement in Khayelitsha, Cape Town, as well as multiple alternative scenarios for night-time lighting solutions.

The main take-away messages were that the City of Cape Town currently plans all its lighting on a planar surface without considering the environment, including built structures and topography. This information is communicated either through a text format, table, or a two-dimensional plan. Among other technical specifications concerning lighting, current lighting policy merely recommends the maximum diameter that a lighting solution is required to illuminate in spatial terms (see figure 113 and 114). Any vegetative or built elements that may be in the way and block lighting penetration do not inform the evaluation and assessment of the choice of lighting solution.

After the exposure to the *DIGITAL URBAN IMAGINARY*, a qualitative interview revealed that policymakers were not aware of the shortcomings entailed by the current lighting solution and lighting policy (see figure 115). Given the inaccessibility of specific neighbourhoods and settlements, some of the actors interviewed had never actually visited these settlements, let alone at night. Policymakers said that the *DIGITAL URBAN IMAGINARIES* could help expose them to these contexts without having to physically be there – not only in terms of future anticipated scenarios but also for the current status quo.

4.7.2. BOGOTÁ: SPECIFIC AUDIENCE WITH POLICYMAKERS

We did this research in collaboration with David Michael Kretzer. On July 23, 2020, a qualitative and remote policy outreach workshop with interview was conducted with stakeholders from Bogotá. We used “Zoom” as the communication platform. The participants included David Kostenwein as a translator from German/English to Spanish and vice versa and the “Unidad Administrativa Especial De Servicios Públicos, Subdirección Servicios Funerarios y



Figure 115: Policymakers from the public lighting department in Cape Town experiencing VR.
Source: Michael Walczak (2019)

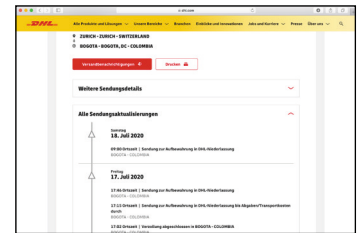


Figure 116: DHL tracking of VR goggles sent from Zurich to Bogotá for the policy event.
Source: Michael Walczak (2020)



Figure 117: Zoom online meeting with Colombian policymakers using low-tech VR goggles to immerse into different lighting scenarios.
Source: Michael Walczak (2020)

Alumbrado Público, Bogotá (UAESP)" and the "Secretaría Distrital de Planeación, Bogotá (SDP)" as policy stakeholders from Bogotá. Both institutes are working on the topic of public lighting in Bogotá with a particular focus on policymaking. The goal of this outreach was to identify if VR could be a useful tool for policy communication and lighting planning.

VR goggles were posted (see figure 116) in advance to each of the different mentioned stakeholders to allow a fully immersive VR experience. The VR goggles were simple, low-cost goggles into which a conventional smartphone could be inserted to enable us to display immersive content (see figure 117). This method allowed access to such technology and communication techniques even from a distance. Travel restrictions, as well as hygiene and social-distancing measures caused by the then ongoing COVID-19 pandemic, also amplified such a situation. The content displayed was provided through the "YouTube" platform (see figure 118), which allows for 360-degree VR content to be uploaded and displayed (see video 03).

In conclusion, VE/VR turned out to be a useful tool to communicate current and alternative policy scenarios to policymakers – mainly to communicate technical aspects to various authorities, laypeople, and the informal context to outsiders. VE/VR constitutes a suitable medium for policy documentation and post-meeting exploration.

The following VE/VR advantages were particularly appreciated: no technical knowledge required to understand the problem, close to reality, different perspectives possible, different scales ranging from an individual building to a whole city, fictitious scenario planning, more dynamic including moving people, vehicles or densification of buildings, and the continuation of lighting planning during COVID-19 restrictions. Besides the qualitative visualisation, the stakeholders from Bogotá recommended that it would still be necessary to complement the visualisation with quantitative evaluation in the form of figures or plots.

In the appendix (see chapter 8.1.) we can view a more in-depth conversation with extracts relevant to the topic of this doctoral thesis. We translated the interview from the original language of Spanish.

4.7.3. SUSTAINABLE DEVELOPMENT GOALS (SDGs)

In the following chapter, we correlate the impact of the developed methodology on governance and policy using the example of the Sustainable Development Goals (SDGs). The 17 goals for sustainable development with their 169 sub-goals (targets and indicators) are the core of the United Nations (UNO) Agenda 2030. The SDGs take into account the economic, social, and environmental dimensions of sustainable development in a balanced way and for the first time, combine poverty reduction and sustainable development in one agenda.

All UN member states are required to achieve all Sustainable Development Goals (SDGs) globally by 2030. This SDG compliance means that all countries

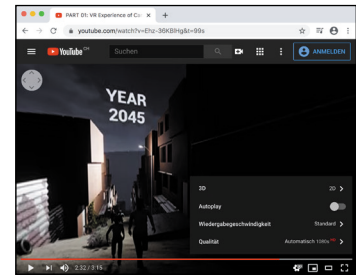


Figure 118: Access to different lighting scenarios through common YouTube interface.

Source: Michael Walczak (2020)



Video 03: 360° 3D VR experience of Caracoli, Bogotá by night with current lighting condition. Source: Michael Walczak; <https://www.youtube.com/watch?v=Ehz-36KBHhg>; accessed 15.12.2020

are being called upon equally to solve the world's pressing challenges together.

All seven research implementation chapters presented particularly speak to the SDG 11 on "Sustainable Cities and Communities, Make cities and human settlements inclusive, safe, resilient and sustainable;" within the context of UN-Habitats "New Urban Agenda" since the focus of this dissertation was on urban transformation processes. Below, a more detailed response to the sub-goals of SDG 11 can be found with a cross-reference to the particular steps:

The first, second, and third step speak to target 11.3, the goal of which is to "enhance inclusive and sustainable urbanisation and a capacity for participatory, integrated, and sustainable human settlement planning and management in all countries by 2030." Due to the developed visualisation framework and the "immersion elicitation" method, a broader audience can debate urban issues since we communicate urbanisation processes on a human eye-level perspective through *DIGITAL URBAN IMAGINARIES*.

The first step places particular emphasis on indicator 11.3.1 from target 11.3, to "tackle the ratio of land consumption rate in comparison to the population growth rate." Due to the developed building regulatory framework, we can now identify the reserves in building density, keeping qualitative aspects such as solar radiation or view, resulting in a *DIGITAL URBAN IMAGINARY* which is optimising the land consumption ratio on a country-wide scale.

The second step considers target 11.6, which focuses on the reduction of the "adverse per capita environmental impact of cities, including by paying particular attention to air quality, municipal and other waste management, by 2030," with specific emphasis on indicator 11.6.2: "to reduce annual mean levels of fine particulate matter (e.g. PM_{2.5} and PM₁₀) in cities (population-weighted)." Due to the measurement campaigns to understand the relationship between fine particulate matter, wind-corridors, building typologies and topography, we developed a processing, simulation, and communication procedure which can be applied elsewhere to improve air quality and environmental issues.

The third step addresses target 11.7, which seeks to "provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities through light and lighting, by 2030." Due to the developed lighting visualisation framework and its related exchange with local policymakers using *DIGITAL URBAN IMAGINARIES*, the novel insights and potential improvements intend to affect future policy implementations.

The survey results of the research (see chapter 4.6.) on using *DIGITAL URBAN IMAGINARIES* for the perception of gated communities in Bogotá emphasises the importance of target 11.7.1: "average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities, within the broader local population."

The first and second step has a particular emphasis on indicator 11.a.1 from target 11.a: "proportion of population living in cities that implement urban and regional development plans integrating population projections and resource needs, by the size of the city." The developed framework, which is simulating evidence in qualitative and quantitative building densities and appropriate climate response in cities, can inform current and future development plans.

The third step focuses on target 11.b to substantially "increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, and resilience to disasters, by 2020." The newly developed *DIGITAL URBAN IMAGINARY* framework can support the decision and policymaking processes since it displays current and future planning policies comprehensively.

The research also selectively contributes to SDG 3 on good health and well-being (for example, the ratio of human sun exposure in relation to building densities simulated in step 1); SDG 9 on industry, innovation and infrastructure (for example, visualisation of current and future traffic infrastructure in chapter 4.1.); SDG 10 on reduced inequalities (for example, access and provision of appropriate lighting solutions simulated in step 3 or study of lighting preferences from local communities in chapter 4.6.); and SDG 13 climate action (for example, reduction of air pollution through the simulation of wind flows in step 2).

5.

Discussion and Conclusion

We can still today partly confirm the spirit of Joseph Weizenbaum's (Weizenbaum et al. 1990) questions: "Can computer help?" and his answer: "Yes, but I still think that the main difficulties are (...) political and human. They can only be influenced to a small extent by technology and can only really be addressed with political will". This dissertation shows that technology, mainly *DIGITAL URBAN IMAGINARIES*, visualisation, and communication technology, can tremendously impact humans' perception, decision and policymaking. The developed methodology is intending to support decision- and policymaking with evidence-based *DIGITAL URBAN IMAGINARIES*. In the following subsequent chapters, the discussion and conclusion is split into multiple key recommendations, messages and findings to potentially support such translation into policy recommendations. Chapter 5.1. to 5.5. mainly conclude the main research question.

- (5.1.) *DIGITAL URBAN IMAGINARIES* as adequate communication medium in citizen-centred design processes;
- (5.2.) *DIGITAL URBAN IMAGINARIES* require a mediator;
- (5.3.) Technical characteristics of *DIGITAL URBAN IMAGINARIES*;
- (5.4.) Socio-technical recommendations for the *DIGITAL URBAN IMAGINARY* implementation;
- (5.5.) Policy recommendations for the citizen-centred design processes and *DIGITAL URBAN IMAGINARY* implementation;
- (5.6.) Synthesis of the "immersion elicitation" method;
- (5.7.) Synthesis of the collecting, processing and communicating method;
- (5.8.) Dangers, limitations and implication of results on further research; and
- (5.9.) Transferability of the research findings.

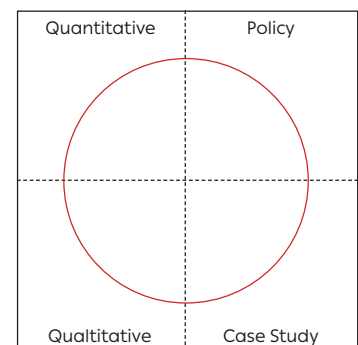


Figure 119: Stakeholder matrix, see chapter 3.3.
Source: Michael Walczak (2021)

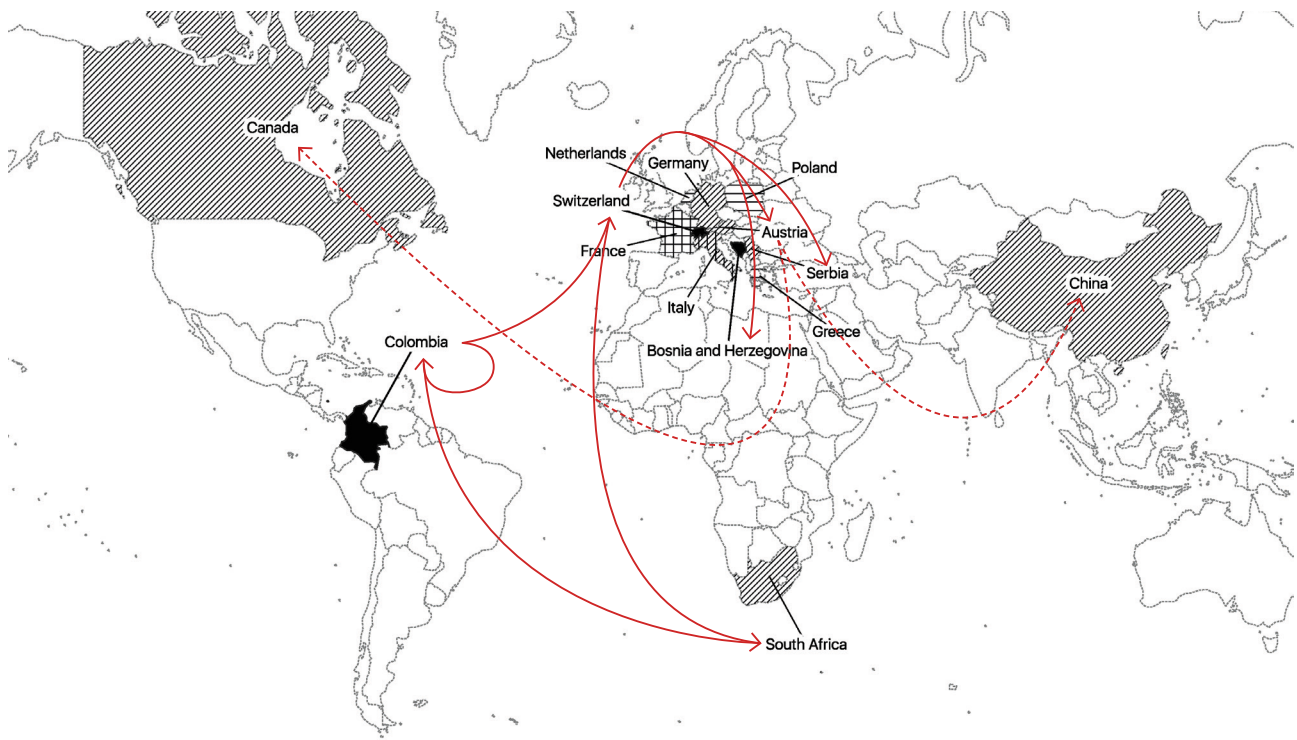


Figure 120: Location and transferability matrix, see chapter 3.2.
Source: Michael Walczak (2021)

5.1. DIGITAL URBAN IMAGINARIES AS ADEQUATE COMMUNICATION MEDIUM IN CITIZEN-CENTRED DESIGN PROCESSES

The power of *DIGITAL URBAN IMAGINARIES* and their impact on precepts is immense. They take as their starting point the possibility of being able to mediate between multiple stakeholders from various professional backgrounds (see figure 119) by using *DIGITAL URBAN IMAGINARIES* as a medium of communication. The *DIGITAL URBAN IMAGINARIES* significantly improved the exchange between engineers (software, mechanical, structural, lighting), architects, urban planners, social scientists, designers, lawyers, and an audience from governmental bodies. *DIGITAL URBAN IMAGINARIES* can “communicate” qualitative as well as quantitative characteristics (see figure 121 - 123 and 132) to different stakeholders in a manner understandable to the layperson. Moreover, we can present the *DIGITAL URBAN IMAGINARIES* over time. The temporal aspect allows the observer to understand various interrelations and projections over several decades, ultimately reaching a definition as a mental construct and theoretical framework to be able to tackle specific “unknown” tasks by providing an educational platform for exchange – a sort of standard glossary. Hito Steyerl (2020) is critical of such a universal language. Still, in the case of this dissertation, we instead speak of a multi-dimensional common language, with each word in the glossary acquiring a multitude of potential

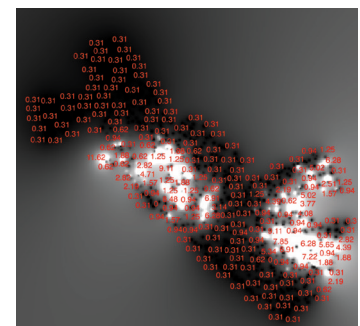


Figure 121: Quantitative data output from qualitative lighting visualisation.
Source: Michael Walczak (2019)

possible meanings. The knowledge of these different meanings is critical for successful use of the *DIGITAL URBAN IMAGINARIES*.

Another advantage of the *DIGITAL URBAN IMAGINARY* is its archival or protocol aspect. Up to now, we have seen such a trend in varying fields, such as in literature through the digitisation of literature and books or in art through the digitisation of paintings or 3D scanning of sculptures. At the same time, it is not only suitable for application in small-scale interventions but can also be used across a whole city scale. The case study location of Caracoli in Bogotá can serve here as an example. During the research period, the local government evicted the whole settlement because it is prone to suffer natural disasters since its residents built it on a landslide risk area (see figure 124 - 127). The *DIGITAL URBAN IMAGINARY* can thus also escape transience and deterioration, and become inevitable. The archive could not only include three dimensions but also show urban transformation processes over time. This would allow the transition from linearity to non-linearity by supplying the power of time, space, and location. The archive can be viewed, accessed, and manipulated from any location, and this would also improve communication in times of travel restrictions such as during pandemics. Even, certain inaccessible areas in reality of cities (roofs, steep topography, etc.) can be made virtually accessible.

Compared to commonly used visualisation techniques such as texts, images, videos etc., the method proposed by this dissertation has a much greater potential to impact perception within both a specific professional audience as well as a broader general one. We can observe those neutral and undecided observation standpoints can be either geared towards a positive or negative decision: a more pronounced, clear, and defined decision point from an unbiased perspective. Nevertheless, in some cases, almost no impact could be observed, mainly when using the method to rank certain aspects to elicit responses from the participants (see chapter 4.6.).

Currently, the prediction of our future, particularly when it comes to the realm of the digital (artificial intelligence, machine learning etc.), is often communicated in the art world in a dystopian way (e.g. Hito Steyerl: This is the future or Trevor Paglen: From "Apple" to "Anomaly"). Critical warnings and caution are the norms, with some exceptions (Pinar Yoldaş: Kitty AI, Artificial Intelligence for Governance) that also point towards the positive impacts of the "digital". Art and literature are mainly driving this critical view in that they often conceive of something absolute as "the" future. Instead, we should open our discourse to a multi-perspective view of the future. We should open the "fan" of possibilities of different scenarios. Such a "fan" would allow us to weigh up what changes in those different scenarios resulted in these diverse possibilities.³⁷ The vision of different future *DIGITAL URBAN IMAGINARIES* could potentially also have the power to impact the future, similar to predictions such as "Moore's law", which literally wrote the future.

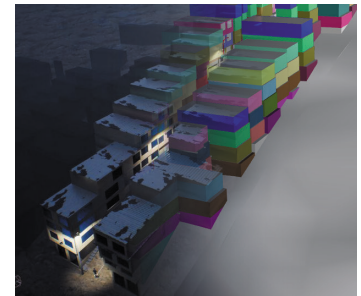


Figure 122: Quantitative data as input to generate qualitative visualisation in Bogotá.

Source: Michael Walczak (2020)

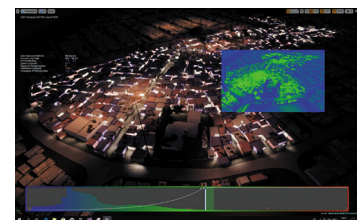


Figure 123: Quantitative lighting evaluation of qualitative visualisation. In the inset, the green colour indicates sufficient lighting, while the blue colour indicates insufficient lighting.

Source: Michael Walczak (2020)

³⁷ Discussed with Christoph Höller (Editor of the "Springerin" magazine in Vienna) at the University of Applied Arts.

February 2019



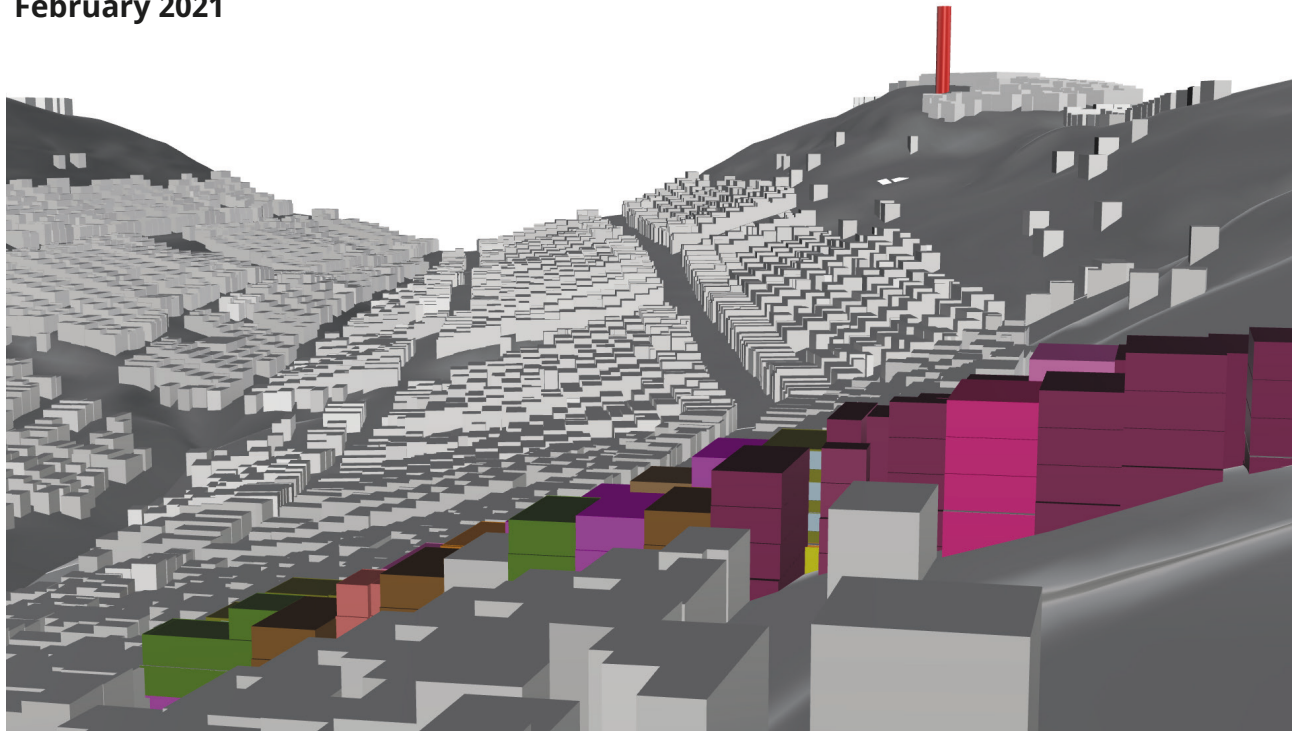
December 2019



Figure 124 and 125: Both images show the neighbourhood Caracoli in Bogotá, which is one case study of this dissertation. The second image from the top, "actual" reality in December 2019, shows that the settlement, seen in the top picture, was evicted because of landslides' risk.

Source: David Michael Kretzer, Incremental Light Space, Reducing Socio-technical Night-Time Public Space Inequality in Bogotá, Dissertation, ETH Zurich (2021)

February 2021



February 2021



Figure 126 and 127: The first visualisation from the top shows the evicted settlement's digital replica, accessed on February 11, 2021, in "virtual" reality. Therefore, it is a "4D protocol" since it also includes the densification process over time. The bottom image shows the nighttime visualisation of the same settlement accessed on February 11, 2021.

Source: Michael Walczak (2021)

5.2. DIGITAL URBAN IMAGINARIES REQUIRE A MEDIATOR

Every construct of a *DIGITAL URBAN IMAGINARY* requires the role of the mediator. We cannot assume that someone from within such a diverse community of citizens and actors will take up such a position, nor would this be useful because of the risk that a particular institutional agenda could bias the role. An actor with a neutral standpoint and who has an understanding of the language of the "computer" is required. In recent times we have frequently heard about the role of a "BIM Manager", so this role would be the "Perception Manager". Not only will the person taking on such a function have considerable responsibility for communication, but they will also benefit from a network of increased knowledge, especially from other fields and professions –because they not only engage with such disciplines but also iteratively implement the knowledge into the format of a *DIGITAL URBAN IMAGINARY*. This process of iteration generates a tremendous amount of experience.

5.3. TECHNICAL CHARACTERISTICS OF DIGITAL URBAN IMAGINARIES

A *DIGITAL URBAN IMAGINARY*, based on evidence that can iterate faster than a human, and in real-time, allows complex decisionmaking processes (see figure 128) to be assisted and supported within each of the different defined scenarios. An evidence-based *DIGITAL URBAN IMAGINARY* is a computer program that can help solve more complex problems, like an expert, by deriving recommendations for action from a data and knowledge base.³⁸ To generate a transparent and controlled knowledge base for the computer using "if-then" relationships, we can present human knowledge in a way that is understandable for computers. This "if-then" relationships can be used to perform different scenarios.

Since *DIGITAL URBAN IMAGINARIES* leave open the question of the medium on which they will be displayed, digital twin,³⁹ either 2D/3D print, display/projection, VR, AR, exhibition etc., they do permit adaptation to trends. In this case, it appears that augmented reality (AR), as opposed to virtual reality (VR), is more likely to become the more commonly used medium in future.⁴⁰

DIGITAL URBAN IMAGINARIES are not limited in terms of scale (from one building to the whole city) and knowledge can be transferred virtually from different contexts and replicated. We can use them as a medium to communicate on-site in informal settlements as well to communicate in museum exhibitions.⁴¹

Due to recent and anticipated developments in technology mainly driven by the "gaming" industry, including hardware and software, the necessary frameworks will become even more accessible. Nevertheless, it is crucial to speak the language of the "computer" to automate specific tasks and/or access vast data structures.

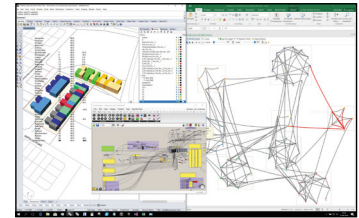


Figure 128: Empower Shack Preferential City Making Tool. Project by Urban-Think Tank. Source: Michael Walczak (2018)

³⁸ Lecture by Michael Huber, Mag.art., VL in the context of the "Computer as medium (media aesthetics)" format from the Department of Digital Arts at the University of Applied Arts in Vienna.

³⁹ A digital twin (DT) is a digital replica of a building's structure and behaviour (in our case, an urban area) with interactive connections to it. These connections transmit information (status, usage or analysis data, control commands, etc.). Moreover, a DT can take different forms depending on the level of detail, the degree of automation and the type of connections and information. Thus, DT maps states (structural and operational) of a real building over time. It can represent an existing building or one that is currently being realised (Wahbeh et al. 2020).

⁴⁰ Discussion on the 20.10.2020 with Michael Huber, Mag.art., VL in the context of the "Computer as medium (media aesthetics)" format from the Department of Digital Arts at the University of Applied Arts in Vienna.

⁴¹ Parangolé Model exhibited during the Urban-Think Tank, "Città Parangolé" show, at MAXXI museum in Rome from the 01.12.2017 until 25.02.2018.

Speaking about non-linearity, the aspect of time is very crucial since it can include dynamic elements such as moving pedestrians, public and private vehicles, densifying buildings, changing materials or sensor-driven adaptive lighting. For the observers, dynamic elements create the illusion of reality and the impression of something familiar. Such features help the observer to understand the scale of the scene and find their orientation. We were able to observe that the understanding of the interrelation between different aspects was greater when using dynamic elements than without them. If the observer also has the possibility to manipulate the scene, the learning factor also increases drastically (see chapter 4.6.).

Compared to images or predefined videos, the *DIGITAL URBAN IMAGINARY* method allows the observer to navigate and freely explore different viewing radiuses. This free navigation allows the viewer to inspect any location within the virtual environment and strengthen the decision they make since "problematic zones" cannot be hidden (see video 04 and chapter 4.6.).

Sound is another crucial factor that can impact more human senses and improve perception and emotion-making. Sometimes sound can express more than images or videos can. Sound evokes imagination and thus plays a vital role within the relationship of *DIGITAL URBAN IMAGINARIES* and perception. See chapter 8.6., where students experimented in an elective course format on how sound/audio design combined with film/motion pictures and digital modelling techniques can strengthen the understanding and emotion-making of complex multi-dimensional content shown.



Video 04: Public lighting in informal settlements: using VR as an evaluation tool for policymaking in "ISTP4Public" video. Source: Michael Walczak and David Kretzer; https://www.youtube.com/watch?v=Mv4HQUH_WY0&t=7s; accessed 15.12.2020

5.4. SOCIO-TECHNICAL RECOMMENDATIONS FOR THE *DIGITAL URBAN IMAGINARY* IMPLEMENTATION

In general, to ensure benefits derived from digital twins and virtual environments, a new form of communication media, such as VR, is required. When we look specifically at the way in which we visualise urban transformation processes, we can observe that it is more effective in certain circumstances to display geometries of the digital twin of a metropolitan area in a more abstract and colour-coded way (see chapter 8.4.). Such colour-coded representation is exceptionally accurate if the data quality is not high enough to be able to reach a high level of detail. In such cases, we do not recommend generating a pseudo and random application of the missing data points such as materials or roof geometries, but rather we let the imagination of the observer complete the gap of the level of detail. In other words, randomisation and gap-filling will not support perception-making because observers cannot identify with the "unknown" and "unfamiliar" virtual environment. If photorealistic visualisations are required, but low data quality is available, we could observe that the realm of the "informal" is better received by the audience than the "formal", as is the visualisation of "night-time" compared to "day-time". Nevertheless, since informal settlements are not bound to building standards, making it impossible

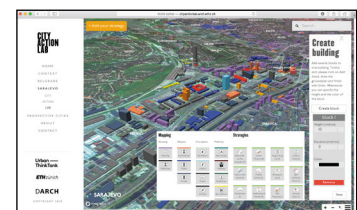


Figure 129: Interactive "City Action Lab" web platform, including 3D visualisation of Sarajevo and Belgrade. Concept: Michael Walczak, Coding: "brainstormunich media". Source: <https://cityactionlab.arch.ethz.ch/wp/sarajevo-lab/>; accessed 15.12.2020

to predict future building characteristics accurately, we observed one meter of inaccuracy, comparing reality and the virtual mapping of reality. We believe it can still serve as a planning basis.

For Sarajevo and Belgrade's case, we developed a 2.5D colour coded web interface (see figure 129), which is an example of how to deal with the scarcity of data in the most appropriate way (see chapter 8.4.). With the help of local citizens, crucial and indispensable data was collected using the method of citizen-centred design processes. Due to the collection by a broad audience and the accessibility through the web, the platform can be seen as a medium "for the masses by the masses".

As platform to display *DIGITAL URBAN IMAGINARIES*, exhibitions (see figure 130 and chapter 8.5.) can be an excellent medium not only for generating visibility, but also eliciting responses from visitors in order to obtain general iterative feedback to the research question.



Figure 130: Digital model translated into a physical model, wall print, digital walkthrough on-screen and urban gaming app on a tablet at the Urban-Think Tank, "Città Parangolé" exhibition, MAXXI museum in Rome from the 01.12.2017 until 25.02.2018. Directed by Alfredo Brillembourg and Hubert Klumpner. Core team: Michael Walczak, Arnout Sabbe, Stephanie Briers and Khensani de Klerk. Source: Clearhos Papanicolaou (2017)

5.5. POLICY RECOMMENDATIONS FOR THE CITIZEN-CENTRED DESIGN PROCESSES AND *DIGITAL URBAN IMAGINARY* IMPLEMENTATION

A specificity that we can observe throughout most governmental bodies ranging from urban planning, lighting, environment, and climate, in all contexts of case studies within this dissertation, is the fact that planning and decisionmaking processes are performed and discussed in two dimensions. In other words, governmental bodies draw decisions on a flat surface, despite the diverse and pronounced topographical, urban, or climatic contexts. We cannot discuss many urgent topics such as climate in two dimensions since, e.g. wind changes at different altitudes, so the built environment should react accordingly to provide air circulation. City policymakers should advocate a four-dimensional zoning regulatory instrument since it will improve, e.g. the climatic response of urban areas on a large scale. Such policy documents are mostly highly static and non-dynamic. Once initiated, put in place, and approved, such documents mostly remain in force for ten years or more. Yet, our societal and environmental changes are much more rapid, requiring a much more dynamic interface with such regulatory frameworks. State-of-the-art technology could allow reconfiguration of such policy documents at a one-second resolution based on current data or other inputs: e.g. the formation of building cluster in relation to its environment rather than individual building consideration detached from its environmental setting. See chapter 8.9. for a more in detail policy brief.

5.6. SYNTHESIS OF THE “IMMERSION ELICITATION” METHOD

We can summarise the novel contribution of the “immersion elicitation” method and our learnings as follows:

- (1) “Immersion elicitation” using *DIGITAL URBAN IMAGINARY* technology with more than 100 local citizens from the township Khayelitsha, Cape Town. The technology was made accessible in the township of Khayelitsha itself;
- (2) “Immersion elicitation” using *DIGITAL URBAN IMAGINARY* technology with more than 200 local actors from the City of Bogotá. The technology was made accessible in the City of Bogotá itself;
- (3) Qualitative engagement with more than 30 policymakers from Bogotá, Cape Town and Sarajevo;
- (4) Improved visualisation and communication technology permits an overall improvement of understanding by 80 percent, evaluated through the use of the “immersion elicitation” method;
- (5) Such a communication method can even effect a complete change in opinion by an average between 35 to 50 percent of the respondents, evaluated through the “immersion elicitation” method.
- (6) The method of “immersion elicitation” requires the assistance of the subjects (we observed that the subjects extended the initial clip length by a factor of 2 due to necessity for assistance or reflection on the decision making). Some participants might experience motion sickness. We recommend exposure of participants not longer than between 10 to 15 minutes. Each participant requires a short introduction and training, speaking the same language as the subjects is advantageous.
- (7) Through “immersion elicitation” we are not only virtually and remotely simulating specific urban transformation processes, but also bringing technology, visualisation and measuring devices into the actual and real locations. The on-site usage of technology allows citizen engagement and exchange with local stakeholders and actors, entirely in the spirit of citizen science and citizen-centred design processes.

5.7. SYNTHESIS OF THE COLLECTING, PROCESSING AND COMMUNICATING METHOD

We can summarise the novel contribution of the research implementation step 1 - 3 "collection" as follows:

- (1) We conducted a multi-resolution policy analysis ranging from a single building lot to a whole agglomeration within the building regulatory framework. It allows for quantification of the impact of spatial policies on the built environment;
- (2) The spatial policy model (SPM) extended the functionalities of the holistic and integrated framework of "EnerPol" (see figure 64). "EnerPol" uses the novel data as input in all existing models;
- (3) Large scale city-wide use of LIDAR technology to collect evidence in the form of wind measurements in urban environments; and
- (4) Data collection including build and natural environment, population statistics and climate, in the context of (alphabetical order): Belgrade (SRB), Bogotá (COL), Cape Town (SA), Cartagena (COL), Katowice (PL), Lausanne (CH), Medellín (COL), Milano (IT), Paris (F), Piacenza (IT), Sarajevo (BiH), Shanghai (CN), Stuttgart (GER), Toronto (CA), Vienna (AT), and Zurich (CH).

We can summarise the novel contribution of the research implementation step 1 - 3 "processing" as follows:

- (1) The development and integration of a spatial policy model (SPM) to account for the characteristics of building lots. It allows the automated assignment of the correct building regulation through interaction between zoning regulations and the municipal and regional location;
- (2) The use of an automated framework, SPM, that yields computation that is up to two orders of magnitude faster than the classical manual translation of building policies into a three-dimensional geometrical representation of these regulations;
- (3) SPM could allow for iterative and hypothetic manipulation of building policies. This would allow instant viewing and inspection of its impact visually and in three dimensions. This could help decisionmakers understand how decisions and changes in the building policies are manifested in physical space. The consequence could be large-scale efficiency and workflow improvement through rapid policy feedback loops;
- (4) Large scale city-wide use of CFD (computational fluid dynamics) simulations informed by LIDAR wind measurements;
- (5) Identification of the climatic correlation between building form, air quality, and wind;
- (6) A novel method presented for the spatial and temporal documentation of rapidly changing informal environments in virtual environments (VE);
- (7) The ability to generate lighting-specific features in multiple future *DIGITAL URBAN IMAGINARIES* in VE/VR;
- (8) Semi-automated framework to generate the built environment including buildings, topography, vegetation, motion patterns of pedestrians

	Comparison	
	Bogotá (Caracoli)	Cape Town (Khayelitsha)
Densification	Incremental vertical densification, particularly in adding floors	Horizontal densification, in rare cases up to two storeys vertical densification
Topography	Pronounced topography	Flat topography
Materials	Buildings made out of stones and bricks	Buildings made out of wood and corrugated steel
Street-widths	Wide streets (>5m)	Narrow streets (<5m)
Floors	Each consecutive floor is stepping in towards the street	Mostly one storey
Public lighting	Self-build informal lights on poles and walls	Self-build informal lights on walls
Activities	Concentration of activities around lights in public space	Concentration of activities around lights in public space
Illegal settlements	No lights in illegal settlements, pole-mounted lights in legalized settlements	High-mast lights
Climate	Temperate, no dry season, warm summer	Temperate, dry summer, hot summer

Table 07: Comparison between characteristics discovered through *DIGITAL URBAN IMAGINARIES* in Bogotá (Caracoli) and Cape Town (Khayelitsha). Comparison can help to identify potentials for scalability and transferability.
Source: Michael Walczak (2020)

and densification processes of buildings in VE/VR; from sources such as satellite images, and cadastral and census data; and

(9) Custom code enhances and enables state-of-the-art game-engine technology with the capability to use temporal large-scale quantitative as well as empirical data sets in an automated manner. The visualisation of motion patterns of pedestrians in the form of animated human skeletons as well as densification processes is a further key concern. A custom graphical user interface (GUI) helps navigate the virtual environment by displaying in text form the current year that the GUI is visualising or the tasks/functionalities that the user can access.

We can summarise the novel contribution of the research implementation step 1 - 3 "communication" as follows:

- (1) SPM compared the maximum buildable volume in 3D to the existing building stock and determined the "building surplus", including the correct roof geometry (i.e. pitched roof);
- (2) SPM can be applied, scaled and transferred to any context if the necessary boundary conditions are fulfilled;

- (3) The use of the method of "evidence-based policy evaluation" to formalise and extend the SDG 2030 target into 2040 *DIGITAL URBAN IMAGINARIES*;
- (4) The dynamic CFD (computational fluid dynamics) simulation framework can be applied, scaled and transferred to any context if the necessary boundary conditions are fulfilled;
- (5) Based on state-of-the-art game-engine technology, a range of media can be deployed to create visualisation output: in this case, VR. Since this research implementation step documented the framework, this presented workflow can be used for future studies, scaled, and transferred to other contexts;
- (6) Custom code allows the expansion of state-of-the-art game-engine technology to accommodate dynamic incremental changes in, for example, luminaire types and their geometries. Custom code allows a dynamic response to user behaviour in the form of additional lighting attributes such as motion sensors. The custom graphical user interface (GUI) can change all of these parameters and characteristics dynamically. The tool is particularly useful for iterative design processes and scenario planning; and
- (7) Research implementation step 4 generated evidence that *DIGITAL URBAN IMAGINARIES* can help policymaking in visually exploring existing and future urban transformation environments.

5.8. DANGERS, LIMITATIONS AND IMPLICATION OF RESULTS ON FURTHER RESEARCH

Nevertheless, it is also crucial to know the limitations and dangers. Dangers lurk particularly in manipulating perception with *DIGITAL URBAN IMAGINARIES* by deviating attention from problematic zones of certain areas or by "beautifying" urgent issues. This power of the image and knowledge may be subject to power interests from, for example, governmental or private institutions (Bridle 2020). The huge impact on human perception speaks in particular to these risks of such techniques to distort or steer individuals' decisionmaking processes. For example, night-time lighting needs to be visualised through movement in a spatial setting in order to overcome such dangers of deviating from problematic zones.

Limitations can be pointed out, particularly in respect of the available data quality and processing input required of us in the preparation of *DIGITAL URBAN IMAGINARIES*. In this regard, we need to make a careful assessment in terms of the aspect of the level of detail the model wants to achieve, at what "cost", and if the level of detail might not actually need to be so high to achieve the desired communication/simulation result. The method of more data and knowledge can result in the "Death of Phantasy" due to the belief in the computational promise of, e.g. prediction and representation (Bridle 2020). The advanced method of this dissertation seeks to posit a positive counter-position for overcoming and coping with such "digital" conditions through citizen science and urbanism.

When looking at different mediums used to communicate the digital model, VR, in particular, can trigger motion sickness of participants if the digital gestures do not align with and correspond to our natural gestures.

Future research and case studies could focus on the implementation of such a communication and visualisation method within a policymaking institution and measure and evaluate how it would impact its policy design and the respective decisionmaking processes. Since the technique of “public advice” (Sager et al. 2020) in policymaking is a well-established and practised method, the less considered method of “policy advice” (Sager et al. 2020) is preferred in this regard and supports the argument for future research.

The current percept study of Cape Town with a sample size of 45 by communication medium (VR 45, images 45, in total 90) is resulting in a 15%⁴² error margin (95% confidence level), compared to a 400,000⁴³ population size of Khayelitsha. The current percept study of Bogotá with a sample size of 203 is resulting in a 7%⁴² error margin (95% confidence level), compared to a 8,000,000⁴⁴ population size of the city. To reduce the margin of error, a further study using more than 200 participants could confirm if the experienced and resulted metrics, change in citizens baseline, match.

⁴² <https://www.qualtrics.com/de/erlebnismangement/marktforschung/stichprobenrechner/>; accessed 14.02.2021

⁴³ <https://census2011.adrianfrith.com/place/199038>; accessed 14.02.2021

⁴⁴ <http://atlasofurbanexpansion.org/cities/view/Bogota>; accessed 14.02.2021

5.9. TRANSFERABILITY OF THE RESEARCH FINDINGS

Once the technological framework for *DIGITAL URBAN IMAGINARIES* is developed, it is universally applicable. Data with complying and matching characteristics and specifications, from any context, can be an input, processed and visualised. In *DIGITAL URBAN IMAGINARIES*, data and objects developed or resulting from a particular context can be virtually transferred, transformed and tested in other locations (see figure 120). The technique behind dynamic and time-related visualisation mechanisms allows replacing the object in motion with any other medium or topic and all of its related characteristics. Another advantage of using *DIGITAL URBAN IMAGINARIES* is the aspect of the “non-scale”. On the one hand, the observational perimeter is limitless and can be as detailed as a single building spanning to a whole country. On the other hand, it allows the automated scalability of one object to an entire city with a particular set of rules (see chapter 8.2.).

- (1) We can apply the visualisation framework created for the context of Bogotá in Cape Town and vice versa;
- (2) The dynamic visualisation framework for private and public traffic data initially developed for the Swiss context was later applied to Vienna, Austria;
- (3) The same dynamic visualisation framework for private and public traffic data initially developed for the Swiss context was later applied in Bogotá to visualise pedestrian motion. The “vehicles” were replaced with human avatars, as well as its characteristics were modified;

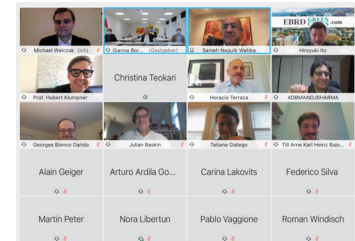


Figure 131: Participation in the Swiss State Secretariat for Economic Affairs (SECO) Urban Round Table Policy event – an encounter between various global partners including the World Bank, the Inter-American Development Bank (IDB), the International Finance Corporation (IFC), the Asian Development Bank (ADB), the African Development Bank (AfDB), the European Bank for Reconstruction and Development (EBRD), the Asian Infrastructure Investment Bank (AIIB), the Islamic Development Bank (IsDB), Cities Alliance and SECO - took place on November 10, 2020, remotely, finding a new format within a period of social distancing. We (Chair of Architecture and Urban Design, Prof. Hubert Klumpner) presented the work on topics related to mobility to the distinguished group, focusing on lighting and light as an enabling factor of last-mile pedestrian mobility for safe and secure access throughout urban areas. Source: <https://istp.ethz.ch/news/2020/11/urban-development-round-table-2020.html>; accessed 19.01.2021

- (4) The luminaire designed for the specific case of Bogotá could be automatically applied to the whole City of Bogotá or tested in the townships of Cape Town **(see table 07)**;
- (5) We used the climatic simulation framework in Toronto and Shanghai, which we initially developed for the case of Sarajevo; and
- (6) The impact of regulatory changes in spatial policies could be instantly and iteratively viewed on a whole scale of the selected agglomeration **(see figure 72)**.

Therefore, *DIGITAL URBAN IMAGINARIES* can be an appropriate platform to test, transfer and scale research findings from one location to another.

Such technology's universal applicability is evident since this dissertations research implementation co-developed a fully licensed software **(see figure 28)** and simulation framework called "EnerPol". The cases in which "EnerPol" is currently operating are completely on another continent, then this dissertations studies. "EnerPol" is now in use under license by the ETH Zurich Spin-Off "SwissAI". Further explanation on "EnerPol" can be found elsewhere, Marini et al. 2019, but the main contribution to "EnerPol" resulting from this dissertation is chapter 4, significantly step 1, 2 and 3.

Ultimately the technological innovation is resulting into social innovation and is a trigger for transformations **(see figure 133)**.

The transferability aspect was also present while constantly test-running this dissertations method as a knowledge transfer and teaching format (see chapter 8.6.). It resulted in establishing and teaching of three elective courses with approximately 100 students, transforming the digital toolbox of future architectural designers.

This dissertation contributed to successful additional research projects in the context of Sarajevo and the Department for Special Topics in Architecture Design (STARCH) at the University of Applied Arts Vienna. Beyond the dissertational work itself, it aided researchers and practitioners in decision- and policymaking processes. It made *DIGITAL URBAN IMAGINARY* technology accessible to more than 300 citizens in the local settlements of the global south. It included more than 100 stakeholders from Bogotá, Cape Town, Lausanne, Vienna and Zurich **(see figure 131)** from various universitarian, governmental and private institutions.

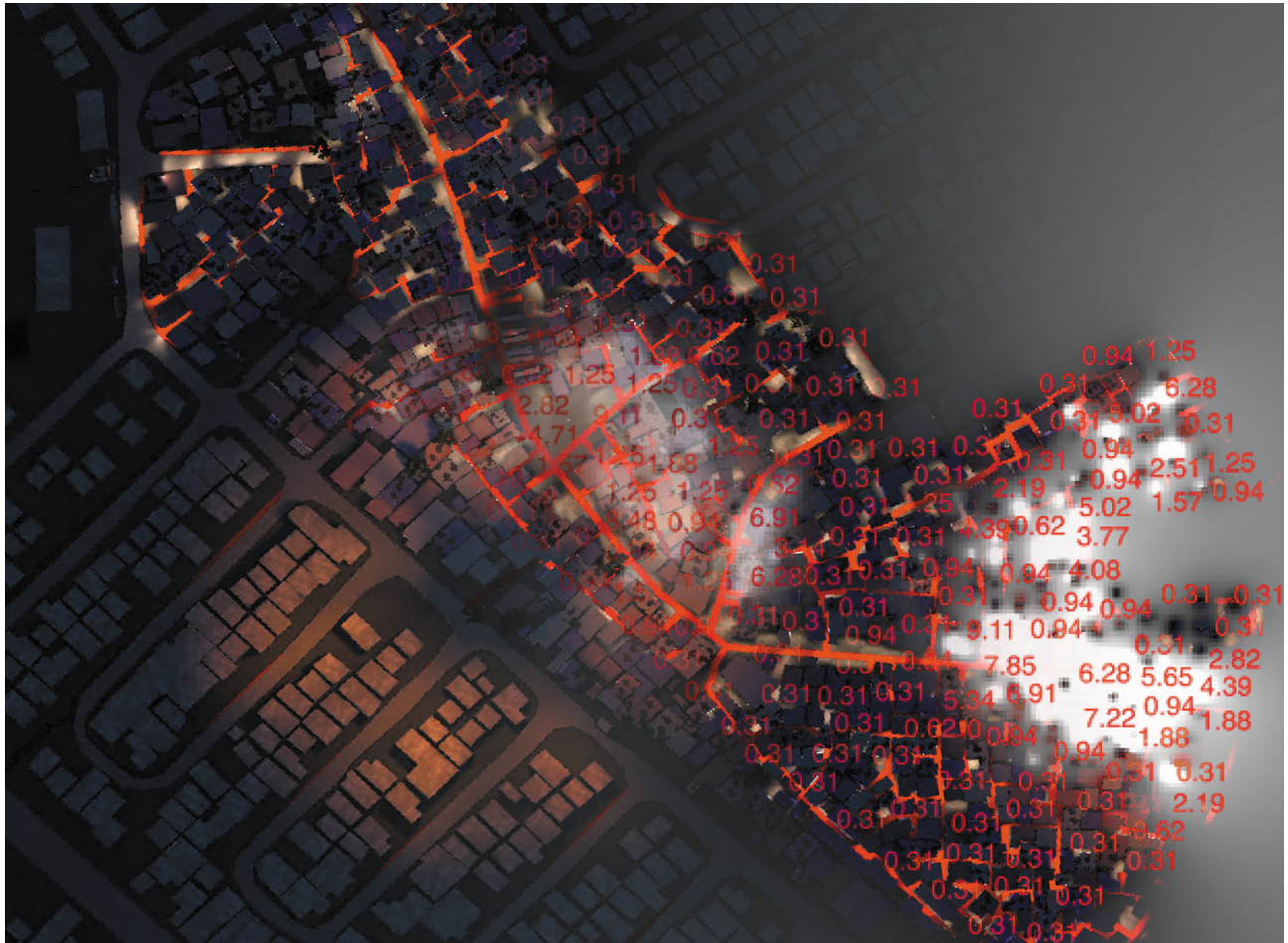


Figure 132: From quantitative lighting evaluation in lux (unit of illuminance) to qualitative lighting visualisation. Here, the case of the PJS settlement in Khayelitsha, Cape Town. Additionally, all walkable streets in the neighbourhood we show in red. This figure is representing the basis for the *DIGITAL URBAN IMAGINARY* performed in Cape Town, Khayelitsha.

Source: Michael Walczak (2019)



Figure 133: 2 out of 90 local citizens participating from the township Khayelitsha, Cape Town, experiencing *DIGITAL URBAN IMAGINARIES* of their neighbourhood. The technology was made accessible in the township of Khayelitsha itself. The high mast light is visible in the background through the window, the settlements prevailing mode of lighting.

Source: Michael Walczak (2019)

6. Epilogue

Shifting baselines not only apply in the context of this dissertation but can also take other forms:

We are currently witnessing two distinct challenges concerning urban transformation processes: an absolute interdependence between the social and the environmental realities: any modification on one directly affects the other, and vice versa.

Poor daylight access and atmospheric contamination in some of the most polluted cities in Europe result from social conflicts, unsolved transport policies, and global warming, resulting in a reduced quality of life. A more careful but determined approach is necessary to reverse global warming. The temperature of a climate zone south of the Alps is rapidly becoming a reality in climate zones north of the Alps. These shifting baselines could be the point of departure for future research using the methodology developed in this dissertation.

The current reality is that the Anthropocene as the root cause of the consumption of natural resources is not the end of our story. After all, there is a thesis that we can reverse global warming by understanding actions that better support the climate through integrated climate-care. Climate-care is a better understanding of, e.g. topography, cold air streams, water bodies, and photosynthesis used by vegetation.

Such imaginaries, interdependencies, and modifications could be virtually simulated using the methodology of *DIGITAL URBAN IMAGINARIES* deployed in this dissertation. It allows for a holistic perspective of the environment and the overall climate of cities as well as the connection of trans-scalar perspectives from a bird's eye view, eye-level metropolis, or regional observation, down to an individual building-level perspective. The consideration of topics such as long- and short-term transformations of topography, seasons, efficiency, orientation, understanding the changing dynamic qualities, existence, or absence of daylight as a source of light and energy, and renewables are essential.

New technologies of trans-scalar and trans-locational modelling tools and expertise in digital simulation and data processing developed within this dissertation's framework could be applied to researching the transforming baselines of city-climate zones. Table 07 is an example of such identified transferability and comparability of knowledge from Cape Town and Bogotá. Interactive digital tools that allow for system thinking based on cybernetic terms, feedback loops, and time and process functions are essential. For instance, atmospheric contamination from transport and heating creates the inversion weather phenomenon, preventing daylight penetration. Such correlations are critical for the shifting baseline in city-climate zone research. Large-scale city-climate zone simulations could include social factors such as population dynamics, programmes, production, and mobility, and climatic factors such as temperature, daylight, sunlight, wind, water, rain-fall, fine-dust, atmospheric pressure, vegetation, and topography. City-climate zone simulations are used to create a selection of site-specific parameters in particular locations and to enable identification of where given urban qualities can be found in the existing urban structure and where they have to be improved, considering current regulatory and policy frameworks and how new ones may be designed, for example, for the case of Toronto. To combine the generated data from "EnerPol" (Walczak 2021a; Marini et al. 2019), real data, and projected data into one common platform, we propose using an automated simulation framework based on game-engine technology as a result of this dissertation.

Art-based research (Falkeis 2015) and its methods can impact science and knowledge production, and vice versa. For example, new instruments such as *DIGITAL URBAN IMAGINARIES* and the medium of VE/VR (virtual environments/virtual reality) allows the observer to immerse themselves in a non-biased, "eye-level" city-climate zone perspective and cross-reference many different city-climate zones in a manner understandable to the observer on different scales and in four dimensions (time).

7. Acknowledgments

In the course of my work at the ETH Zurich Institute of Science, Technology and Policy, the Chair of Architecture and Urban Design under Prof. Hubert Klumpner as well as the Laboratory for Energy Conversion under Prof. Reza S. Abhari I have found a unique interdisciplinary research environment. Coupled with the University of Applied Arts Vienna (Angewandte) Department for Special Topics in Architecture Design under Prof. Anton Falkeis, as my doctoral research institution, enabled me to expand my horizons and dive into multiple spheres of imagination. I would like to express my sincere gratitude to Prof. Falkeis, Prof. Klumpner, Prof. Abhari and Dr Ndaona Chokani for supervising my research and all their academic advice, Stasia Kremer for unprecedented "everydaylife" supporting and bearing me during all these years and final assisting in finishing this document, my family, Tomasz, Jola, Patrick and Philipp, for all their unconditional support and strength, and all my colleagues who contributed in one way or the other to this work, particularly (alph.): Stephanie Briers, Alfredo Brillembourg, Diego Ceresuela, Melanie Fessel, Anna Gawlikowska, Khensani de Klerk, David Kostenwein, David Michael Kretzer, Marcello Marini, Klearjos Eduardo Papanicolaou, Bojana Papic, Haris Piplas, Aleksandr Saprykin as well as all administrative support by Marlene Hegner, Dietmar Huber and Flavia Reginato.

This work was supported by an ETH Zurich ISTP Research Incubator Grant, a Swiss State Secretariat for Economic Affairs SECO Scoping Study Grant "Urban Transformation Project Reactivate Sarajevo" and by an ETH Zurich Innovedum Grant.

8. Appendix

The appendix is composed of:

- (8.1.) Policy Outreach Transcription (Excerpt)
- (8.2.) List of Digital Models
- (8.3.) State of the Art Digital Tools
- (8.4.) Publications During the Doctoral Studies (Excerpt)
- (8.5.) Exhibitions During the Doctoral Studies (Chronological Order)
- (8.6.) Teaching During the Doctoral Dtudies
- (8.7.) Conferences During the Doctoral Studies (Chronological Order)
- (8.8.) Online Publications During the Doctoral Studies (Chronological Order)
- (8.9.) Policy Brief
- (8.10.) C++ Code (Excerpt)
- (8.11.) Unreal Engine Blueprint Code (Excerpt)
- (8.12.) Curriculum Vitae

Appendix: 8.1. Policy Outreach Transcription (Excerpt)

Interview conducted online through Zoom on the 23.07.2020 between David Michael Kretzer and Michael Walczak, and policymaking stakeholders from Bogotá: "Unidad Administrativa Especial De Servicios Públicos, Subdirección Servicios Funerarios y Alumbrado Público, Bogotá (UAESP)" and "Secretaría Distrital de Planeación, Bogotá (SDP)". During the interview, David Kostenwein assisted with the translation from English to Spanish and vice versa. The interview was translated from Spanish to English. The talk's main topic was the use of digital communication techniques such as VR for lighting planning and policymaking.

Person	Time	Discussion
Michael Walczak (MW)		The lighting conditions were presented to you in four ways: by numbers, a render, a false colour scheme and in a virtual reality environment. Can you please classify these four forms of presentation according to the ability to illustrate the lighting situation?
"Unidad Administrativa Especial De Servicios Públicos, Subdirección Servicios Funerarios y Alumbrado Público, Bogotá (UAESP)" (R4)	#00:02:06:31# until #00:02:07:31#	In my case I am not an engineer, but I would understand that it would depend on the public, that is a matter of communication. Obviously, if one is talking to engineers, the figures of these technical issues would be immediately familiar to them. These topics on design and lumens per watt, well all that series of technical measures is important to them, but let's say at a visual level or for the community or for an authority, who are not engineers, the issues of virtual or mental reality are very interesting as they give a greater approximation to how that lighting would potentially look like, as we are seeing here, right? So that answer is not the best one, but it depends.
R4	#00:02:07:34# until #00:02:07:40#	It really depends on who you are talking to at the time to make communication more efficient.
"Unidad Administrativa Especial De Servicios Públicos, Subdirección Servicios Funerarios y Alumbrado Público, Bogotá (UAESP)" (R3)	#02:08:06-2# until #02:08:23-9#	I have the same opinion of Omar, but to give an answer, from the perspective of my training, virtual reality is the best way to visualise the conditions of illumination.
"Secretaría Distrital de Planeación, Bogotá (SDP)" (R2)	#02:08:44# until #02:09:14-6#.	No, I agree with them, with Omar and Paula, because it is true that virtual reality reaches all audiences, that is, you don't need to be a technician, you don't need to be a specialist in the subject, you see how the lighting is. In that case, the virtual reality changes depending on the conditions, that is, I think that the one that reaches all audiences is virtual reality, because you do have to be a technical person in the subject to understand figures.
David Kretzer (DK)		Did it help you, since you are not planning lighting and you are from another profession?
R2	#02:09:35# until #02:09:47-5#	Of course, I did, because it showed me how the changes occurred at certain widths and according to time. Everything looks perfect.

"Unidad Administrativa Especial De Servicios Públicos, Subdirección Servicios Funerarios y Alumbrado Público, Bogotá (UAESP)" (R1)	#02:09:58# until #02:10:23-7#	Yes, I agree with everyone, however I think the same way as Omar, that it depends on the person who is going to see the presentation, because let's say, if it is presented in the type for engineers, who know about the subject, they will complement it very well with the theme of virtual reality. Although I think that even though I did not have the 3D glasses, virtual reality seemed to be the best one, I think it is the best way to present it.
DK		Lina, you personally what is your opinion?
R1	#02:11:10# until #02:11:29-4#	Yes, and above all because one is in the place, in the field, in the place where you are socializing the idea. Than one sees the floor, the house, the light, and one feels like familiarised and understands the situation.
MW		Do you think it adds value to the illustration of lighting planning (compared to numbers, renderings and false color schemes)? If so, please describe why?
R4	#00:02:13:21# until #00:02:13:15#	Yes, I think we touched on it in the previous answer. Let's say that it is like Lina said, to be at the location, in some way, in conditions as close as possible to reality or to project it in time, right? and complemented, because obviously, if I go with an expert, an engineer or with the norm, well, the numbers.
MW		With VR it is not only possible to look at one street but also at a whole city, it is possible to plan on a very large scale.
DK		Omar, would VR help you personally since you are from the field of lighting planning (false colour schemes, numbers etc.) and if so what would it be?
R4	#00:02:14:15# until #00:02:15:24#	... that we talked about that point, I think the tool of augmented reality or virtual reality is very useful, very dynamic, very tactile as Lina said, that you feel you are on the site and can get the light sensation. If I than had to go to an expert, the regulator, an engineer or a lighting designer, I would complement it with figures. Well, let's say, I think there would be all the necessary information. I would think that if I had to go to an expert, I would surely have to complement with figures and parameters, but as almost everyone agreed in the comments, the virtual reality tool is a tool that is valid for the whole public, it is very intuitive, very didactic and makes it very easy to visualise by any public.
MW		Do you think virtual reality environments would support your organization in assessing and/or communicating lighting planning?

R4	#00:02:17:37# until #00:02:18:47#	Mainly communication not planning, communicate new ideas What I insist on here is that I am not a lighting engineer as such, but what I saw was that this tool gives you a three dimensional vision, where you can review the different perspectives from one place and complement it with what you were talking about. I can zoom out and look not only at one point of light but go through an entire street, or I can elevate through the map and see the entire neighbourhood. Obviously, it's an optimal visualisation, right? Than I understand that the limitation of a render or the others that were mentioned before are focused on particular dimensions to a vision of a plane to which I approach, I move away and suddenly I turn it and that's all, but the virtual reality talks to me about the third dimension and I think that's the interesting thing, isn't it? and what you were explaining is that I can zoom out to a street or the vision of a neighbourhood, right?
R4	#00:02:19:43# until #00:02:21:04#	I think that in general the whole topic of virtual reality is a very, very good tool, in this case for planning, to be specific, but also to disseminate or promote a solution because as you mentioned now, and we have insisted, it is very realistic... let's say, it generates an impact quite close to the solution. it is much better understood if one is going to explain it to a person as such who lives in the neighbourhood. It would be much easier to see it and feel it, whereas the person would never understand by seeing a render of those figures themselves, right? So, yes I think it is a very useful tool... for example, one would also see that in these communities where there are millennials and people who are closer to this type of technology, because it is a much more motivating factor since they are beginning to get used to these types of technological tools, Well, my answer is yes, of course I found it to be an ideal tool, not only for planning and promotion but also for communication.
MW		How do you communicate now?
R4	#00:02:21:59# until #00:02:22:46#	Yes, I mean, in general I see that the use of virtual reality or augmented reality tools has increased, even because of the pandemic, right? Because you can already see the use of virtual reality when accessing virtual events, and you enter a conference site and everything, and you can see pavilions, and everything is virtual reality. But I would say that in the Colombian case, it is not that the general use in institutions is so massive, although I would believe that the tendency to use it is increasing.
R4	#00:02:22:59# until #00:02:23:53#	I would say that, as it stands, communication media are still the traditional ones. Let's say, at this time of the pandemic, I think they will become more popular, because these types of virtual meetings will keep increasing, right? Even all this type of digital communication. Social networks have increased in general and are used by all people, but I think that when we return to normal, this will also be combined with more face-to-face matters. I don't know, but I see the traditional meeting as a combination of communication solutions. But I think that in Colombia we were in a very traditional position and now due to the pandemic we have been encouraged by the need to use digital tools.

R1	#02:23:54-7# until #02:25:01-0#	Yes, in fact we do, because since we communicate all the institutional issues through the media, mainly social networks and also the entity has and above all, well the whole entity, each sub-directorate and on the whole theme of public lighting there is a social team that teams up with communities. This social team is also taken care of by CODENSA—the operator of the service—and what they do in all the meetings is that the local boards or the council specifically assign some councilmen, or some communities as such and it is the job of these social managers to participate. Because we are still managing the issue of meeting with the community and talking and being asked how a particular lighting works. That person than gives them the whole context, but also as Omar pointed out, now almost everything is being handled mostly by social networks and such virtual channels of communication.
MW		Many districts are inaccessible, not only during pandemics such as COVID-19. In order to imagine the districts VR could become a planning tool and not only stay a communication medium?
R2	#02:28:17# until #02:29:03-6#	In this case, it would be like when the entities are going to work, because it would be interesting to look at the places where it would be unsafe or dark for the issue of security, where lighting would be needed. In that case, it would be when the exercise is done and I also think that, for example, in the issue regarding the paths. I mean, when the model is run it shows you which paths in the building are unsafe because of their width, that is, which would also be the ideal width for the planning. I think that it would be an interesting instrument.
DK		Omar, when you communicate with other lighting stakeholders such as CODENSA what do you provide to them? Which documents? Numbers, tables, renders?
R4	#00:02:29:49# until #00:02:30:40#	I would say the traditional, that is, renders and these sort of tables and figures. Because, let's say, that is how it is usually done here in that medium... presentations, brochures and all that. You have to take into account - I do not know if they already explained it to you - that CODENSA operates the (not clear) in Bogotá but there are some topics that are not covered as such, than you have to weigh all that, but as an operator it uses traditional communication tools, and I do not think that they are so advanced as to use such virtual reality features.

Appendix: 8.2. List of Digital Models

Locations and specifications of digital twins generated during the process of the dissertation.

City (Primary)	Buildings	Topography	Vegetation	Lighting	Satellite Imagery	Pedestrian Simulation	Traffic Simulation	Scale	VR	Automatised	2D data
Bogotá, Colombia	2.5D (Footprints + Floors Extrusion)	Yes	Yes	Yes	Yes (Drone Footage)	Yes	No	City-Scale	Yes	Yes	Yes
Vienna, Austria	3D	Yes	Yes	No	Yes	No	Yes	City-Scale	No	Yes	Yes
Cape Town, South Africa	2.5D (Footprints + Floors Extrusion)	Yes	No	Yes	No	No	No	City-Scale	Yes	Yes	Yes
Sarajevo, Bosnia and Herzegovina	2.5D (Footprints + Floors Extrusion)	Yes	No	No	No	No	No	City-Scale	No	Yes	Yes
Zurich, Switzerland	3D	Yes	Yes	No	Yes	No	Yes	City-Scale	Yes	Yes	Yes
Agglomeration of Lausanne, Switzerland	2.5D (Footprints + Floors Extrusion)	Yes	No	No	Yes	No	Yes	City-Scale	No	Yes	Yes
City (Secondary)											
Belgrade, Serbia	2.5D (Footprints + Floors Extrusion)	No	No	No	Yes	No	No	Local-Scale	No	No	Yes
Piacenza, Italy	3D	Yes	No	No	Yes	No	No	Local-Scale	No	No	Yes
Cartagena, Colombia	2.5D (Footprints + Floors Extrusion)	No	No	No	Yes	No	No	Local-Scale	No	No	Yes
Toronto, Canada	2.5D (Footprints + Floors Extrusion)	No	No	No	No	No	No	City-Scale	No	Yes	Yes
Shanghai, China	2.5D (Footprints + Floors Extrusion)	No	No	No	No	No	No	City-Scale	No	Yes	Yes

Appendix: 8.3. State of the Art Digital Tools

Following list is including a selection of current state of the art digital tools and its specifications as a starting point of this dissertation. This list shall be seen as digital tools review similarly to a literature review.

Name	Platform	Open Source	2D/3D/4D	Real-time	VR/AR	Scale	Description	Link	Comments
Urban-Think Tank City Action Lab	Web	No	3D	-	-	City	Data Visualisation, User generated Content	https://cityactionlab.arch.ethz.ch/wp/sarajevo-lab/	
URscape	Web, Standalone	No	2D	-	-	Country	Data Visualisation	https://urs.sec.sg/ur-scape/	
Morphcode Urban Layers	Web	No	2D	-	-	City	Data Visualisation	http://io.morphocode.com/urban-layers/	
Morphcode Explorer	Web	No	2D	-	-	City	Data Visualisation	https://explorer.morphocode.com/map	
Roads to Rome	Web	No	2D	-	-	City	Data Visualisation	https://www.move-lab.com/project/roadstorome/cities	Interactive part out of function
Streetscape.gl	Web	Yes	4D	-	-	Neighbourhood	Data Visualisation	https://avs.auto/demo/index.html	
Great Escape	Web	No	2D	-	-	Country	Data Visualisation	https://greatescape.co/	
City Planner	Web	No	3D	-	-	City	Data Visualisation	https://cityplanneronline.com/stockholm/stockholmvaxer	
Treepedia	Web	No	2D	-	-	City	Data Visualisation	http://senseable.mit.edu/treepedia	
Cityways	Web	No	3D	-	-	City	Data Visualisation	http://senseable.mit.edu/cityways/app/	
Big Time BCN	Web	No	2D	-	-	City	Data Visualisation	http://bigtimebcn.30000kms.net	
Arcgis City Engine	Web, Standalone	No	3D	-	-	City	Data Visualisation	https://hub.arcgis.com/datasets/86f88285788a4c53bd3d5dde6b315dfe	
Deck.gl	Web	Yes	4D	-	-	City	Framework	https://deck.gl/#/	
Unreal Engine	Standalone	Yes	4D	Yes	VR, AR	Country	Framework, Animation	https://www.unrealengine.com/en-US/	Definition according to Fankhänel et al. (2020)
Unity	Standalone	Yes	4D	Yes	VR, AR	Country	Framework	https://unity.com	
Q-GIS	Standalone	Yes	2.5D	-	-	Country	Data Visualisation	https://www.qgis.org/de/site/	
ArcGIS	Standalone	No	2.5D	-	-	City	Data Visualisation	https://www.qgis.org/de/site/	
EnerPol	Standalone	No	-	-	-	Country	Framework	https://lec.ethz.ch/research/enerpol.html	
Urban-ThinkTank CityBuilder	Web	No	3D	-	-	Neighbourhood	Data Visualisation, User generated Content	https://cityactionlab.arch.ethz.ch/cityBuilder/	
Gauteng City Region Observatory Interactive GIS	Web	No	2D	-	-	City	Data Visualisation	https://gcro1.wits.ac.za/gcrojsgis/	
RAY.diosity 3D by Thomas Diewald	Standalone	No	3D	-	-	City	Framework	https://vimeo.com/182030824	
RAY.diosity 2D by Thomas Diewald	Standalone	No	2D	-	-	Neighbourhood	Framework	https://vimeo.com/228387816	
TOOLZ Smart Favela	-	No	3D	-	-	Neighbourhood	Data Visualisation	http://www.toolz.fr/uk/en_EN/projet_en.php?inc_smart_favela_en	
Qua-Kit	Web	No	2.5D	-	-	Neighbourhood	Data Visualisation, User generated Content	https://qua-kit.ethz.ch/editor	

Name	Platform	Open Source	2D/3D/4D	Real-time	VR/AR	Scale	Description	Link	Comments
Omni Sci Taxi Demo	Web	No	2D	-	-	Country	Data Visualisation	https://www.omnisci.com/demos/taxis	
Omni Sci Oil and Gas Demo	Web	No	2D	-	-	Country	Data Visualisation	https://www.omnisci.com/demos/oil-and-gas	
Kinetica Demo	Web	No	2D	-	-	Country	Data Visualisation	https://www.kinetica.com/product/demo/	
Remix	-	No	2D	-	-	Country	Data Visualisation	https://www.remix.com	
Urban Footprint	-	No	2D	-	-	Country	Data Visualisation	https://urbanfootprint.com	
Dialux	Standalone	No	3D	-	-	Building	Framework, Simulation		
Hilite	Standalone	No	3D	-	-	Building	Framework, Simulation		
Velux daylight visualiser	Standalone	No	3D	-	-	Building	Framework, Simulation		
Radiance	Standalone	Yes	3D	-	-	Building	Framework, Simulation		
Ladybug/Honeybee for Grasshopper3D	Plugin	Yes	3D	-	-	City	Framework, Simulation		
Rhinoceros3D	Standalone	No	3D	-	-	City	Framework, Modelling		Definition according to Fankhänel et al. (2020)
Grasshopper3D for Rhinoceros3D	Plugin	No	3D	-	-	City	Framework, Scripting		Definition according to Fankhänel et al. (2020)
Cinema 4D	Standalone	No	4D	-	VR, AR	Neighbourhood	Framework, Animation		Definition according to Fankhänel et al. (2020)
Autodesk Maya	Standalone	No	4D	-	VR, AR	Neighbourhood	Framework, Animation		Definition according to Fankhänel et al. (2020)
EnerPol	-	No	4D	-	-	Country	Framework, Simulation		
GEMSim	Standalone	No	4D	-	-	Country	Framework (Traffic)		
MatSim	Standalone	Yes	4D	-	-	Country	Framework (Traffic)		
Archicad	Standalone	No	3D	-	-	Building	CAD, Analysis		Definition according to Fankhänel et al. (2020)
Vectorworks	Standalone	No	3D	-	VR, AR	Building	CAD, Drawing		Definition according to Fankhänel et al. (2020)
Autodesk Revit	Standalone	No	3D	-	-	Building	CAD, Analysis		Definition according to Fankhänel et al. (2020)
Enscape	Plugin	No	3D	Yes	VR, AR	Building	Framework, Animation		

Name	Platform	Open Source	2D/3D/4D	Real-time	VR/AR	Scale	Description	Link	Comments
Blender	Standalone	Yes	4D	-	VR, AR	Building	Framework, Animation		Definition according to Fankhänel et al. (2020)
Sketchup	Standalone	No	3D	-	-	Building	CAD, Modelling		Definition according to Fankhänel et al. (2020)
AutoCAD	Standalone	No	3D	-	-	Building	CAD, Drawing		Definition according to Fankhänel et al. (2020)
Google Environmental Insights Explorer	Web	No	2D	-	-	Country	Data	https://insights.sustainability.google	
Sidewalk Labs Delve	Web	No	3D	-	-	Neighbourhood	Framework, Simulation	https://hello.delve.sidewalklabs.com	
Google COVID mobility change data	Web	No	2D	-	-	-	Data	https://www.google.com/covid19/mobility/	
En-Roads	Web	Yes	2D	Yes	-	-	Framework, Simulation	https://en-roads.climateinteractive.org/scenario.html?v=2.7.29	
Urban Data Lab	-	No	-	-	-	-	Service	https://urbandatalab.ch/#rect197565643	
Archilyse	-	No	-	-	-	-	Service	https://www.archilyse.com	
Swiss Prop Tech	-	No	-	-	-	-	Service	https://swissproptech.ch	
Senozon	-	No	-	-	-	-	Service	https://senozon.com	
Space Maker AI	-	No	-	-	-	-	Service	https://www.space-makerai.com	

Appendix: 8.4. Publications During the Doctoral Studies (Excerpt)

This publication results from the SNF SCOPES research project "Smart and Creative Cities in Central-Eastern Europe" from 2015-2018 at the Chair of Architecture and Urban Design at ETH Zurich.

For this dissertation, we emphasised the development of the interactive 3D web interface, which included a data collection workshop in Belgrade from the 01.06 until the 05.06.2017 and a workshop in Sarajevo from the 17.10 until the 31.10.2017.

We summarised this publication's result under the chapter: "Design Your City: Lab Interactive Map".

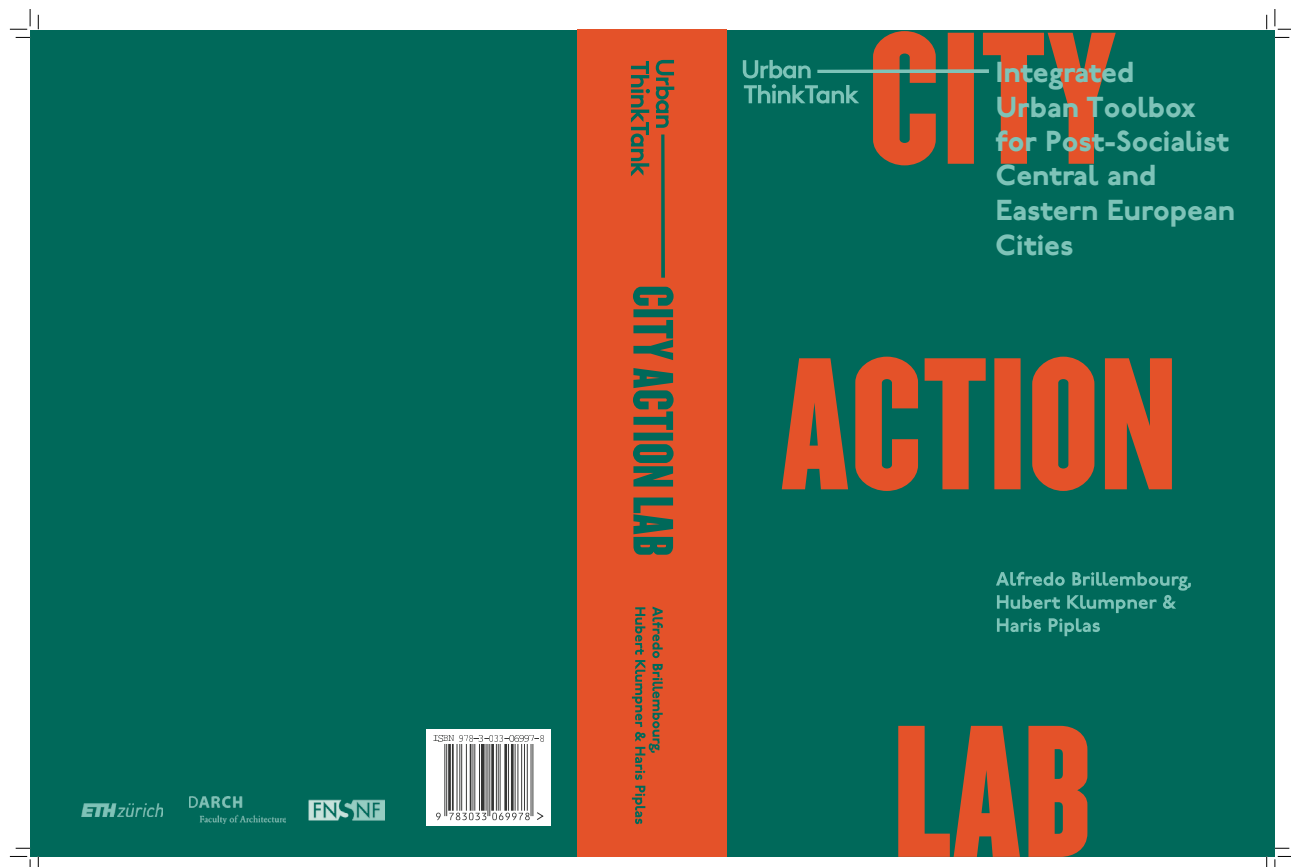


TABLE OF

P – 14
INTRO
City Action Lab:
Integrated urban toolbox for
Central Eastern European Cities

01
THEORY

P – 22
Urban Challenges of CEE Cities

P – 24
SARAJEVO

P – 30
Reactivating Sarajevo:
Revolutionary Urbanism
of a Contested City

P – 40
Viva La transición. Fragmented City

P – 52
Sarajevo: Intelligent City, Urban
Heritage and the Academy

P – 56
Urbanism at the Global Cultural
Frontline. Shifting planning
strategies in Canton Sarajevo

P – 60
Activating landscape investments
in transition economies:
A green infrastructure approach
for Sarajevo

P – 66
R-Lab in Sarajevo: Agonistic Body
Workshop & "Exercise", 2017

P – 68
Sarajevo Now. People's Museum,
Urban-Think Tank

P – 74
Reactivating Sarajevo's
(dis)continuous Urbanism

P – 80
Spatial Reading: New Sarajevo

P – 88
BELGRADE

P – 92
Novi Beograd: Unfinished visions
and realized needs. The first decade
of Post-Socialist transition
of the Modernist City

P – 94
Novi Beograd 2000s:
Development in Neoliberal
Capitalism

P – 96
Neglected bigness: Kaludjerica,
Belgrade's informal Suburbia

P – 105
Housing complex building
form typologies

P – 108
BRATISLAVA

P – 116
TARTU

P – 124
SKOPE

P – 144
What have you always wanted
to know about Skopje
(but were afraid to ask)

02
PRODUCT

P – 148
Political Will Letters

P – 150
Collaboration with Festival
Dani Arhitekture 2015

P – 152
Movie: Reactivate Sarajevo Now

P – 154
Movie: People's Museum

P – 158
Reactivate Sarajevo Symposium

P – 160
Declaration signed

P – 162
Scapes Lab 2014:
Big projects

P – 164
International Workshop for Smart
& Creative Cities for Knowledge –
Based Society, 2015

P – 166
Urban Tools for Reactivating
Belgrade Workshop

P – 168
Housing the City

P – 170
Zurich: Radical City

CONTENTS

P – 174
"DIY in Architecture" 2013

P – 176
Elective Course Balkanstrasse 2014

P – 177
Balkan-ness in Transition, 2014

P – 178
Urban Stories Lecture, 2016

P – 180
Venice: Participation in the 2016
Venice Architecture Biennale

P – 184
Balkanise! Event, Lausanne 2018

P – 186
Skopje Architecture week 2012:
Keynote & Panel

P – 188
Skopje Architecture Week 2013
"On Urban Relevance"

P – 191
City Creative Network, 2014

P – 194
99 Files: #Skope Brutalism

P – 196
Metropolis Nonforma Munchen
2011: Landscape, Infrastructure and
Urbanism in the Global South

P – 198
Banjaluka: Urban Walks as part of
the city transformation process

P – 200
Kotor: Double Symposium
"Re-use" & "The Debate"

P – 204
Kiev: Canaction206

P – 206
Reactivate Khrushchevkas
How to transform
post-Soviet Cities

P – 208
Pristina Architecture Week 2014

P – 209
Workshop: Prishtina informal
toolbox "Kodra e Trimave"

P – 218

P – 218
New Urbanity: The hacker,
the band, the tycoon and the
creative director urban reuse in
the post-socialist city

P – 252
The abstract Architecture of Boris
Magas framework of transition

P – 258
(Post) Yugoslav cities emerged
from its cultural-artistic grassroots
movements: reflection on the city
of Skopje

P – 216
**Design your City:
Lab Interactive Map**

P – 222
Potential Prototype Intervention

P – 262
OUTCOMES
Bridging Theory and Practice:
Collaborative multi-stakeholder
project platform

P – 264
Project History & Credits

03
LAB

04
GUEST
ARTICLES

03

LAB

MANIFESTO

**DESIGN
YOUR CITY:
LAB INTERACTIVE
MAP**

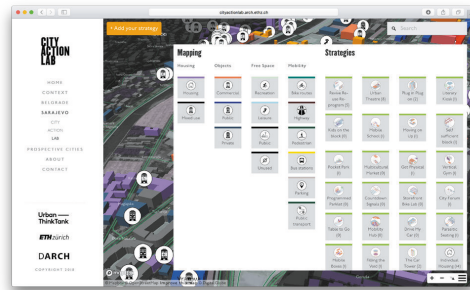
**MICHAEL
WALCZAK**

216

The intention of the lab is to create context specific strategies and interventions for the development of each city in the CityActionLab. The lab is a virtual space that is able to generate urban scenarios and to encourage the implementation potential of projects with the insight of local inhabitants' proposals. The Lab allows the user to locate a site in the city with an awareness of the challenges and potentials explained to them in the CityAction aspect of the site. Thereafter, the user can suggest an intervention, specifying the height, in order to show the impact of densification in the city. In specifying interventions, users are able to detail the function of the intervention through word descriptions, and attach functions that are suggested in the action aspect of the site. Once the intervention has been suggested in the lab, other users are able to view and comment on the urban proposal. The site gives an indication as to how many other people support or do not support ideas and displays comments for reading. The aim of the lab is to encourage a sharing of ideas, and to observe and learn how people would like to grow their city. The overall process allows urban planning and design stakeholders to implement proposals in the economic and political space with situated impact tailored to the needs of the inhabitants in that particular city. The Lab is a space that encourages how bottom up processes can meet top down processes in an accessible language of play in the city.



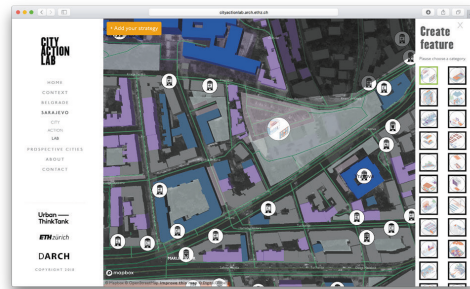
01. General overview of the 3D map interface.



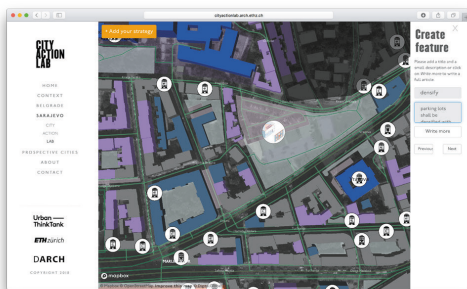
02. Layers selection for elements to be displayed. Existing elements and proposed strategies by users.



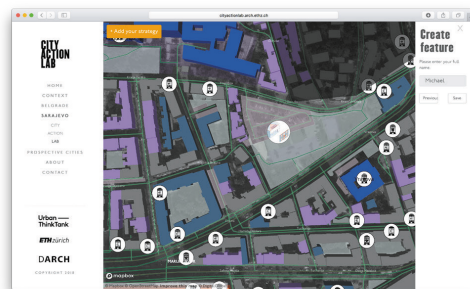
03. Search function for finding proposed elements by username, title, description, intervention and/or tool.



04. Generate new content by user. Propose new ideas for a chosen location. Choose a predefined feature from a selection of the proposed toolbox.



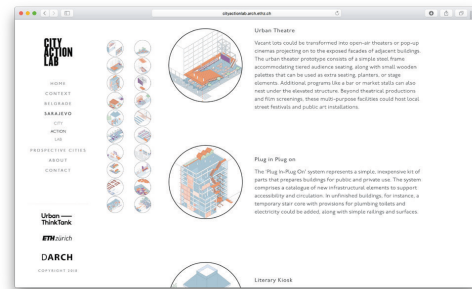
05. Describe the idea.



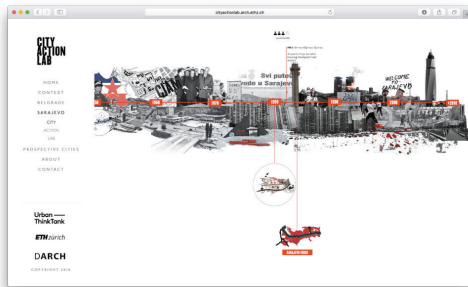
06. Specify the username.



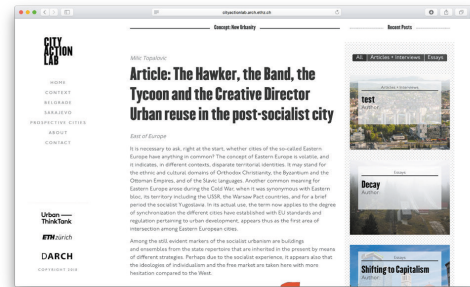
07. Click on existing user generated ideas and proposals for more information and comments. Comment them, Like or Dislike them.



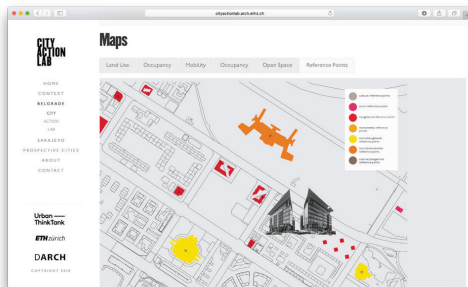
08. Read about different proposals for Actions in the Toolbox



09. Study the timeline and history of the different locations.



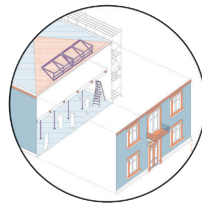
10. Read articles of researches in the given context.



11. Check interactive maps for more information about the location, such as landuse, mobility, occupancy or reference points.

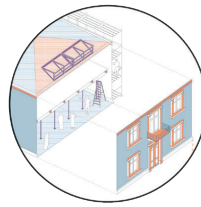
POTENTIAL PROTOTYPE INTERVENTION

The intention of the Action component of the City Action Lab platform is to provide a toolbox of strategic potential interventions that can be used when intervening in the Lab space. Each action is born out of a potential response to a challenge in the cities of study and explained in a simple way, so as to allow various users to understand the capacity of the toolbox. The idea is to encourage bottom-up creative initiative by equipping people with a comprehensible toolbox.



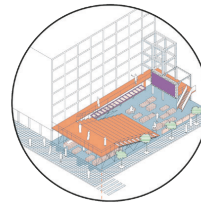
REVIVE RE-USE RE-PROGRAM

Restoring and re-purposing listed buildings would help to reverse the state of decay, while generating employment opportunities and promoting awareness of cultural assets. To revive vacant and deteriorating sites at low-cost, as well as building future capacity, a scheme should be implemented combining restoration work with targeted vocational training.



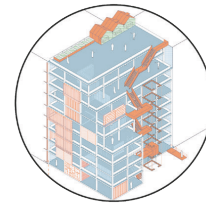
KIDS ON THE BLOCK

Playgrounds provide social, physical, and developmental benefits for children, as well as welcoming spaces for cross-cultural interaction. While playgrounds reinforce community cohesion, in the end, proximity predicts use. A series of publicly owned vacant lots could be transformed into playgrounds.



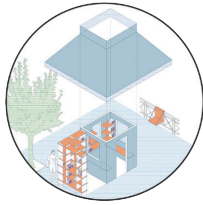
URBAN THEATRE

Vacant lots could be transformed into open-air theatres or pop-up cinemas projecting on to the exposed facades of adjacent buildings. The urban theatre prototype consists of a simple steel frame accommodating tiered audience seating, along with small wooden palettes that can be used as extra seating, planters, or stage elements. Additional programs like a bar or market stalls can also nest under the elevated structure. Beyond theatrical productions and film screenings, these multi-purpose facilities could host local street festivals and public art installations.



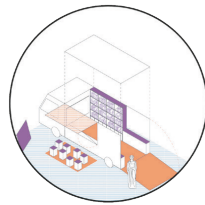
PLUG IN PLUG ON

The 'Plug In-Plug On' system represents a simple, inexpensive kit of parts that prepares buildings for public and private use. The system comprises a catalogue of new infrastructural elements to support accessibility and circulation. In unfinished buildings, for instance, a temporary stair core with provisions for plumbing toilets and electricity could be added, along with simple railings and surfaces.



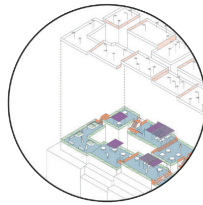
LITERARY KIOSK

Kiosks in the city centre could be re-purposed and added to serve as small-scale libraries or book exchanges that contribute to the integration of diverse communities. The revamped kiosk design could include both book storage and seating to encourage patrons to linger in an open-air 'reading room'.



MOBILE SCHOOL

The 'Mobile School' model, which began in Guatemala and Bolivia, represents a way to re-engage children locked out of the conventional schooling system through informal educational activities delivered in a familiar environment. Combining and adaptable mobile school cart with tailored educational games that touch on themes from literacy and numeracy to health awareness and creative therapy, the program would not only break down social barriers, but also temporarily activate underused public spaces in the city.



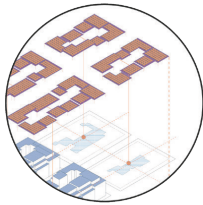
MOVING ON UP

Connecting clusters of rooftops using a system of simple elements like stairs and ladders could not only introduce a new form of vertical accessibility, but also open up the possibility of elevated networks of semi-public spaces for neighborhood interaction and integration.



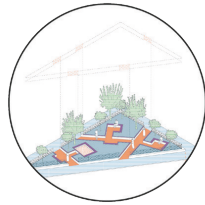
DRIVE MY CAR

The peer-to-peer car-sharing model operated in German cities by 'Tamyca' could be introduced in the city centre as a way to incentivize lower rates of car ownership, liberate public space dedicated to parking, and reduce congestion. Using an online platform, car owners could rent out their vehicle when it would otherwise be sitting idle, most often to neighbouring residents. Maximizing efficiency, it is estimated that one car participating in this car sharing scheme is able to compensate for up to nine cars usually on the road.



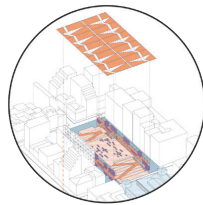
SELF SUFFICIENT BLOCK

A decentralized energy system achieved through the installation of rooftop photovoltaic and thermal panels could allow buildings to become partially self sufficient, reduce the cost of maintenance over time, and lessen the energy burden on the city. Excess energy generated via this updated infrastructure could be sold back to the city grid, raising revenues for reinvestment. In time, various blocks could be brought together in a neighborhood-scale network, consistent with a 'district energy' model.



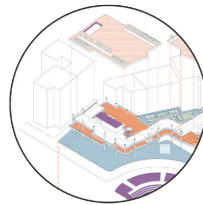
POCKET PARK

Cutting through these fences to create new entry and exit points, as well as the carving out of low-cost bench seating, would be a simple way to realize the true potential of existing fragmented "pocket parks" as engaging neighborhood green spaces. Similarly, minor improvements like the planting of additional trees and shrubs via a participatory community process would not only increase visual appeal and address issues of neglect, but also help shift expectations about future maintenance and upkeep by promoting local ownership.



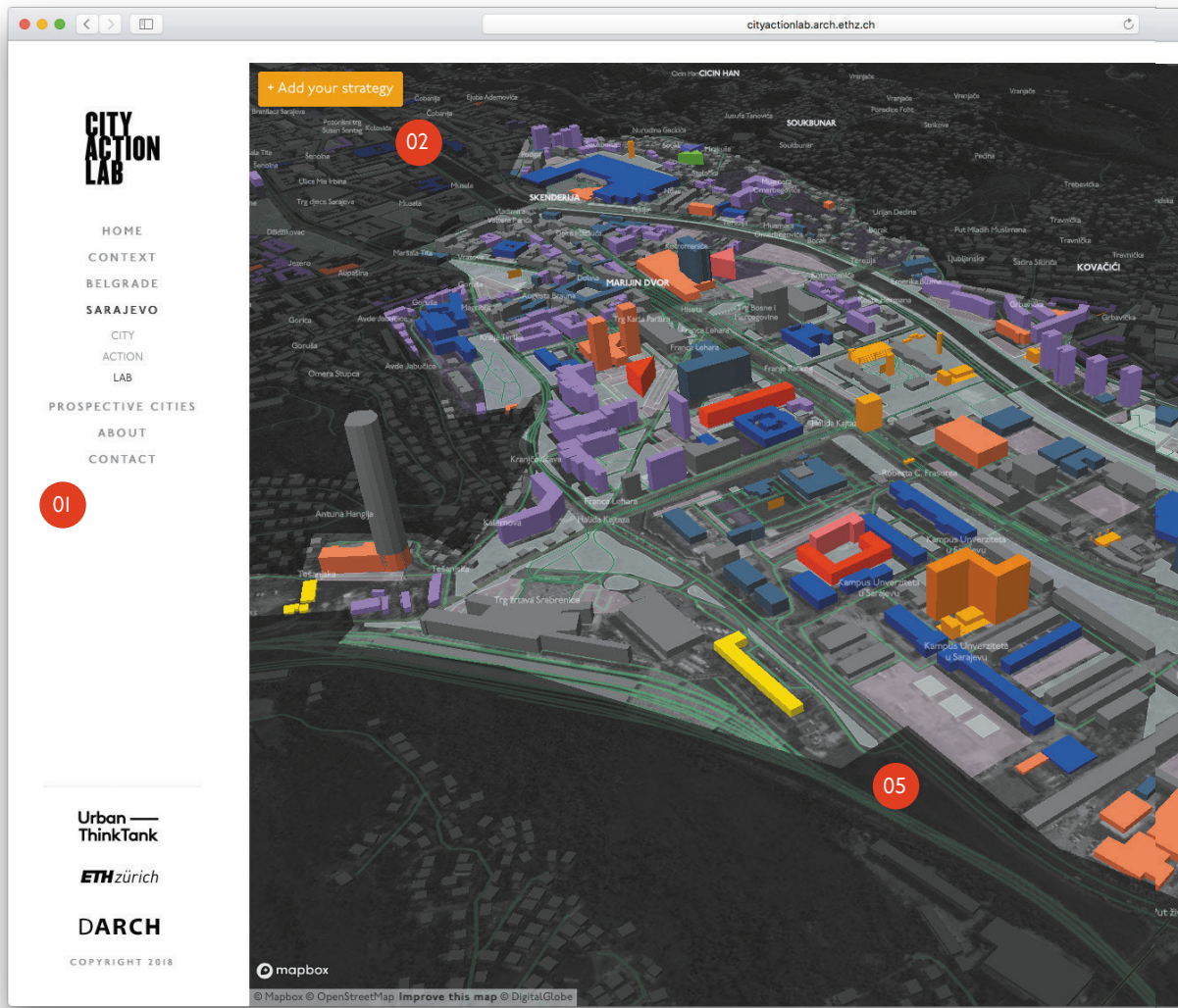
MULTICULTURAL MARKET

The addition of a lightweight roof over the often-deserted square would provide a protected area for all weather conditions, while a simple and adaptable scaffolding-based support structure would also create spaces for temporary mobile vendor stalls. Additional public seating beneath could complement these interventions. Due to its flexible design, the market would be able to accommodate other uses at different times, including events to activate the square and surrounding streets in the evening, when activity usually ceases after the adjacent central market closes.

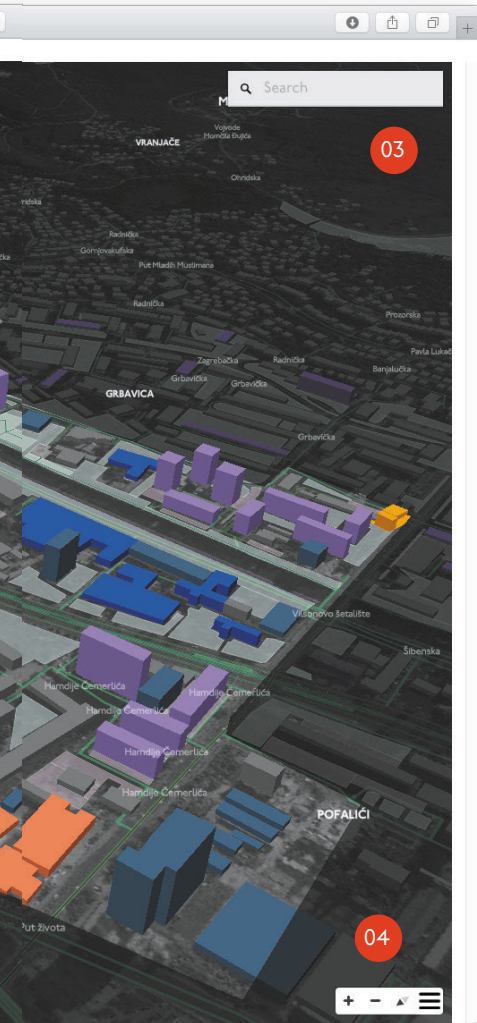


GET PHYSICAL

Sport has the capacity to activate unused spaces while providing safe, inclusive environments for children and youth, as well as promote healthy lifestyles for residents of all ages. Several of the vacant lots in the city center are larger than a single building plot. With the addition of a simple roof design and basic landscaping, these could be transformed into year-round, multifunctional playing spaces. Similarly, a manual that outlines the field dimensions and basic infrastructure required for a range of popular sports and games would empower local communities to repurpose smaller lots.



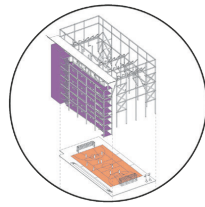
Main graphical user interface of the City Action Lab platform



01. Main navigation menus of the platform
02. User generated input for strategies
03. Search mask to find existing elements and strategies placed into the platform
04. Navigaton including layerselection
05. Main 3D interactive canvas

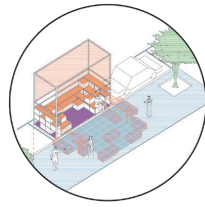
During several onsite workshops in Belgrade and Sarajevo following existing key elements including a 3D building survey where collected on a open source platform made accessible through the City Action Lab platform:

- | | | | |
|---|---------------------|---|----------------------|
|  | Commercial objects |  | Pedestrian paths |
|  | Highways |  | Private institutions |
|  | Informal activities |  | Public housing |
|  | Informal paths |  | Public institutions |
|  | Leisure |  | Recreation |
|  | Parking |  | Urban gardening |



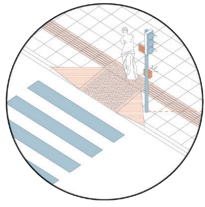
VERTICAL GYM

The 'Vertical Gym' is a low-cost, flexible design for a multi-level recreation complex, comprised of a pre-fabricated kit of parts that can be assembled in three months and customized to maximize the latent potential of any public space. The foundation slab is superimposed upon an existing sports field, while the structure can be custom configured over four levels to support a multitude of sports and cultural activities, capped by a rooftop open-air playing pitch with covered spectator zone. The gym can also be adapted to the needs and means of clients, whether by building specific parts, or in phases over time.



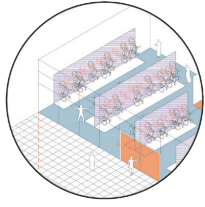
PROGRAMMED PARKLET

The 'parklet' model initiated by Rebar in San Francisco represents a simple, 'user-generated' strategy to expand the public realm where existing sidewalk width is insufficient to support a vibrant street life. Parklets are inexpensive projects that occupy curbside parking spaces and provide pop-up public amenities or micro green zones. Similarly, in contrast to partial sidewalk extensions intended largely to boost walkability and reduce traffic flows, parklets play a more dynamic role as multi-functional public spaces capable of hosting a range of flexible programs.



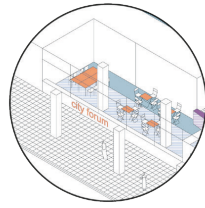
COUNTDOWN SIGNALS

Elderly and disabled people need to know they have sufficient time to complete their crossing safely. The introduction of a network of pedestrian countdown signals at key intersections, informing pedestrians of the remaining seconds available for them to cross, would be a simple and inclusive gesture to improve the accessibility of the city center. Once extra municipal funds became available, additional crosswalk enhancements could then follow in specific locations, including extending crossing times, shortening crossing distances by altering curbs and sidewalks or constructing pedestrian islands, restricting vehicular turns, and narrowing roadways.



STOREFRONT BIKE LAB

The lack of bicycle infrastructure remains a key stumbling block though to mass uptake, including an absence of secure public parking and storage facilities to protect against vandalism and theft. In response, vacant storefronts adjacent to major transportation hubs and other focal points throughout the city could be transformed into a dispersed network of 24-hour 'Bike Labs'. These well lit, but access restricted spaces could be fitted with wall mounted vertical racks to maximize capacity, and include repair stations with tools, pumps, and other maintenance equipment.



CITY FORUM

A new civic laboratory with a permanent physical presence in the city center could function as a neutral participatory platform encouraging closer collaboration between citizens, urban researchers, designers, local councils, and municipal officials. The 'City Forum' could further encourage the CityActionLab app for civic engagement. The City Forum could engage residents in the redesign and maintenance of the built environment as a means to boost social inclusion, sustainability, and livability.

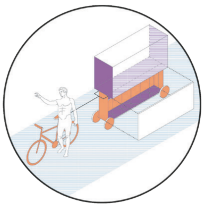
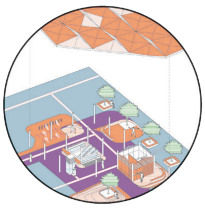


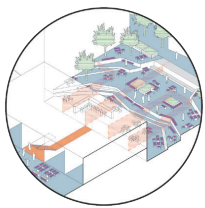
TABLE TO GO

The 'Table to Go' is a modular prototype that seats 12 people and could be towed around by a single cyclist. Due to its portability, it could be used to foster new encounters between diverse groups of citizens, while also activating empty public spaces. The mobile table represents a flexible piece of micro-infrastructure that could further strengthen efforts of community solidarity.



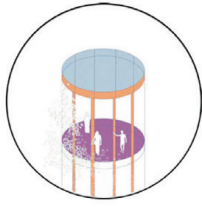
MOBILITY HUB

The 'Mobility Hub' is a new prototype that could be implemented in key transit nodes to not only facilitate and augment links between mobility options, but also densify and program these strategically important public spaces. Each hub is comprised of a roof structure that would provide the basic framework for a nested set of related programs. While flexible, in time these could potentially include bike parking (and eventually bike sharing), charging stations, public restrooms, seating, and micro retail.



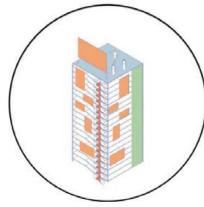
PARASITIC SEATING

The provision of public seating is a simple gesture that encourages lingering, interacting, and the use of public spaces as more than thoroughfares. Given the continued lack of funds available for public investment, a quick fix solution could be to introduce low-cost, parasitic designs that attach to existing urban infrastructure. For instance, signposts, traffic lights, and railings can all provide the support for simple, mounted chairs and benches that favor functionality and material efficiency. More importantly, their easy installation and replication would empower local communities to reshape the urban fabric of their neighborhoods to better suit the patterns of everyday life.



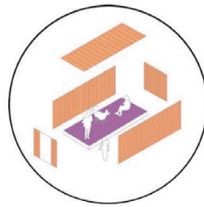
FILLING THE VOID

Inserting punctual vertical circulation interventions in existing socialist buildings to include new functions that will complement housing according to the needs of the local and their personal adaptations. These can include urban gardening, play spaces for children and workspaces that can be accessed by residents giving choice for semi-public recreational space.



THE CAR TOWER

The car tower aims to resemble the six existing towers in volume and rhythm of the façade in the its particular site of intervention. All the cars parked on the ground in the surrounding area will be placed in the tower alleviating the ground level with space for public use. The car tower aims at encouraging people to use cars less with reduced parking convenience.



MOBILE BOXES

By reoccupying parking spaces with small scale interventions, the mobile box aims at discouraging private cars from parking on the street and encourages people to enjoy and use public space. These mobile boxes are prefabricated and can adapt to various functions according to the demand and needs of the locals. The functions should differ and be located at comfortable walking distances in order. This has potential to diversify the monofunctional landuse of the site and encourage pedestrian movement through the landscape.

PROJECT HISTORY & CREDITS

ETH ZÜRICH & SARAJEVO CASE STUDY

Chief Principal Investigators
Prof. Alfredo Brillembourg
Prof. Hubert Klumpner

**Project Director,
Chief Publication Editor**
Haris Piplas, PhD (cand.)

Website tool designer, Project assistance
Michael Walczak, PhD (cand.)

Project and editorial assistance
Iva Shokoska

External consultant, Editorial assistant
Jana Konstantinova, PhD (cand.)

Academic & Administrative assistance
Nadya Vonmoos
Head of Administration
Flavia Reginato

Academic assistants
Alexis Kalagas
Gianmaria Socci
Daniel Wills
Rebecca van Beeck
Amy Rusch

Student assistants
Edvardas Bukota
Khensani de Klerk
Fernande Bodo
Alexandra Zervudachi
Mihai Radulescu
Isabel Syrek

External consultants
Carolina Giraldo Nohra
Sabina Biser
Masha Aganović
Mersel Bujak

TARTU CASE STUDY

University Professor
Prof. Dr. Kristiina Tonnisson

Postdocs
Uku Varblane
Kadri Leetmaa
PhD Candidates
Maarika Muuga
Kadi Magi

Senior Researcher
Kristijan Vassil

264 City Action Lab

PhD student
Marten Veskimäe

Analyst, assistant
Elvo Themás

Students
Johanna Holvandus
Kadi Jõgi
Aivi Themás
Tarmo Puolokainen

BELGRADE CASE STUDY

University Professor
Vladan Djokic

Associate Professors
Ana Nikezić
Ksenija Lalović

Assistant Professor
Ratka Čolić

PhD
Verica Medjo

PhD Candidate
Nataša Janković

PhD student
Aleksandra Đorđević

City of Belgrade
Milena Vukmirović

Academic researchers
Jelena Radosavljević
Ivan Simić

Partner organizations
Žaklina Gligorijević (Urban Planning Institute of Belgrade)
Milutin Folić (City Architect, City of Belgrade)

BRATISLAVA CASE STUDY

University Professors
Prof. Dr. Ing. Arch. Maros Finka
Dagmar Petriková

Postdocs
Dr. Ing. Vladimír Ondrejička
Matej Jaško
Dr. Ing. Dejan Popović
Dr. Juraj Berdis
Zuzana Ladziánská

Researcher
Jan Legen

Partner organization
Dr. Ing. Veronika Poklembova (Office of the Bratislava City Architect, Section: Public spaces)

SUPPORTERS AND PARTNERS

Swiss Federal Institute of Technology

City of Zurich

State Secretariat For Economic Affairs, Economic Development and Cooperation

City of Sarajevo

Matica of Bosnia and Herzegovina

University of Sarajevo

Swiss National Science Foundation (SNSF)

ETH Zürich Department of Architecture

State Secretariat for Economic Affairs (SECO)

Matica of Bosnia and Herzegovina

City of Sarajevo

University of Sarajevo

Embassy of Switzerland to Bosnia and Herzegovina

Historical Museum of Bosnia and Herzegovina

Ars Aevi Museum of Contemporary Art Sarajevo

Baier Bischofberger Architekten

Stadt Zürich, Department für Stadtentwicklung

École Polytechnique Fédérale de Lausanne EPFL ENAC IA LAPIS

Skopje Architecture Week

KotorAPSS: The Architecture Prison Summer School

Research Center for Spatial Planning Banja Luka

Haus der Architektur Graz

CANACTION, International Architectural Festival

Prishtina Architecture Week

Centar Arhitekture, Novi Sad

DESIGN

Web Design
Brainstormunich Media

Publication Design
Mayra Monobe

Appendix: 8.5. Exhibitions During the Doctoral Studies (Chronological Order)



Figure 134: Places en Relation / Centre Pompidou, Paris, 21.01.2018 – 24.02.2018 – CIVIC CITIES NETWORK #horspistes13 / Centre Pompidou, Co-Directors: Alfredo Brillembourg & Hubert Klumpner, Core Team: Melanie Fessel, Diego Ceresuela, Michael Walczak.
Source: <http://u-tt.com/exhibition/places-en-relation-centre-pompidou-paris/>; accessed 18.12.2020

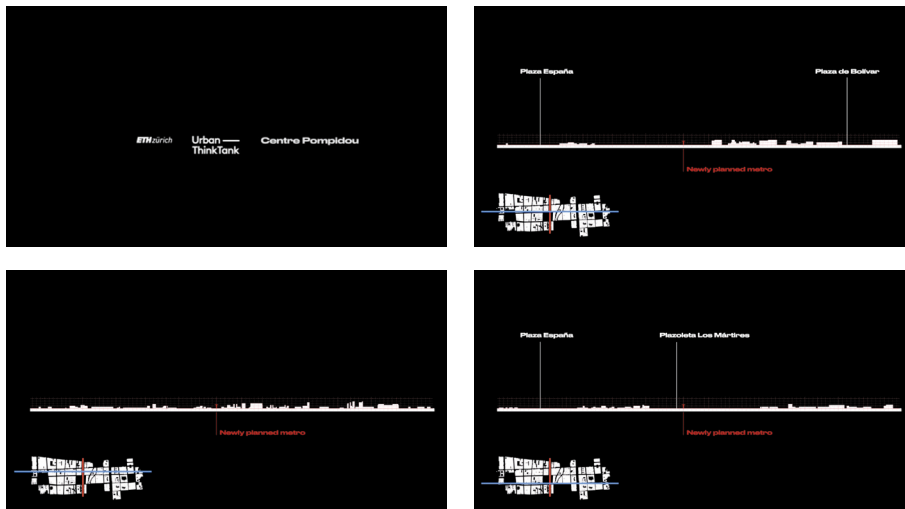


Figure 135: Stills from Sectionmaker exhibited at Places en Relation / Centre Pompidou, Paris, 21.01.2018 – 24.02.2018 – CIVIC CITIES NETWORK #horspistes13 / Centre Pompidou.
Source: Michael Walczak (2018)



ciudad isla

29.8.- 11.10 2019 //
Museo de Arquitectura
Leopoldo Rother

Créditos

Universidad Nacional de Colombia

Dolly Montoya, Rectora

Jaime Franky, Vicerrector de Sede Facultad de Artes

Carlos Naranjo, Decano

Museo de Arquitectura Leopoldo Rother

Ricardo Daza, Director

Experiencia inmersiva de realidad virtual en Bogotá

Michael Walczak, Estudiante de Doctorado

ORGANIZAN

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich




ISTP
Institute of Science, Technology and Policy
Institut für Wissenschaft, Technologie und Politik

civic city institute for critical
research and sciences
in design
www.civic-city.org

Museo de Arquitectura Leopoldo Rother
Facultad de Artes
Sede Bogotá

APOYAN

 Schweizerische Eidgenossenschaft
Confederazione Svizzera
Confederaziun Svizra
Confederaziun svizra
Embajada de Suiza en Colombia
Cooperación Económica y Desarrollo (SECO)

 **EL TIEMPO**

Figure 136: Webpage of "ciudad isla" exhibition in Bogotá.
Source: <https://ciudadisla.com>; accessed 03.02.2021

Appendix: 8.6. Teaching During the Doctoral Studies

Elective Fall '19
Start: 17. September 19
10:00 ONA, E16
 Prof. Hubert Klumpner
 Doz. Klearjos Eduardo Papanicolaou
 Arch. Michael Walczak

Mapping Narrative S Creative Geographies on Film

The course aims to use diverse qualitative research methods and practical recording tools to interrogate the notions of place-making, map-making, and socio-spatial navigation through a multi-disciplinary lens including urbanism, social research and media use.

Elective Spring '20
Start: 17. February 20
10:00 ONA, E16
 Prof. Hubert Klumpner
 Doz. Klearjos Eduardo Papanicolaou
 Arch. Michael Walczak

Filming the (un)Real City

Elective Fall '20
Start: 21. September 19
10:00 ONA, E16
 Prof. Hubert Klumpner
 Doz. Klearjos Eduardo Papanicolaou
 Arch. Michael Walczak

4D Urban Flux 24 Frames Per Second

'If photography is truth, cinema is truth 24 frames per second', the words of Jean-Luc Godard guide us we disentangle the complex urban landscape through image and sound.

This course develops new forms of urban literacy by combining ethnographic social research methods with filmmaking (using smartphones and Adobe Premiere Pro) and 3D modelling (using the Adobe After Effects and Cinema 4D).

Figure 137, 138 and 139: Elective poster on the Chair of Architecture and Urban Design website at ETH Zurich. In Fall 2019 placing films into digital models using the Unreal Engine and Adobe Premiere, in Spring 2020 and Fall 2020 putting digital models into films using Cinema 4D, Adobe Aftereffects and Adobe Premiere Pro. Teaching team: Prof. Hubert Klumpner, Klearjos Eduardo Papanicolaou and Michael Walczak. In total, 61 students attended the three editions. Source: Klearjos Eduardo Papanicolaou (2020)



Figure 140: Exemplarily still of student work, semester fall 2020 at ETH Zurich, Chair of Architecture and Urban Design. We are using Cinema 4D, Blender, Adobe Aftereffects and Adobe Premiere Pro. Source: Vinzenz Leuppi (2020)

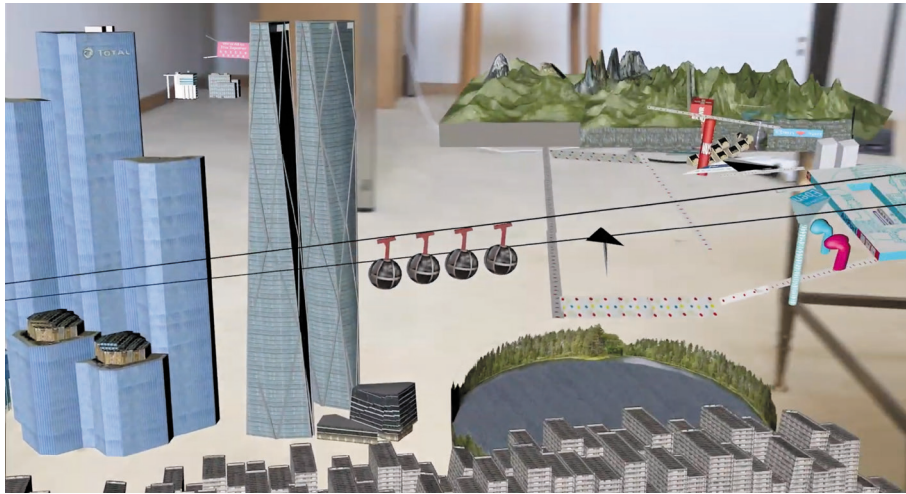


Figure 141: Exemplarily still of student work, semester spring 2020 at ETH Zurich, Chair of Architecture and Urban Design. We are using Cinema 4D, Adobe Aftereffects and Adobe Premiere Pro.
Source: Pierre Maxime Jean Bertrand Ligen (2020)



Figure 142: Exemplarily still of student work, semester spring 2020 at ETH Zurich, Chair of Architecture and Urban Design. We are using Cinema 4D, Adobe Aftereffects and Adobe Premiere Pro.
Source: Geraldine Patricia Clausen & Ming Fung Ki (2020)



Figure 143: Exemplarily still of student work, semester fall 2020 at ETH Zurich, Chair of Architecture and Urban Design. We are using Unreal Engine and Adobe Premiere Pro.
Source: Laure Dekoninck (2019)

Urban ThinkTank Chair of Architecture and Urban Design

BOGOTÁ, COLOMBIA

Design Studio: Architecture & Urban Design with Landscape
 Prof. Alfredo Brillembourg & Prof. Hubert Klumpner,
 Assistants: Diego Ceresuela Wiesmann, Melanie Fessel.
 Collaboration: Prof. Christophe Girot, Integrated Discipline Landscape.

Start
 19. Sept. 2017
 10:00 ONA, E25

Advisors:
 Michael Walczak
 Introduction to Graphic Tools:
 Rhinoceros 3D, V-Ray, Grasshopper,
 Illustrator, Photoshop, and InDesign.
 No special software skills required.

Integral Ruedi Baur
 Graphic Design

Research Partners:
 Universidad Nacional de
 Colombia, City of Bogotá
 Secretaría Distrital de
 Planeación, City of Bogotá
 Embassy of Switzerland in
 Bogotá, Colombia
 State Secretariat for Economic
 Affairs SECO, Switzerland

Organization:
 Architectural Design V-IX
 ECTS Credits - 14
 Integrated Discipline Planning
 ECTS Credits - 2

Language: German and English
 Work Group Size: 21 Individual
 Location: ONA, E25

Seminar Week: 23-27 October 2017
 Travel dates: 23-29 October 2017
 (The seminar week is not obligatory but highly recommended.)
 Participants: max. 18 students

URBAN PROTOTYPE STUDIO
 The studio will explore new building typologies for reclaiming the public spaces and urban landscapes in the area of Plaza de Los Héroes along a newly planned metro line in the city of Bogotá.

Students will undertake research by reading existing international best cases, examining local design systems, planning urban scenarios, modeling their design through various formats, and communicating their intentions in a series of sketches and renderings. Students will be encouraged to develop an individual and critical position on the potential of the selected program design process within broader social, political and economic contexts.

A series of lectures, screenings, readings, and discussions will accompany the design process. There will be plans to attract experts from the areas of architecture, urbanism, landscape, building technology and material disciplines, as well as experts from the Urban Think Tank Chair, Workshop and studio towards will be provided to raise students in effective methods of representing complex ideas through visual media.

Students will design an alternative architectural project for creating urban prototypes for the Colombia capital of Bogotá. Bogotá's typology, integrated infrastructure, and historical urban context will be analyzed. The design process will be supported by an international approach to urban development, mobility and open space. Bogotá is an emerging city that faces the pressure of the global urbanization process in the 21st century. A post-war urban model, one that is solving a new identity in the midst of a process of urbanization and reconstruction of the fragmented urban fabric in the search for a new urban identity. The design studio is seeking advanced opportunities to create an inclusive urban vision for the next metropolitan.

The public space in the city of Bogotá was last decades ago to social and political turmoil, and it is now, that the space will be re-imagined. The new urban model will be in the historic center, and its various urban forms, open spaces, parks, and adjacent built environment around Plaza de los Héroes and Avenida Central. Along the main artery of the city, the new Plaza de Héroes, an elevated metro system that will identify by creating the urban fabric and value of real estate in the area. This studio will explore advanced opportunities to develop an experimental city scenario in the three-dimensional urban building fabric, because modern and hybrid programming.

Supported by the Chair of Landscape Architecture of Prof. Christophe Girot, the studio will collaborate with representatives from the City of Bogotá and international partners and experts from the Urban Think Tank in Bogotá.

DARCH ETH

Chair of Architecture & Urban Design
 Prof. Alfredo Brillembourg & Prof. Hubert Klumpner
 Assistants: Melanie Fessel, Scott Lloyd.

Urban ThinkTank

Start
 10. Feb. 2018
 10:00 ONA, E25

This studio will explore new building typologies for addressing gentrification and immigration in one of Zurich's last authentic inner-city zones of diversity and inclusion in the Langstrasse district.

Students will design an alternative architectural project for creating urban prototypes within the historical context of the Langstrasse district of Zurich. The design process will be supported by an international approach to urban development, mobility and open space. Zurich is a city that faces many of the same challenges as other cities in the world. The design studio will explore advanced opportunities to create an inclusive urban vision for the next metropolitan.

In the role of the Swiss Patent examiner for Zurich, students will explore an approach to architecture and to time-based urban interventions by re-imagining the historical, social and economic fabric of the Langstrasse district. The design studio will explore advanced opportunities to create an inclusive urban vision for the next metropolitan.

Students will undertake research by reading existing international best cases, examining local design systems, planning urban scenarios, modeling their design through various formats, and communicating their intentions in a series of sketches and renderings. Students will be encouraged to develop an individual and critical position on the potential of the selected program design process within broader social, political and economic contexts.

A series of lectures, screenings, readings, and discussions will accompany the design process. There will be plans to attract experts from the areas of architecture, urbanism, landscape, building technology and material disciplines, as well as experts from the Urban Think Tank Chair, Workshop and studio towards will be provided to raise students in effective methods of representing complex ideas through visual media.

The studio will collaborate with associated local and international partners and experts from the fields of architecture, urbanism, landscape, building technology and material disciplines, as well as experts from the Urban Think Tank Chair, Workshop and studio towards will be provided to raise students in effective methods of representing complex ideas through visual media.

Research Partners:
 Seco

Organization:
 Architectural Design V-IX
 ECTS Credits - 14
 Integrated Discipline Planning
 ECTS Credits - 2

Language: German and English
 Work Group Size: 21 Individual
 Location: ONA, E25

Seminar Week: 19-23 March 2018
 Travel dates: 19-23 March 2018
 (The seminar week is not obligatory but highly recommended.)
 Participants: max. 18 students

DARCH ETH

LANGSTRASSE WITH LOVE

ROGUE URBANISM
 Design Studio | Spring '18

For questions, please contact
 Melanie Fessel
 mfessel@arch.ethz.ch

For more information please visit
 the Chair website
 www.ethz.ch/teaching/

Start
 18. Sept. 2018
 09:30 ONA, E25

URBAN PROTOTYPE LAB
 How can we design alternative urban paradigms that provide qualities in new town developments?

The studio proposes an inclusive urban vision for a new town development for 25,000 migrants on the edge of the city in Cartagena, Colombia. A new settlement strategy and methodology for urbanization will be designed to grow a village into a city. The design will focus on one central space within this development that provides identity, centrality, and safety. Each student will design a prototypical plan building type of production, addressing mobility and hybrid programming including work and education.

Colombia is an emerging middle-income country that faces many pressures of rapid growth. The Caribbean port city of Cartagena is experiencing rapid growth and a number of social and economic challenges. The studio will focus on one central space within this development that provides identity, centrality, and safety. Each student will design a prototypical plan building type of production, addressing mobility and hybrid programming including work and education.

After 10 years of civil war, Colombia is re-building and discovering its role. The studio will explore advanced opportunities to create an inclusive urban vision for the next metropolitan.

City Making requires the definition of the urban elements both public and private that make up a city.

Supported by the Post-Industrial Foundation, founded by Hubert and Friederike Klumpner, the studio will collaborate with associated local and international partners and experts from the fields of architecture, urbanism, landscape, building technology and material disciplines, as well as experts from the Urban Think Tank Chair, Workshop and studio towards will be provided to raise students in effective methods of representing complex ideas through visual media.

This semester's studio will allow students to travel to Sarajevo (Bosnia) with the aim of engaging in the real city. They will develop solutions in collaboration with local partners with government, academia, and industry backgrounds, developing a multi-disciplinary approach that builds upon a common base. By tackling real-world urban challenges, the studio is looking to create qualities through urban and architectural projects that transcend the commercial plane.

Chair of Architecture & Urban Design
 Urban-Think Tank | Prof. Hubert Klumpner

HOW CAN YOU INVENT A CITY?

PLANO DELA POBLACION.

Urban ThinkTank

Start
 18. Sept. 2018
 09:30 ONA, E25

Team:
 Prof. Hubert Klumpner,
 Melanie Fessel,
 Scott Lloyd,
 Diego Ceresuela-Wiesmann
 (in Colombia)

Research Partners:
 ETH Zurich
 ETH Institute for Science, Technology and Policy
 SECO, State Secretariat for Economic Affairs, Switzerland/Colombia
 IDB Inter-American Development Bank
 Pontifical Bolivarian University, Medellín, Colombia
 Municipality of Cartagena

Advisors:
 Michael Walczak
 Introduction to Graphic Tools:
 Rhinoceros 3D, V-Ray, Grasshopper,
 Illustrator, Photoshop, and InDesign.
 No special software skills required.

Integral Ruedi Baur
 Project Presentation Layout

Organization:
 Architectural Design V-IX
 ECTS Credits - 14
 Integrated Discipline Planning
 ECTS Credits - 2

Language: German and English
 Work Group Size: 21 Individual
 Location: ONA, E25

Seminar Week: CARTAGENA, COLOMBIA
 Seminar Weeks: 21-26 Oct. 2018
 Travel dates: 20-28 Oct. 2018
 (The seminar week is not obligatory but highly recommended.)
 Participants: max. 18 students

CARTAGENA, CO
 Design Studio | Fall '18

DARCH ETH

For questions, please contact
 Melanie Fessel
 mfessel@arch.ethz.ch

For more information please visit
 the Chair website
 www.ethz.ch/teaching/

Chair of Architecture & Urban Design
 Prof. Hubert Klumpner
 Assistants: Melanie Fessel, Scott Lloyd
 In Collaboration with
 Chair of Landscape Architecture
 Prof. Christophe Girot

Urban ThinkTank

Start
 19. February 2019
 09:30 ONA, E25

OPEN CITY SARAJEVO URBAN PROTOTYPE LAB
 Sarajevo is an area which has lost its urban identity. The design studio will explore an approach to architecture and to time-based urban interventions by re-imagining the historical, social and economic fabric of the Langstrasse district. The design studio will explore advanced opportunities to create an inclusive urban vision for the next metropolitan.

We will define an urban paradigm based on a proactive approach to design prototypical projects in different scales in relation with local stakeholders. Projects will be developed on specific sites and urgently needed programs. The existing morphology of different regions and ethnic populations requires a new paradigm of indoor and outdoor spaces and a narrative of architecture and urban design in practice. We ask for an integration of the social, economic, and cultural re-development of the city.

The design students are focusing on identifying an underlying logic that connects the urban fragmented neighborhoods, its topographical asymmetries and asymmetries, and the nature and human-made divisions that simultaneously separate and connect Sarajevo. How can the existing infrastructure and the lack thereof, challenge and limited mobility, climate crisis and security create an inclusive urban vision that could regenerate, revitalize and transform the city?

This semester's studio will allow students to travel to Sarajevo (Bosnia) with the aim of engaging in the real city. They will develop solutions in collaboration with local partners with government, academia, and industry backgrounds, developing a multi-disciplinary approach that builds upon a common base. By tackling real-world urban challenges, the studio is looking to create qualities through urban and architectural projects that transcend the commercial plane.

Research Partners:
 Chair of Landscape Architecture,
 Prof. Christophe Girot
 ETH Case | WohnForm
 City of Zurich, Prasadilant
 SECO, State Secretariat for Economic Affairs, Sarajevo
 City of Sarajevo, Mayor's office, Bosnia and Herzegovina
 University of Sarajevo, Faculty of Architecture, Prof. Adnan Pasic
 Cantonal Agency for Planning of Urban Development, Sarajevo, Gordana Hennevisic

Advisors:
 Haris Ropis
 Expert on Post-Socialist Urban Transformation
 Michael Walczak
 Drawing & Representation Skills
 Introduction to Graphic Tools:
 Rhinoceros 3D, V-Ray, Grasshopper,
 Illustrator, Photoshop, and InDesign.
 No special software skills required.

Integral Ruedi Baur
 Graphic Design

Organization:
 Architectural Design V-IX
 ECTS Credits - 14
 Integrated Discipline Planning
 ECTS Credits - 2

Language: German and English
 Work Group Size: 21 Individual
 Location: ONA, E25

Seminar Week: SARAJEVO AND THE
 Seminar Weeks: 23-28 March 2019
 Travel dates: 22-28 March 2019
 (The seminar week is not obligatory but highly recommended.)
 Participants: max. 18 students

DARCH ETH

OPEN CITY SARAJEVO


URBAN PROTOTYPE
 Design Studio | Spring '19

For questions, please contact
 Melanie Fessel
 mfessel@arch.ethz.ch

For more information please visit
 the Chair website
 www.ethz.ch/teaching/

Figure 144, 145, 146 and 147: Design Studio Posters of Fall 2017, Spring 2018, Fall 2018 and Spring 2019 in the Urban-Think Tank Chair of Architecture and Urban Design, Prof. Alfredo Brillembourg and Prof. Hubert Klumpner, at ETH Zurich. Michael Walczak, Introduction to Graphic Tools: Rhinoceros3D, V-Ray, Grasshopper3D, Illustrator, Photoshop, and InDesign. Source: <http://u-tt.com/teaching/>; accessed 18.12.2020

Chair of / Cátedra de / Lehrstuhl für
Architecture & Urban Design
Prof. Hubert Klumpner



Design Studio | Fall '19
Start 17. September 2019
09:30 ONA Studio, E25

Urban prototype: Meta morphosis Medellín

The city teaches us valuable transformative lessons: 1) physical environment, 2) environmental, 3) people's resilience. The studio will design a prototypical urban and architectural projects inside a 60 ha area.

We will define an urban prototype based on a specific geographic location and architectural projects inside a 60 ha area.

This semester's studio will allow students to travel to Medellín, Colombia (winter week) with the aim of engaging with the urban in the real city. They will develop solutions in collaboration with local partners with government, non-profit and industry backgrounds to develop a multi-disciplinary approach to the local urban challenges. This is looking to create a dialogue through urban and architectural projects that transcend the conventional plans.

Informed by the chair's ongoing research in Colombia, the studio explores the relationship between the city, research, and the prototype.

For questions, please contact
Malena Fessel: fessel@arch.ethz.ch

Prof. Hubert Klumpner
Assistant:
Malena Fessel (ETH Zurich)
Design Representative (ETH Zurich)
In Collaboration with:
Prof. Diego Contreras Alcamano (ETHZ COL / PSU Medellín)
Prof. Alejandro Restrepo Montoya (PSU Medellín)

Organization:
Architectural Design V-IX
ECTS Credits: 18
Integrated Discipline Planning
ECTS Credits: 3
Language: German, English & Spanish
Work: Group (max. 2) Individual
Location: ONA, E25

Seminar Weeks: 21.22, October 2019
Travel dates: 20.22, October 2019

Research Partners:
ETH Hoffmann
ETH Institute for Science, Technology and Policy
UNICO Swiss Research for Economic Affairs, Switzerland / Colombia
Global Knowledge Center (GKC)
IADB Inter-American Development Bank
Pontificia Bolivariana University, Medellín
Municipality of Medellín

Institute for Landscape and Urban Studies
LUS
ARCH
ETH zürich

Chair of / Cátedra de / Lehrstuhl für
Architecture & Urban Design
Prof. Hubert Klumpner



Design Studio | Spring '20
Urban Prototype
Start 17. February 2020
09:30 ONA Studio, E25

Liquid City Rijeka

RE-ACTIVATING RIJEKA
Designing Land and Water-Borne Urbanization Processes

Rijeka is not a city with a harbor but a harbor with a city.

What do the dynamic situation of global investments, geopolitical conditions, and the remote case in the 21st century mean for Rijeka, located on the border between east and west, water and land?

The studio will re-design, re-program, and re-invent an urbanization zone for the re-establishment of a new model for a harbor city, designing toward the land and the water. Rijeka, on the border of inhabiting in the Adriatic Sea, is known to be a harbor with a city. This studio is proposing the design of a coastal prototype for the Mediterranean and the Adriatic Sea. The development mission for Rijeka, the European Capital of Culture 2020, Rijeka is a city on the border between Europe and Eastern Europe of Rijeka. The valley with, ever captures, the natural division between languages, cultures, and political systems. Setting borders and existing borders will be a design strategy for the studio, proposing a Social Cultural Zone (integrating both sides of the river in Rijeka) and a new urban prototype in the center of environmental, social, and governance issues. We provide the space for each student to develop their own multi-disciplinary approach that builds urban design projects upon common ground. Students will be encouraged to interpret the limited information and to develop their own design proposals, including an individual and critical position on the potential role of the urban form in design projects with broader social, political, and economic systems. Informed by the chair's ongoing research in the Balkan region, starting in Athens, Santiago, this semester, engages in Rijeka, Croatia, with teaching, meeting, and researching the city.

Team:
Prof. Hubert Klumpner
Malena Fessel
Diego Figueroa

Organization:
Architectural Design V-IX / ECTS Credits: 18
Integrated Discipline Planning / ECTS Credits: 3
Language: German and English
Work: Group (max. 2) Individual
Location: ONA, E25

Seminar Weeks:
Weeks 17A, Rijeka 18B, Lugano 19C
Travel dates: 16. 22, March 2020
Highly recommended:
Highly recommended

Skills:
Drawing & Representation | Michael Walczak
Introduction to Urban Design | Prof. Grasshopper, Illustrator, Photoshop, and InDesign


Graphic Design | Integral, Road and Vera Bour
Creative Commons | CC BY-NC On the Week City is offered on an extension to the studio, both in form of a 3D modeling, storytelling, and learning.

Research Partners:
ETH Hoffmann - ETH CAS
European Capital of Culture 2020 | City of Rijeka
UNICO Lab | Warsaw Helsinki

For questions, please contact:
Malena Fessel: fessel@arch.ethz.ch

Institute for Landscape and Urban Studies
LUS
ARCH
ETH zürich

Chair of / Cátedra de / Lehrstuhl für
Architecture & Urban Design
Prof. Hubert Klumpner



Design Studio | Fall '20
Urban Prototyping
Start: 15. September 2020
09:30 ONA Studio, E25

Cities within Cities

Negotiating Cultural Density

How can we re-imagine ordinary neighbourhoods through strategically engaging and internalizing their creative potential, embracing their identity through their traditions, rituals, new temporary art and cultural events?


Students are introduced to design methods and tools for neighbourhood design through cultural co-production, festivals, exhibitions, celebrations, and case-studies from the Urban-Lecture Series.

Strategic concepts respond to, negotiate and link productive collisions with diverse processes and factors that shape densification of city blocks and streetscapes. Considering day-light, programming and imagining growth processes, small scale neighbourhoods are transformed into legitimate districts, towns and Cities within Cities.

Team:
Prof. Hubert Klumpner
Diego Figueroa

In Collaboration with:
Prof. Anna Schwaninger (ETH Zurich)
Dr. Maria Gösser (ETH Hoffmann) - ETH CAS
Prof. Diego Contreras Alcamano (ETHZ COLLUR Medellín)

Organization:
Architectural Design V-IX / ECTS Credits: 18
Integrated Discipline Planning / ECTS Credits: 3
Language: German, English, Spanish and Portuguese
Location: ONA, E25



Institute for Landscape and Urban Studies
LUS
ARCH
ETH zürich

Figure 148, 149 and 150: Design Studio Posters of Fall 2019, Spring 2020 and Fall 2020 in the Chair of Architecture and Urban Design, Prof. Hubert Klumpner, at ETH Zurich. Michael Walczak, Introduction to Graphic Tools: Rhinoceros3D, V-Ray, Grasshopper3D, Illustrator, Photoshop, and InDesign.

Source: <https://klumpner.arch.ethz.ch/teaching/design-studio/>; accessed 18.12.2020

Appendix: 8.7. Conferences During the Doctoral Studies (Chronological Order)



Figure 151: #4 International City-Gaming Conference, Games for Cities Conference at the Het Nieuwe Instituut (NAi), Rotterdam, 20. - 21.04.2017. The Games for Cities programme hosted the first international conference on city-games, with leading "city-game" design experts from around the world together with urbanists and decisionmakers, exploring the role for play and games in city-making strategies. Invited Keynote Speakers: Alfredo Brillembourg and Michael Walczak. Source: Play the City (2017)

EPFL | YOU ARE | BY SCHOOL | ABOUT EPFL





English

2018 International Tech4Dev Conference > 2018 Tech4Dev Preliminary Program > Breakout Sessions > DAY 1 – Monday 2 May

[EVE09-HAB] Preferential City Making: New digital Tools for In-situ Informal Settlement Upgrading

COOPERATION & DEVELOPMENT CENTER CODEV


Le CODEV | Chaire UNESCO | Recherche | Formation | Conférence UNESCO | MOOCs pour le développement | Réseau RESCIF | CODEV calls

Share:    

[EVE09-HAB] Preferential City Making: New digital Tools for In-situ Informal Settlement Upgrading

DAY 1 – Wensday 27 June – 1:30pm-3:00pm
SwissTech | Room 2B | Level Garden

Presenters








Contact

EPFL CODEV

CM 2 - Station 10 Tel +41 21 693 60 12
CH-1015 Lausanne

cooperation@epfl.ch

Where to find us?

LAST PUBLICATIONS

Planning the Intermediate City, or How to Do Better with Little: The Case of the City of Nueve de Julio, Argentina, Prof. Jean-Claude Bolay

Rapport annuel 2017

EPFL Magazine - La coopération nord-sud pour relever les grands défis planétaires

Scott Lloyd,
URBAN-THINK TANK ETHZ, Switzerland
lloyd@arch.ethz.ch

Scott Lloyd MSc, ETH Arch. SIA works on architecture, publishing and curatorial projects with focus on alternative urban environments and the politics and aesthetics of space. He is currently a research coordinator at the Urban-Think Tank, ETHZ where he leads workshops on design and construction and coordinates the design studio. He currently operates between Zurich and Cape Town on designing and implementing participatory spatial planning workshops, negotiating research and design innovation with local construction industry and labor practices, and oversees the integration of an interface application and computational analysis from affiliated ETHZ departments.

Khensani de Klerk,
URBAN-THINK TANK ETHZ, Switzerland
deklerkk@student.ethz.ch

Khensani de Klerk is an architectural designer having recently obtained her Bachelor in Architectural Studies undergraduate degree with distinction at the University of Cape Town, South Africa. She has worked at DesignSpaceAfrica among other Cape Town firms that focus on social architecture. Her interest, work and writing focus on the relationship between identity politics and architecture, an evident response to a socially troubled Post-Apartheid South Africa. She writes about these notions of Intersectional Space in her blog *Matr-Arch(itecture)*

Michael Walczak
URBAN-THINK TANK, ETHZ
walczak@arch.ethz.ch

Michael a architect, researcher, lecturer and assistant. He has studied architecture at the Bern University for Applied Sciences (BFH) in Burgdorf, where he attended a project semester at Stanford University and an exchange semester at the Bremen University of Applied Sciences. Michael is bridging interdisciplinary to the ETH Zurich institutes Laboratory for energy conversion (LEC) and the ISTEP Urbanization Research Incubator. He is currently working on a PhD between ETH and the University of Applied Arts in Vienna and lecturing on digital technologies at the University of Applied Sciences and Arts Northwestern Switzerland (FHNW) in Muttenz.

Summary

The interactive workshop will be focused around a role-playing simulation of an insitu urban upgrade supported by a physical model of an informal settlement and real-time digital planning tool simulations. Participants will be assigned a role as a resident and be given certain parameters and preferences that will shape the decision making and input to the digital tools (current unit size, preferential neighbors, micro-finance affordability assessment, family size) with this, participants will then select preferred locations and unit sizes and participate in the group discussions on preferred street layouts, courtyard sizes. The structure will be formatted to maximize participant preference inputs based on assigned roles and encourage debate and negotiation.

Agenda and Speakers

INTRODUCTION PRESENTATION (25 mins)

Presentations by:

- Scott Lloyd, Australian, Architect / Researcher, U-TT ETHZ, lloyd@arch.ethz.ch
- Khensani de Klerk, South African, Social Entrepreneur / Researcher, U-TT ETHZ, deklerkk@student.ethz.ch
- Michael Walczak, Polish, Architect / Researcher, U-TT ETHZ, walczak@arch.ethz.ch

FIND AND MEET (10 mins)

Participants are given data sheets that correspond to specific units on the model. Participants are asked to find their unit and assume the character of the unit resident.

LAND READJUSTMENT EXERCISE WITHOUT DIGITAL TOOLS (25 mins)

Participants are requested to negotiate a land readjustment for the settlement based on guidelines given by

Figure 152: Interactive workshop using digital tools for land readjustment at the International Tech4Dev: Voices of the Global South UNESCO Conference, EPFL Lausanne, 27. - 29.06.2018.
Source: https://archivweb.epfl.ch/cooperation.epfl.ch/cooperation/2018tech4dev-program-day1-eve09-hab_1/index.html; accessed 05.01.2021

8th Mini Economic Forum Bosnia Herzegovina Annual Meeting 2018

29th November 2018, Thursday 14:00 to 17:00

Zurich University of Teacher Education, Lagerstrasse 2, 8090 Zurich (LAB-F040)

TOPIC

DIGITALISATION AND THE TECHNOLOGICAL TRANSFORMATION IN THE COUNTRIES IN SOUTH-EASTERN EUROPE
SOCIETY | DIGITAL TRANSFORMATION | BUSINESS | ECOSYSTEM | INNOVATION | EDUCATION | RESEARCH

Agenda

13.30	Registration
14.00	Presentations, short-inputs, à 10 minutes
15.00	Open forums
16.00	Apéro & Networking (LAB-F000)
17.00	<i>Short city walk</i>
17.30	Field visit in the City Zurich, KOSMOS (https://kosmos.ch/)
19.00	Dinner in KOSMOS

Speakers

Prof. Dr. Hubert Klumpner, Head of ETH Zurich institutes Urban-Think Tank Chair of Architecture and Urban Design & Architect **Michael Walczak**, PhD candidate, ETH Zurich Chair of Architecture and Urban Design, Laboratory for energy conversion (LEC) and the ISTP Urban Research Incubator

Title: Digitalisation and urban transformation

Dr. Adis Merdžaović, Political scientist & journalist

Title: Democracy in the Digital Age

Semir Mušinić, Dipl. Eng. Adviser for spatial planning and investments, Mayor's Office, City of Sarajevo

Title: Digitalisation and the future challenges in the City Sarajevo

Anna Schindler, Director of Urban Development Office, City of Zurich

Title: Smart City Strategy

Prof. Dr. Muhamed Hadžabić, International University Sarajevo & **Dr. Adnan Mašić**, Faculty of Mechanical Engineering, University Sarajevo

Title: Digitalisation and science - practical experiences

Sibylle Hägler, State Secretariat for Economic Affairs, Economic Cooperation and Development

Title: Urban Infrastructure - Challenges and Potential of Digitalisation in Developing and Transition Countries

Figure 153: Presentation of "Digitalisation and Urban Transformation" during the program of the 8th Mini Economic Forum of Bosnia Herzegovina hosted in Zurich on the 29.11.2018.
Source: Matica of Bosnia and Herzegovina (2018)

MATICA BOSNE I HERCEGOVINE
INTERNATIONAL CENTER OF MATICA BIH
BLEICHERWEG 64A
CH-8002 ZÜRICH

Mini Economic Forum
Bosnia Herzegovina

Aims of event

- This is a standard periodical meeting to discuss and review the current economic situation in BiH
- In the long term, it should enhance economic links between Switzerland (and Europe) with Bosnia, aiming at stimulating its economy and reducing unemployment
- It should contribute and help Bosnia to emerge from its current economic low position
- It should analyse the ways of encouraging investments in Bosnia
- It should build up a network of people who share common commercial interests and aims
- It should highlight the advantages and problems arising through business connections with Bosnia

If you need further information, please don't hesitate to contact us via mail or below the number +41 76 399 68 69.

8th Mini Economic Forum Bosnia Herzegovina has been organised in open cooperation with:



Figure 154: Aims and partners of the 8th Mini Economic Forum of Bosnia Herzegovina hosted in Zurich on the 29.11.2018.

Source: Matica of Bosnia and Herzegovina (2018)



Figure 155: Participants of the 8th Mini Economic Forum of Bosnia Herzegovina hosted in Zurich on the 29.11.2018.

Source: Matica of Bosnia and Herzegovina (2018)

ETH Zurich > D-ARCH > SHARELAND Doctoral Colloquium English

ETH zürich

SHARELAND Doctoral Colloquium

Background Expert Critics Programme Call for Papers - CLOSED Venue/Travel Information Registration

Homepage > Programme

Programme

Open all + Close all -

Plenary Schedule	Open +
Thematic Track Session: 'Sharing' (ONA E16)	Open +
Thematic Track Session: 'Dwelling' (ONA E 30)	Open +
Thematic Track Session: 'Co-creating' (ONA E 34)	Close -

Begins	Details
16:00	MICHAEL WALCZAK Qualitative visualization of quantitative urban models impacting policy decision making: A case study of urban infrastructure intervention
16:40	Moderated Discussion

Figure 156: Paper presentation at the Shareland Doctoral Colloquium, ETH Zurich, 06.04.2019.
Source: <https://shareland.colloquium.arch.ethz.ch/programme.html>; accessed 05.01.2021



Figure 157: Participants of the Shareland Doctoral Colloquium, ETH Zurich, 06.04.2019.
Source: <https://shareland.colloquium.arch.ethz.ch>; accessed 05.01.2021



Athens Institute for Education and Research
A World Association of Academics and Researchers
 25 Years of Non-Euclidean Improvement



Home Page Mission Policy Conferences-Events Conference Information General Information Publications Web Tv Contact

10th Annual International Conference on Urban Studies & Planning
 Program (Athens Local Time)
 (In the program presentations are included from all the subjects scheduled to be presented in parallel)
 (Note: each presentation includes at least 10 minutes for questions and discussions if available)

Tuesday 2 June 2020

13:00-13:30
David Michael Kretzer, PhD Student & Research Assistant, ETH Zürich, Switzerland.
Michael Walczak, PhD Student & Research Assistant, ETH Zürich, Switzerland. *Title: The Impact of Vertical Densification on Public Lighting in Informal Settlements: Using Virtual Environments as Evaluation Tool for Policy-Making. (PowerPoint)*

◀ Show Less

There are a variety of reasons to support the premise that public lighting is beneficial to urban communities. However, the provision of public lighting in informal settlements is challenged by their constant physical transformation. The aim of this paper is to evaluate Virtual Environments (VE) application in lighting planning and policy-making. Even though VEs offer the opportunity to explore an environment by freely navigating through it, including environments which change over time, this feature is rarely taken into account in decision-making processes. A VE-based analysis tool for informal settlement lighting based on a case street in the informal settlement Caracoli in Bogotá is presented. A household survey, spatial measurements, participants observations, and luminous intensity distribution curves constituted the main data basis for the VE scenarios. Time-related data on the incremental construction of Caracoli's informal dwellings were collected by the household survey, and those data then projected into past, present and future night-time scenarios. Customized game engine technology and GPU computing was used, which allowed for real time visualization of various lighting scenarios. This setup therefore enables fast iterative feedback loops with regards to current and future lighting policy scenarios and the resulting lighting design. On the one hand, a VE can illustrate well how the current lighting policy results in a significant delay of lighting provision in the early stage of a settlement. Furthermore, that there is a mismatch between lighting technology and the built environment during the vertical densification phases. On the other hand, the VE is able to show alternative lighting technology and policy approaches as well as the resulting lighting effects. This allows for a visual comparison of different policy scenarios over several decades. It will be concluded by arguing that the dynamic VE technology seems to be a promising decision-making tool to illustrate potential planning and design shortcomings, in layman's terms, to policy stakeholders.

Figure 158: Paper presentation at the 10th Annual International Conference on Urban Studies & Planning, 01. - 04.06.2020, Athens, Greece.
 Source: <https://www.atiner.gr/2020tra-pro>; accessed 05.01.2021

kunst universität linz mailsystem ufgonline deutsche version

University Studies Arts.Research Gallery Current

Studies: Degree Programmes > PhD Study > News

back

SYMPOSIUM

3. Doktorand_innen Symposium der Architektur

17. und 18. Oktober 2019
 Kunstuniversität Linz, Hauptplatz 6, 5. OG, Repräsentationsraum West

Das öffentliche Symposium bringt Doktorand_innen der sechs kooperierenden Universitäten zusammen mit dem Ziel, aktuelle Perspektiven der Architekturforschung zu diskutieren.

FREITAG
18. Oktober 2019

09.00 bis 12.15 Uhr
PANEL III: CITY / URBANISM (in English)
Respondentin: Lina Streeruwitz

Karin Miesenberger (Angewandte): Massively Parallel Cloud Construction. Application Matrix for Emerging Technologies in the Implementation of high-density Residential Construction Projects in challenging Environments. Case Study "Slums in Mumbai"
Xian Zheng (UFG): Performative Urbanism as social strategy to research village life
Kamile Batur (TU Wien): Istanbul between Fear and Hope. Governing by Emergency
Michael Walczak (Angewandte): Qualitative visualization of quantitative urban models impacting policy decision making: A case study of urban infrastructure interventions








Figure 159: Paper presentation at the "3. Doktorand_innen Symposium der Architektur", Kunstuniversität Linz, 17. - 18.10.2019.
 Source: <https://www.ufg.at/Newsdetail.6932+M53e86b656d5.0.html>; accessed 05.01.2021


Appendix: 8.8. Online Publications During the Doctoral Studies (Chronological Order)

NSL Netzwerk Stadt und Landschaft
Network City and Landscape

[Projekte](#) [Lehre](#) [Publikationen](#) [Aktuell](#) [Kontakt](#) [DE](#) [Q](#)

ETH zürich

Urban Game: Action! On the Real City



Initiated in 2014, the Urban-Think Tank Chair is developing an urban game that aims to facilitate decision-making and design processes to understand complex, real-life urban transformations in cities worldwide. Part educational tool, part platform for scenario planning, the ongoing project supports a sustainable approach to urban development while incorporating principles of social design.

The interest of the Urban-Think Tank Chair of Architecture and Urban Design in gaming arose out of our commitment to exploring new forms of participatory planning. We were inspired, for instance, by the work of Lucien Kroll, where an evolving physical model became a record of the design process. The first version of our urban game, a board game, was conceived around the idea that there should be no winners or losers. The game was developed as a basis for discussion and negotiation between different players adopting the roles of various stakeholders in the process of urban development. Participants learnt how to define common visions and justify urban planning decisions in an integrated, trans-disciplinary framework free from competitive dynamics.

The environment of the first prototype was a simplified *tabula rasa* grid that included a limited selection of urban elements: building blocks (commercial, residential, and productive), roads, and public infrastructure. In the period since, the game has been updated through an ongoing iterative process connected to a series of workshops and elective classes with students. The second prototype increased the complexity by shifting the baseline scenario to a pre-existing context and distributing specific stakeholder roles with clear individual objectives that were linked by a common focus on improving the overall «urban quality». As a result, moves within the game evolved from isolated decisions to more cooperative consensus-generating proposals.

The Ultimate Vision: A Gaming Tool for All Kinds of Urban Planning

The third and fourth game prototypes are attempting to make the jump to digitalization, as a means to improve elements of scenario projection and agent-based modeling. This will allow the better incorporation of factors like time, land value, service delivery, and social cohesion. The main challenges encountered to date include: identification of relevant parameters constituting the urban environment, simplification of real case studies, and the creation of a coherent and transferable «urban quality index». Our ultimate vision is to establish a suite of physical and digital gaming tools that can be employed to support real-world planning processes at different scales – from the reorganization of community housing in a South African township, to simulations that project future scenarios across an entire urban territory.

Michael Walczak is scientific collaborator at the Institute of Science, Technology and Policy (ISTP). Author: Alexis Kaiagas.

Dieser Artikel wurde im folgenden Newsletter publiziert:

34 | Juni 2017: Ein Blick in die Zukunft

Autonome Fahrzeuge auf der Überholspur?
The Future is (the Housing) Cooperative
Urban Game: Action! On the Real City
Visionierung in der partizipativen
Landschaftsentwicklung

Kurzmeldungen

«Common Water – The Future of an Alpine Resource»
– NSL Kolloquium am 21. Oktober 2017
Landschaft in einer neuen Dimension erleben
Renewable Energy Infrastructures for Switzerland
Theater for Informal Settlement
Filme zu guten Beispielen der Innenentwicklung

Publikationen

Cost-based analysis of autonomous mobility services
Reactivate Athens: 101 Ideas
Spielräume für Dichte. Der
Innenentwicklungskompass als problemorientierte
Methode für Verdichtung in kleinen und mittleren
Gemeinden
Autonomous vehicles: Pedestrian heaven or
pedestrian hell?
Effects of low speed limits on freeway traffic flow
Arcadia. A Journey into the Pastoral

Figure 160: ETH Zurich NSL Newsletter on the urban game: Action! On the Real City published in June 2017

Source: <https://www.nsl.ethz.ch/urban-game-action-on-the-real-city/>; accessed 18.12.2020


University of Sarajevo

[About University](#)
[Study](#)
[Research and Cooperation](#)
[News and Events](#)

Home / News / Cooperation between ETH Zurich and the University of Sarajevo on the Urban Transformation Project REACTIVATE SARAJEVO
ENGLISH / BOSNIAN

Cooperation between ETH Zurich and the University of Sarajevo on the Urban Transformation Project REACTIVATE SARAJEVO



Thursday, May 9, 2019 - 11:06

As part of the Urban Transformation Project REACTIVATE SARAJEVO project, implemented by the Department of Architecture ETH Zurich and the University of Sarajevo, from 7 May 2019, research and measurements of wind and air flow in the Sarajevo area are carried out in the University of Sarajevo Campus. The above research is carried out by a mobile station in the vehicle windRoverII using the LIDAR system.

On Wednesday, 8 May 2019, H.E. Andrea Rauber Saxer, Ambassador of the Swiss Confederation in Bosnia and Herzegovina was present at the project implementation. The attendees were addressed by Prof. Dr. Rifat Škrijelj, University of Sarajevo Rector, who welcomed the attendees and expressed the wish to further enhance the cooperation of the University of Sarajevo with one of the most prestigious technological universities in the world such as ETH Zurich.

Visits were also attended by Mr. Patrick Egli, Deputy Director of the Swiss Embassy in BiH, Prof. Dr. Adnan Pašić, team leader in front of the University of Sarajevo, Mr. Miroslav Živanović, Head of the Cabinet of the Rector, Mr. Bojan Papić from the Swiss Embassy in BiH, Mahmuta Maša Aganović, member of the local team of the project, Ms. Gordana Memišević, expert advisor of the Sarajevo Canton Planning Bureau and employees Directorate for the construction and maintenance of the UNSA Campus Iris Bilalagić and Mirza Mehaković.

Researchers from ETH Zurich, Bojana Papić and Michael Walczak demonstrated the work of the mobile measuring station to the gathered people and introduced them to her research capabilities. The research will contribute to a better understanding of the air flow through the Sarajevo basin, with a special focus on the coverage of Marijin Dvor, which will greatly assist in the planning, design and construction of new construction structures, which is the current problem of Sarajevo.

The project was supported by the Sarajevo Canton Development Planning Institute, SECO, the City of Sarajevo, the City of Zurich and the Matica Bosne i Hercegovine.

LATEST NEWS



Guest lectures at the Department of Dramaturgy, Academy of Performing Arts
12/11/2020 - 17:20



LLL-Courses for lifelong learning within the Erasmus + project ALL4R&D
12/11/2020 - 17:14



The University of Sarajevo Presents 19 Scientific, Research And Development Projects
12/11/2020 - 17:01



The University of Sarajevo Presents 19 Scientific, Research And Development Projects
12/11/2020 - 16:58



UNSA Student Support Office: KJU Family Counseling on Pandemic Stress
12/11/2020 - 16:53

[more >](#)






UNIVERSITY OF SARAJEVO

Oslova Kulina Bana 7/II
71000 Sarajevo
Bosnia i Hercegovina
Telefon: +387 33 56 51 18
E-mail: javnost@unsa.ba

QUICK LINKS

Directory

UNSA Locations

Academic Calendar

Public Procurement

ISSS

© University of Sarajevo | [Contact](#) | [Freedom of Information and Access to Information](#)

Figure 161: Presenting the "windRover" to the Swiss ambassador in Sarajevo, the rector of the University of Sarajevo and the local team involved in the project. 09.05.2019.
Source: <https://www.unsa.ba/en/novosti/cooperation-between-eth-zurich-and-university-sarajevo-urban-transformation-project>; accessed 18.12.2020



Figure 162: ETH Zurich NSL newsletter on “Co-creating Public Lighting Technology and Policy for Informal Settlements” published in May 2020.
 Source: <https://www.nsl.ethz.ch/co-creating-public-lighting-technology-and-policy-for-informal-settlements/>; accessed 18.12.2020

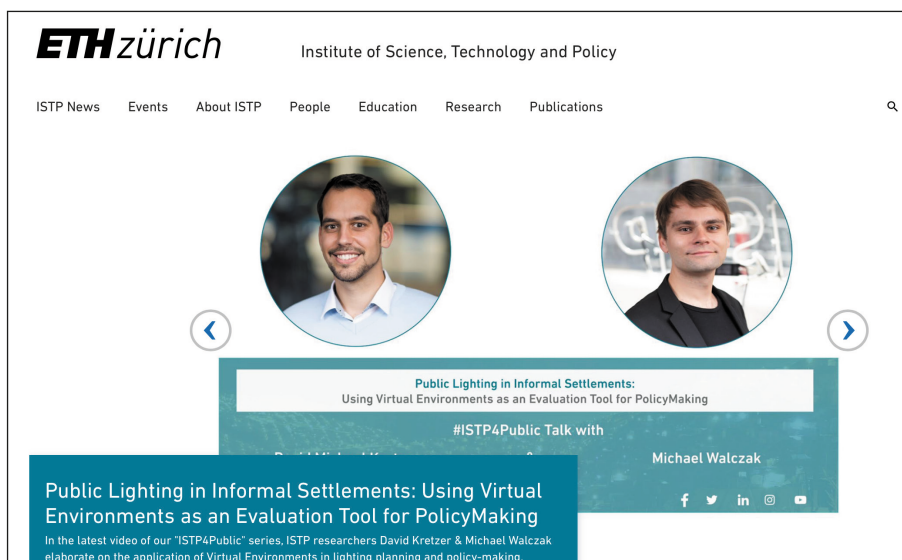


Figure 163: Publication of the “ISTP4Public” talk “Public Lighting in Informal Settlements: Using Virtual Environments as an Evaluation Tool for Policy Making” on the ISTP frontpage/splash screen.
 Source: <https://istp.ethz.ch>; accessed 22.12.2020

Appendix: 8.9. Policy Brief

ISTP Policy Brief

ETHzürich

ISTP
Institute of Science, Technology and Policy
Institut für Wissenschaft, Technologie und Politik

A DIGITAL TWIN FOR PERCEPTION MAKING IN LIGHTING PLANNING

Digital simulations of lighting and urbanization processes in informal settlements for policy communication and evidence based decision making processes.

Michael Walczak, 08/2020

INTRODUCTION

Lighting design tends to be a rather static process that is conducted before the installation of luminaires takes place. In a 'formally' built environment, it can be expected that the street and building design have been approved by a planning commission and that little physical change will take place in the future. Consequently, the lighting design is likely to be adequate for several decades. However, in an incrementally growing informal environment (dwelling material, dwelling width, dwelling length, and dwelling height are in a state of permanent transformation), the quality of the lighting design (done before the luminaire installation) is unlikely to be maintained over a long period of time.

Hence, a virtual lighting-design planning process that considers future building-density scenarios is ideal. Virtual reality (VR) based on virtual environments (VE) represents a technological opportunity for time-related design planning of this type. Existing VE and VR frameworks permit real-time visualisations to be performed using GPU technology. This makes it possible to visually explore the planning outcomes by freely navigating within a virtual space including buildings, topography and vegetation. Custom coding enables the implementation of further large-scale time-related datasets such as architectural structures (i.e. building year, material change), and footfall (i.e. motion patterns of pedestrians).

More recently, VR has been gaining attention not only in the gaming industry, but also in scientific research including medication treatments, human decision-making, and analyses of human perception.

In short, Peter Weibel (2019) summarized it as follows: "A static image can represent complex information, but it is only through animation [VR] that complex information and the impression of reality can be transmitted over a series of images shown in time."

SUMMARY

- Lighting design tends to be a static process compared to constantly changing and incrementally growing informal environments.
- Policy- and decision makers lack physical accessibility to informal environments not only during pandemics and its related "lockdown".
- Virtual access and communication for policy and decision makers could overcome the lack of perception and understanding of informal environments.
- Initiatives that focus on the development of digital twins of informal environments, could provide valuable decision making improvements in the form of planning scenarios.
- To ensure benefits derived from digital twins and virtual environments, new forms of communication media, such as virtual reality are required.
- Long-term presence of digital modelling practitioners could enhance the productivity as well as well-supported university programs for knowledge transfer/exchange.

1

Figure 164: Page 01/04 of the ISTP Policy Brief with the title: "A digital twin for perception making in lighting planning."

Source: Michael Walczak (2020)

Key Findings and Policy Implications

Apart from the lighting planning, a VE/VR tool has significant potential for lighting policy making in informal settlements, since huge parts of cities in the Global South may be informally built: 50% of Bogotá, for example, is of informal origin. First of all, access to informal settlements is often limited for outsiders – both during the day and at night. Furthermore, it can be limited because of crisis such as pandemics and its resulting social distancing and 'lockdowns'. A digital twin allows free visual exploration of highly complex built environments and urbanization processes that could also contain temporal and motion data (including information on the age, gender, and activities of people), its interrelations translated into a visual experience. The specific nature of incremental informal building growth and its direct interplay with the lighting is embedded into such a VE/VR tool as well, based on best available survey data.

Furthermore, VE is not limited in terms of scale: it could range from a one-room dwelling to a whole city – and many of the required data for the creation of the VE can automatically be processed from sources such as satellite images, and cadastral and census data. For policy makers, a VE/VR offers the opportunity to assess large-scale lighting scenarios, not only with regards to lighting quality but also regarding aspects such as legalisation processes, luminaire maintenance, lighting financing, and electricity consumption. In addition to the application of lighting planning, the VE/VR offers the

opportunity for policy makers to translate cadastral data and satellite imagery into a visual archive of city development including the time component. The data in the tool presented could automatically reconstruct a large scale informal settlement based on cadastral data and satellite imagery, with an uncertainty of only around one meter per façade which might be caused by overhangs. However, since informal settlements are not bound to building standards, which makes it impossible to accurately predict future building characteristics, this one meter of inaccuracy can still serve as a planning basis.

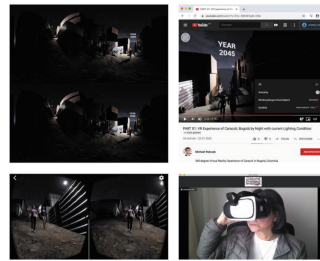


Fig. 1: Perceiving the virtual environment through different media. Top left, 360-degree 3D screenshot of virtual environment; top right, accessibility of clip through 'YouTube' platform; bottom left, 3D view for left and right eye; bottom right, policy makers in Bogotá exploring the VE clip through low-tech goggles complying with social distancing and hygienic measures during pandemics.

Figure 165: Page 02/04 of the ISTP Policy Brief with the title: "A digital twin for perception making in lighting planning."

Source: Michael Walczak (2020)

Furthermore, a pixel color comparison of the virtual environment with an actual photograph showed a very high accuracy and suggests a high degree of matching with reality.

RECOMMENDATIONS

Temporal 3D environments should be a priority for planning departments:

A VE appears to be a promising tool for the evaluation of lighting technologies in informal environments in addition to common lighting calculations. It could 'communicate' the lighting characteristics to different stakeholders in a manner understandable to the layman – for example to the non-technical staff of a city's public lighting department, to the urban planning department, to NGOs, to international donors, and to the residents of informal settlements. Moreover, the lighting characteristics can be presented in a temporal way, which would be a helpful evaluation tool for policy makers because lighting policy consequences can be projected over several decades.

Compared to a lighting evaluation based on numeric calculation results, static renderings, or pseudo colour images, a VE offers several additional key possibilities for the planning of lighting for informal settlements:

- (1) **Virtual accessibility:** Due to limited access to informal settlements, VE/VR allows the immersive and virtual exposure, inspection and planning of such settlements. VE/VR complies

with social distancing and hygienic measures which could allow for virtual communication with local residents.

- (2) **Free navigation:** The viewing radius in VE/VR is unrestricted, allowing the observer to turn around or to look up and down. Moreover, low-tech head-mounted displays (HMD) adapt the viewing direction to the natural movement of the head. This allows for a better evaluation of aspects related to the built environment such as the feeling of enclosure in a very narrow street. An observer can freely explore a three-dimensional environment from an eye-level perspective instead of relying on predefined viewpoints or camera paths.
- (3) **Dynamic objects:** A VE can include moving objects such as people which offers the possibility of exploring fear of crime caused by the lighting design in a more realistic way. As well as dynamic lighting technology such as sensor-driven adaptive lighting can be simulated.
- (4) **Urbanization processes such as densification:** Physical transformation of the built environment including materialisation (e.g. horizontal and vertical densification over time) can be dynamically illustrated.
- (5) **Numerous scenarios:** In a VE, a daylight scenario can be integrated as a direct comparison to the night-time lighting scenarios, which helps to study such effects on the fear of crime visually. Thus, it may even be possible to simulate dynamic elements of a daytime condition such

Figure 166: Page 03/04 of the ISTP Policy Brief with the title: "A digital twin for perception making in lighting planning."

Source: Michael Walczak (2020)

Further Reading:

- Kretzer, D. M., Walczak, M. [shared first authorship], (2020). The impact of vertical densification on public lighting in informal settlements: using virtual environments as an evaluation tool for policy making, *Athens Journal of Architecture*, 6, pp. 1-30.
- Walczak, M. (2019). Qualitative visualization of quantitative urban models impacting policy decision making, *Symposium der Architektur, Kunstuniversität Linz*.
- Weibel, P. (2019). *Kunst und Medien, Enzyklopädie der Medien*, Hatje Cantz Berlin.

as wind, moving clouds and trees, fog, or rain in VE/VR. Scenarios could help decision makers to visually and adequately assess 'what if' questions.

Long-term involvement with universities: To maximize the gains that can be potentially obtained from digital twins and real-time visualization technology, efforts must be made to encourage and support the relationship with local and international universities. Specific strategies could include PhD programs, semester projects or elective courses to strengthen the development and transfer of knowledge. Specific case studies could prepare the technology for decision making processes.

Who is involved in the mentioned actions:

Unidad Administrativa Especial De Servicios Públicos
 – UAESP, Subdirección Servicios Funerarios y Alumbrado Público, Bogotá

Secretaría Distrital de Planeación – SDP, Bogotá

Local residents from Caracoli district, Bogotá

Institute of Science, Technology and Policy

The ISTP is a novel, policy-oriented institute at ETH Zurich that combines research and teaching with a focus on policy, interdisciplinary research and teaching at the intersection of engineering-, natural-, and social sciences.

Mission Statement:

The ISTP seeks to support public policy-making processes by educating future policy analysts and decision-makers, supporting innovative interdisciplinary research with a policy focus, and promoting exchange between scientists, policy-makers, and society.

4

Michael Walczak is a PhD candidate at the Institute of Science, Technology and Policy (ISTP) working within the interdisciplinary Urban Research Incubator (URI) focusing on Urban Transformation towards safer, more inclusive Cities. His current research focuses on the communication of urban infrastructure scenarios in Bogotá, Colombia and Cape Town, South Africa through the development of real time visualization technology. A special emphasis lies on the interaction with policy makers, local stakeholders and residents.

Figure 167: Page 04/04 of the ISTP Policy Brief with the title: "A digital twin for perception making in lighting planning."

Source: Michael Walczak (2020)

Appendix: 8.10. C++ Code (Excerpt)

```
void AimportMobility::runGemSim()
{
    m_dCurrentTime = ((GetWorld()->GetTimeSeconds()) + timeAdd);
    double CurrentTime = ((GetWorld()->GetTimeSeconds()) + timeAdd);

    float nearest_02 = roundf(CurrentTime * 10) / 10;
    float nearest = CurrentTime;

    int time = 0;
    int hour = 0;
    int min = 0;
    int sec = 0;

    time = m_dCurrentTime;

    hour = time / 3600;
    time = time % 3600;
    min = time / 60;
    time = time % 60;
    sec = time;

    GEngine->AddOnScreenDebugMessage(-1, 1.00f, FColor::White, FString::Printf(TEXT(„%f seconds”), nearest));

    GEngine->AddOnScreenDebugMessage(-1, 1.00f, FColor::White, FString::Printf(TEXT(„%i hours, %i minutes, %i seconds”), hour, min, sec));

    for (int i = 0; i < eventtimeFinal.length(); i++)
    {
        for (int j = 0; j < subNetwork->getLinkCount(); j++)
        {
            if (linkidFinal[i] == subNetwork->getLinkId(j) && (eventtimeFinal[i] == m_dCurrentTime))
            {
                int time = eventtimeFinal[i];
                int person = personidFinal[i];

                getxfrom = (subNetwork->getLink(subNetwork->getLinkId(-j))->getFromNode()->getLocation().x());
                getyfrom = (subNetwork->getLink(subNetwork->getLinkId(-j))->getFromNode()->getLocation().y());

                getxto = (subNetwork->getLink(subNetwork->getLinkId(j))->getToNode()->getLocation().x());
                getyto = (subNetwork->getLink(subNetwork->getLinkId(j))->getToNode()->getLocation().y());

                LocationStart = FVector(getxfrom, getyfrom, 0.0f);
                LocationEnd = FVector(getxto, getyto, 0.0f);

                double distance = (subNetwork->getLink(subNetwork->getLinkId(-j))->getLength());

                int traveltime = speedFinal[i];

                float vehiclespeed = ((distance / traveltime) / distance);
            }
        }
    }
}
```

```

//%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%LOAD VEHICLES%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

FVector Direction;
FVector DirectionFinal;
LocationEnd - GetActorLocation() = Direction;

FRotator Rotation = FRotationMatrix::MakeFromX(LocationEnd -
LocationStart).Rotator();

FActorSpawnParameters SpawnInfo;

Avehicle *vehicle = GetWorld()->SpawnActor<Avehicle>(Locati-
onStart, Rotation, SpawnInfo);

vehicle->SpeedV2 = vehiclespeed;

vehicle->LocationStart = LocationStart;
vehicle->LocationEnd = LocationEnd;

vehicle->id = person;

vehicle->starttime = time;

vehicle->getxfrom = getxfrom;
vehicle->getyfrom = getyfrom;

vehicle->getxto = getxto;
vehicle->getyto = getyto;

FString id_label = FString::FromInt(person);

vehicle->SetActorLabel(*id_label);

//%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%RUNNING%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

vehicle->SetLifeSpan(traveltime);

break;
    }
}
}
}

```

Figure 168: Real-time C++ code excerpt to execute and run "GEMSim" public and private traffic simulation data in the visualisation framework.
Source: Michael Walczak (2020)

```

void AimportGDAL::readBuildEnvironment()
{
    GDALDataset      *poDS2;

    poDS2 = (GDALDataset*)GDALOpenEx(„F://GUI/Ressources/Lausanne/densification/densification.
shp“, GDAL_OF_VECTOR, NULL, NULL, NULL);
    if (poDS2 == NULL)
    {
        UE_LOG(LogTemp, Log, TEXT(„Open failed“));
        exit(1);
    }
    else
    {
        UE_LOG(LogTemp, Log, TEXT(„Open succeeded“));
    }

    OGRLayer *poLayer;

    poLayer = poDS2->GetLayerByName(„densification“);
    if (poLayer == NULL)
    {
        UE_LOG(LogTemp, Log, TEXT(„NoLayerName“), poLayer);
    }
    else
    {
        UE_LOG(LogTemp, Log, TEXT(„Layer“), poLayer);
    }

    OGRFeature *poFeature;

    poLayer->ResetReading();
    float x = PlayerLocationX;
    float y = PlayerLocationY;
    poLayer->SetSpatialFilterRect(x - radius, y - radius, x + radius, y + radius);

    int pointsCountDensification = 0;
    int pointsCountDensification2 = 0;

    while ((poFeature = poLayer->GetNextFeature()) != NULL)
    {
        OGRGeometry *poGeometry;

        poGeometry = poFeature->GetGeometryRef();
        if (poGeometry != NULL
            && wkbFlatten(poGeometry->getGeometryType()) == wkbPolygon)
        {
            TArray<FVector> vertices;
            TArray<int32> triangles;
            TArray<FVector2D> uvs;

            TArray<FVector> vertices2;
            TArray<int32> triangles2;
            TArray<FVector2D> uvs2;

            OGRPolygon *poPolygon = (OGRPolygon *)poGeometry;
            OGRLineString *poExteriorRing = (OGRLineString *)poPolygon->getExteriorRing();

            int numPoints = poExteriorRing->getNumPoints() - 1;

            OGRPoint *centerPoint = new OGRPoint;
            poPolygon->Centroid(centerPoint);

            OGRPoint *currentPoint = new OGRPoint;

```

```

if (pointsCountDensification % 2 == 1)
{
    for (int i = 0; i < numPoints; i++)
    {
        poExteriorRing->getPoint(i, currentPoint);
        vertices.Add(FVector(currentPoint->getX(), current-
Point->getY(), 0));
        uvs.Add(FVector2D(i, i + 1));

        if (i + 1 < numPoints)
        {
            triangles.Add(i);
            triangles.Add(i + 1);
            triangles.Add(i + numPoints);

            triangles.Add(i + numPoints + 1);
            triangles.Add(i + numPoints);
            triangles.Add(i + 1);
        }
        else
        {
            triangles.Add(i);
            triangles.Add(0);
            triangles.Add(numPoints * 2 - 1);

            triangles.Add(numPoints);
            triangles.Add(numPoints * 2 - 1);
            triangles.Add(0);
        }
    }

    for (int i = 0; i < numPoints; i++)
    {
        poExteriorRing->getPoint(i, currentPoint);
        vertices.Add(FVector(currentPoint->getX(), current-
Point->getY(), height));
        uvs.Add(FVector2D(i + 1, i));

        if (i + 1 < numPoints)
        {
            triangles.Add(i + numPoints);
            triangles.Add(i + 1);
            triangles.Add(i);

            triangles.Add(i + 1);
            triangles.Add(i + numPoints);
            triangles.Add(i + numPoints + 1);
        }
        else
        {
            triangles.Add(numPoints * 2 - 1);
            triangles.Add(0);
            triangles.Add(i);

            triangles.Add(0);
            triangles.Add(numPoints * 2 - 1);
            triangles.Add(numPoints);
        }
    }
}
}

```

```

else
{
    for (int i = 0; i < numPoints; i++)
    {
        poExteriorRing->getPoint(i, currentPoint);
        vertices2.Add(FVector(currentPoint->getX(), current-
Point->getY(), 0));
        uvs2.Add(FVector2D(i, i + 1));

        if (i + 1 < numPoints)
        {
            triangles2.Add(i);
            triangles2.Add(i + 1);
            triangles2.Add(i + numPoints);

            triangles2.Add(i + numPoints + 1);
            triangles2.Add(i + numPoints);
            triangles2.Add(i + 1);
        }
        else
        {
            triangles2.Add(i);
            triangles2.Add(0);
            triangles2.Add(numPoints * 2 - 1);

            triangles2.Add(numPoints);
            triangles2.Add(numPoints * 2 - 1);
            triangles2.Add(0);
        }
    }

    for (int i = 0; i < numPoints; i++)
    {
        poExteriorRing->getPoint(i, currentPoint);
        vertices2.Add(FVector(currentPoint->getX(), current-
Point->getY(), height));
        uvs2.Add(FVector2D(i + 1, i));

        if (i + 1 < numPoints)
        {
            triangles2.Add(i + numPoints);
            triangles2.Add(i + 1);
            triangles2.Add(i);

            triangles2.Add(i + 1);
            triangles2.Add(i + numPoints);
            triangles2.Add(i + numPoints + 1);
        }
        else
        {
            triangles2.Add(numPoints * 2 - 1);
            triangles2.Add(0);
            triangles2.Add(i);

            triangles2.Add(0);
            triangles2.Add(numPoints * 2 - 1);
            triangles2.Add(numPoints);
        }
    }
}

```

```

        TArray<FVector> normals;

        TArray<FColor> vertexColors;
        TArray<FProcMeshTangent> tangents;

        mesh07->CreateMeshSection(pointsCountDensification, vertices, triangles,
        normals, uvs, vertexColors, tangents, false);

        FString MaterialAddress = „Material'/Game/StarterContent/Materials/M_
        Basic_Wall.M_Basic_Wall'";
        UMaterial* materialDensification;
        materialDensification = Cast<UMaterial>(StaticLoadObject(UMaterial::
        StaticClass(), nullptr, *MaterialAddress, nullptr, LOAD_None,
        nullptr));
        mesh07->SetMaterial(pointsCountDensification, materialDensification);

        pointsCountDensification += 1;

        TArray<FVector> normals2;

        TArray<FColor> vertexColors2;
        TArray<FProcMeshTangent> tangents2;

        mesh08->CreateMeshSection(pointsCountDensification2, vertices2, tri-
        angles2, normals2, uvs2, vertexColors2, tangents2, false);

        FString MaterialAddressRoof = „Material'/Game/StarterContent/Materi-
        als/M_Basic_Wall.M_Basic_Wall'";
        UMaterial* materialDensification02;
        materialDensification02 = Cast<UMaterial>(StaticLoadObject(UMateri-
        al::StaticClass(), nullptr, *MaterialAddressRoof, nullptr, LOAD_None,
        nullptr));
        mesh08->SetMaterial(pointsCountDensification2, materialDensification02);

        pointsCountDensification2 += 1;
    }

    else
    {
        UE_LOG(LogTemp, Log, TEXT(„no polygon geometry\n"));
    }
}

```

Figure 169: C++ code excerpt to import geo-located GIS building data into visualisation framework including 3D extrusion, roof geometry and materialisation.
Source: Michael Walczak (2020)

Appendix: 8.11. Unreal Engine Blueprint Code (Excerpt)

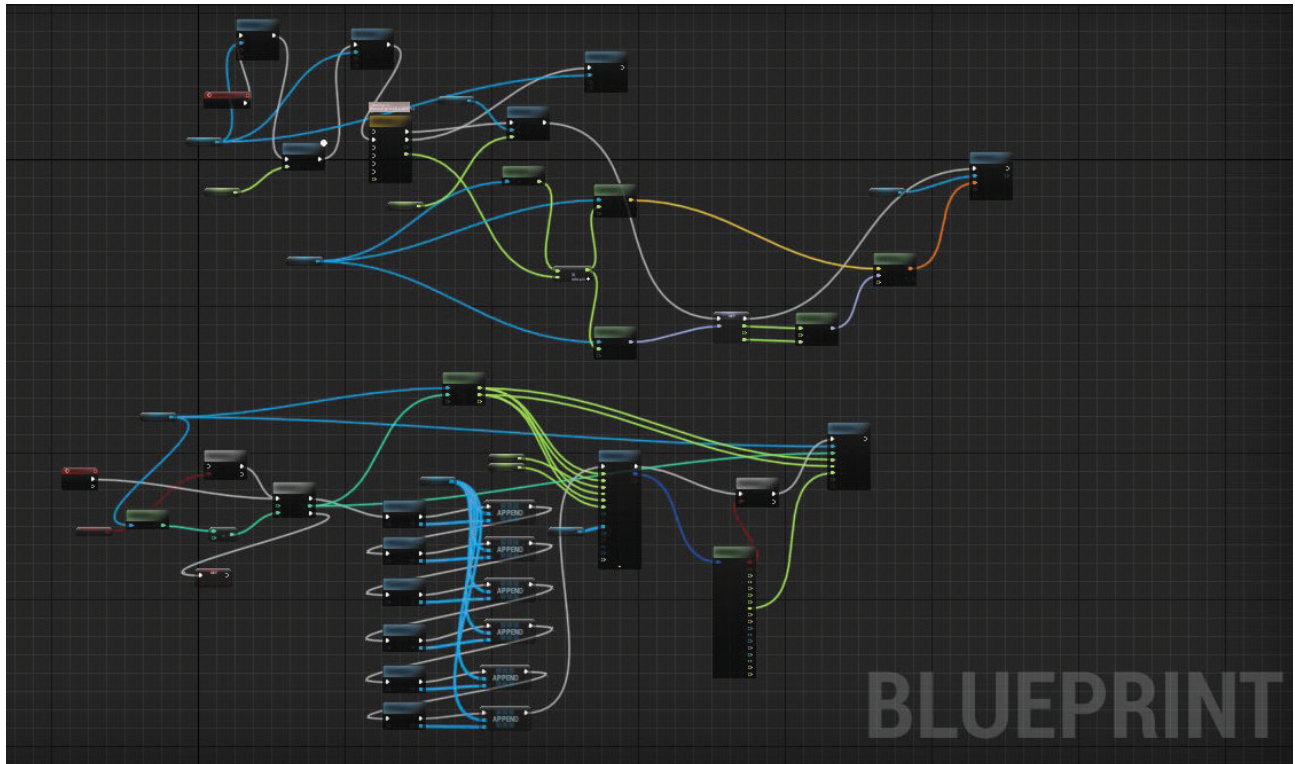
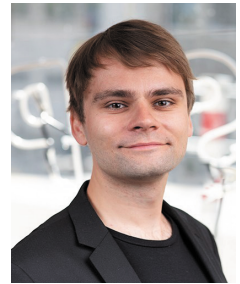


Figure 170: Unreal Engine Blueprint Code excerpt to import geo-located pedestrian motion data into a visualisation framework including a walking path, speed and 3D avatar.
Source: Michael Walczak (2020)

Appendix: 8.12. Curriculum Vitae

Michael Walczak

cand. Dr. techn. University of Applied Arts Vienna (Angewandte) (AT), ao. Univ.-Prof. Mag.arch. A. Falkeis
Master of Arts HES-SO/BFH in Architecture
Scientific Assistant at ETH Zurich; D-ARCH, Chair of Architecture and Urban Design, Univ.-Prof. H. Klumpner;
D-MAVT, Laboratory for Energy Conversion, Univ.-Prof. Dr. R.-S. Abhari; and
D-GESS, Institute of Science, Technology and Policy, Urban Research Incubator
Teacher/Docent for Digital Technologies in Architecture (Design and Modelling)
at the University of Applied Sciences and Arts Northwestern Switzerland FHNW Basel/Muttenz



Personal Details

Address Albisstrasse 82, 8038 Zurich, Switzerland
Phone +41 79 736 10 58
E-Mail michael.walczak@me.com

Education

2017 - 2021 University of Applied Arts Vienna (Angewandte) (AT), ao. Univ.-Prof. Mag.arch. Anton Falkeis
cand. Dr. in Technical Sciences (Dr. techn.)
2013 Stanford University California (USA)
Project-Semester
2012 - 2016 Bern University for Applied Sciences Burgdorf (CH)
Master of Arts HES-SO/BFH in Architecture
2011 School of Architecture Bremen (GER)
Exchange-Semester
2009 - 2012 Bern University for Applied Sciences Burgdorf (CH)
Bachelor of Arts BFH in Architecture
2007 - 2009 FOS Memmingen (GER)
High-School Diploma

Work Experience

2020 Co-teaching Guest Professorship at TU Vienna with Univ.-Prof. H. Klumpner
since 2019 Co-teaching Elective at Chair of Architecture and Urban Design, Univ.-Prof. H. Klumpner
since 2017 Scientific Assistant at ETH Zurich; D-ARCH; Chair of Architecture and Urban Design, Univ.-Prof. H. Klumpner;
D-MAVT; Laboratory for Energy Conversion; Univ.-Prof. Dr. R.-S. Abhari; and
D-GESS; Institute of Science, Technology and Policy; Urban Research Incubator
since 2016 Teacher/Docent for Digital Technologies (Design and Modelling) at University of Applied Sciences and Arts
Northwestern Switzerland FHNW Basel/Muttenz (CH)
for Bachelor of Arts in Architecture Students
2016 - 2017 Scientific Collaborator Research and Development Department Area of competence
Dencity - Urban Development and Mobility
Bern University for Applied Sciences BFH Burgdorf (CH)
2014 - 2016 External Expert for Digital Technologies (Design and Modelling) at University of Applied Sciences and Arts
Northwestern Switzerland FHNW Basel/Muttenz (CH)
for Bachelor of Arts in Architecture Students

- 2012 - 2016 Assistant Research and Development Department Architectural-Processes and Area of Competence
Density - Urban Development and Mobility, part-time with Master-studies
Bern University for Applied Sciences BFH Burgdorf (CH)
- 2012 - 2016 Project architect tomi architekten (CH)
Diverse freelance Work for App-Programming, BIM-Support, Visualisations and construction of architectural Models
- 2010 - 2011 Tutorage at Bern University of Applied Sciences BFH Burgdorf (CH)
- 2008 Internship art-J, architektur & design (GER)
- 2008 Internship Baufrizt Eco-Prefabricated-Houses Erkheim (GER)
- 2008 Internship Memminger Kurier Magazine Memmingen (GER)
- 2007 Internship Pfeifer-Marketing Media-Design Memmingen (GER)
- 2004 - 2006 Junior Company mm-netrix for IT-Support of all Computer Infrastructure (Linux & Windows) in Economy School
Memmingen (GER)

Scientific Achievements

- 2018 - 2020 Development of a large-scale, automatised and time-related simulation/visualisation framework for scenarios within
South Africa, Colombia, Switzerland and Austria, with particular focus on real-time, densification, mobility, pedestrian
motion, lighting and policy communication. ETH Zurich (CH)
- 2020 / 08 Using the visualisation framework and virtual reality as medium to communicate and qualitative study with
Colombian policy stakeholders during COVID-19 travel restrictions with particular focus on densification,
pedestrian motion and lighting. ETH Zurich (CH)
- 2019 Co-developer of the holistic and integrated agent-based simulation/software framework „EnerPol“.
Distribution under commercial software license, LEC ETH Zurich (CH)
- 2019 Setting up of an international and independent network of blockchain nodes for testing purposes.
- 2019 / 09 Elicitation study with visualisation framework and virtual reality as medium with 200 participants in
Bogotá, Colombia at Architecture Museum Lepoldo Rother, National University of Colombia. (COL)
- 2019 / 05 On-site climatic measurements with mobile laboratory in Sarajevo (BiH) including wind and air quality,
extrapolation of results with CFD simulations to city-scale and correlation with daylight. ETH Zurich (CH)
- 2019 / 01 Virtual reality perception study focusing on lighting and night-time with 100 participants
in an informal settlement in Cape Town (SA). ETH Zurich (CH)
- 2018 - 2019 Development of an automatised quantitative building regulation model for Switzerland
including qualitative measures such as daylight and views. ETH Zurich (CH)
- 2017 Co-Development of an interactive 3D webplatform for data visualisation and co-design in Sarajevo and Belgrade.
ETH Zurich (CH)
- 2017 Co-Development of an „urban gaming“ app to facilitate decisionmaking and design processes,
to understand complex, real-life urban transformations including a daylight evaluation index. ETH Zurich (CH)
- 2014 - 2017 SCCER 6 (SwissCompetenceCenter for EnergyResearch) Development of automatised model to identify building
typologies on the country scale of Switzerland. Bern University of Applied Sciences (CH)
- 2015 - 2016 Masterthesis „Contextual.Datascape.“ Development of automatised model to perform analysis of proposed urban
layouts including program, orientation, sunlight, shading, pedestrian flows and dimensions, based on data scraping and
comparison. Bern University of Applied Sciences (CH)
- 2014 / 10 Application of „Efficient-Solar-Planning Tool“ on Renovation of Housing Tower with all around Photovoltaic Facade.
Swissrenova, Bern (CH). Bern University of Applied Sciences (CH)

- 2014 / 04 Interface for realtime drawing of IFC-Objects with a Leica 3D-Disto Laser measurement.
Leica Geosystems AG; Heerbrugg (CH)
- 2012 - 2014 Development of automatised analysis of building facades for solar energy „Efficient-Solar-Planning Tool“
Bern University of Applied Sciences (CH)
- 2012 Development of parametric tool for dB-input of exhibition visitors to control interactive installation.
Designer Saturday Langenthal. Bern University of Applied Arts (CH)

List of Publications

- 2021 (tbd) Book-chapter Publication
M.Walczak. „Urban Informatics.“ Special Topics Magazine. Institute of Architecture. University of Applied Arts Vienna.
Birkhäuser Publisher.
- 2021 (tbd) Journal Publication, In review
M.Walczak. „Airquality is the result of the new 3D's paradigm: Daylight, densification and domain.“ as part of
UN-HABITAT SDG 11, volume. MDPI Journal Basel.
- 2021 / 04 Journal Publication
D. M. Kretzer and M.Walczak. „The Impact of Vertical Densification on Public Lighting in Informal Settlements:
Using Virtual Environments as an Evaluation Tool for Policy Making.“ Athens Journal of Architecture
- 2021 / 01 Journal Publication
M.Walczak. „A Multi-Dimensional Spatial Policy Model for Large-Scale Multi-Municipal Swiss Contexts.“
Environment and Planning B: Urban Analytics and City Science
- 2020 / 06 Paper Publication
D. M. Kretzer and M.Walczak. „The Impact of Vertical Densification on Public Lighting in Informal Settlements:
Using Virtual Environments as an Evaluation Tool for Policy Making.“ Conference on Urban Studies & Planning. Athens
- 2019 / 10 Paper Publication
M.Walczak. „Qualitative Visualisation of Quantitative Urban Models Impacting Policy Decision Making: A Case Study
of Urban Infrastructure Interventions.“ 3. Doktorand_innen Symposium der Architektur. Linz: Kunstuniversität Linz.
- 2019 / 04 Paper Publication
M.Walczak. „Qualitative Visualisation of Quantitative Urban Models Impacting Policy Decision Making: A Case Study
of Urban Infrastructure Interventions.“ Shareland Doctoral Colloquium, ETH Zurich.
- 2019 Book-chapter Publication
M.Walczak. „Design Your City: Lab, Interactive Map.“ City Action Lab, Integrated Urban Toolbox for Post-Socialist
Central and Eastern European Cities
- 2018 / 06 Paper Publication
K. de Klerk, S. Lloyd and M. Walczak. „Preferential City Making: New digital Tools for In-situ Informal Settlements
Upgrading.“ UNESCO Tech4Dev Conference. EPFL.
- 2016 / 10 Paper Publication
Prof. Dr. J. Huber and M. Walczak. „From GIS to the Automatic Density Analysis Model (ADAM).“
International Bauhaus Colloquium. Dust and Data. Bauhaus University Weimar.
- 2016 / 09 Paper Publication
Prof. Dr. J. Huber and M. Walczak. „From GIS to the Automatic Density Analysis Model (ADAM).“
19. BRENET Conference. ETH Zurich.
- 2014 / 12 Book-chapter Publication
R.Vital and M.Walczak. „Comparison with evolutionary algorithms of meshes produced by laser scanning and by
photogrammetry from a drone.“ Masada Notebooks, Report of the research Projects 2014, Vol. II, edifir edizione
Firenze.

- 2014 / 11 Paper Publication
R.Vital and M.Walczak „Photographing Masada by a Drone: Quantifying the Accuracy of Photogrammetry.“
18. ICOMOS Symposium. Firenze.
- 2014 / 09 Paper Publication
Prof. Dr. J. Huber and M.Walczak „Efficient-Solar-Planning Tool.“ 18. BRENET Conference 2014. ETH Zurich.
- 2014 / 05 Workshop Publication
Prof. Dr. D. J. Gerber, Prof. Dr. O. Schoch and M.Walczak „Holistic Creativity - Swiss performative design approach“
CAADRIA. Kyoto Institute of Technology (JP)

Awards/Prizes

- 2018 Urban planning competition Stuttgart ‚Rosenstein‘ with Johannes Tovatt and Ramboll Studio Dreiseitl (4th Prize)
- 2014 / 05 Finalist SolarWorld Junior Einstein Award with Efficient-Solar-Planning Tool (Top 6)
Deutsche Solar GmbH, Freiberg (GER)
- 2014 / 02 Burgdorf Innovation Prize with Event-Pavillon „FlexPlyPavilion“ (2nd Prize)
Burgdorf (CH)
- 2013 Nomination and Exhibition for Design Prize Switzerland with Event-Pavillon „FlexPlyPavilion“ (Top 4)
Langenthal (CH)

Competences

- Languages German (Mother tongue), Polish (Mother tongue), English (fluent in writing and speaking), French (Basics)
C++, Grasshopper; Python, Processing, Shell, Bash
JavaScript, PHP, HTML, CSS
- Frameworks Unreal Engine, Rhino, Ethereum Blockchain, Grasshopper Plugins including Quelea, Honeybee, Ladybug etc., EnerPol, GEMSim, Q-GIS, ArcGIS, ArchiCAD, Revit, Dialux, Ecotect, Arduino, Raspberry Pi, Access, Excel, Adobe Suite (Photoshop, Indesign, Illustrator; Dreamweaver; Premiere, AfterEffects and Lightroom), Cinema 4D, Maya, Sketchup
- OS Windows, Mac, Linux
- Hobbies Playing, Recording and Experimenting with Music Instruments
Reading, Drawing, Hiking, Plants

Effective 14.02.2021


Michael Walczak

9. Bibliography

Administration cantonale vaudoise. (2017). Zones d'affectation du sol et zones réservées.

Ahmed, F. (2017). Using 3D GIS as a Decision Support Tool in Urban Planning. 401-404.

10.1145/3047273.3047360.

Alcaldía Mayor de Bogotá D.C. (2001). Manual Único de Alumbrado Público. [Unique Manual of Public Lighting.] Bogotá: Alcaldía Mayor de Bogotá D.C.

Angel S, Lamson-Hall, P. & Blanco, Z.-G. (2016). Anatomy of density 1: Six measurable factors that together constitute urban density. Atlas of Urban Expansion, Cambridge, MA, USA: Lincoln Institute of Land Policy.

Arnheim, R. (1932). Film als Kunst. In.: Texte zur Theorie des Films (1998). Reclam Verlag. Stuttgart.

Artheau, M. (2018). Der Einfluss der digitalen Welt auf die Kulturvermittlung. In.: Share Medientechnologie und Kulturvermittlung. HeK (Haus der elektronischen Künste). Christoph Merian Verlag Basel.

Avdakovic, S. Dedovic, M.-M. Dautbasic, N. & Dizdarevic, J. (2016). The influence of wind speed, humidity, temperature and air pressure on pollutants concentrations of PM₁₀ – Sarajevo case study using wavelet coherence approach. 2016 XI International Symposium on Telecommunications (BIHTEL), Sarajevo, 2016, pp. 1-6.

Avrami, E. (Ed.). (2019). Issues in Preservation Policy. Preservation and the New Data Landscape. Heritage Data and the Next Generation of Preservation Policy. Institutionalizing Data. Co-Producing Knowledge. Building Evidence-Based Narratives. Informing Policy Agendas. Columbia Books on Architecture and the City. Columbia University Press.

Bădescu, G. (2015). Dwelling in the Post-War City Urban Reconstruction and Home-Making in Sarajevo. Revue d'études comparatives Est-Ouest, no 46,(4), 35-60.

Baecker, D. (2018). 4.0 oder Die Lücke die der Rechner lässt. Merve Verlag. Berlin.

Bargh, J. (2018). *Vor dem Denken. Wie das Unbewusste uns steuert*. Droemer Verlag. München.

Baseline. (2000). In *The New Penguin English Dictionary*. First edition. Penguin Books. London.

Bau-, Planungs und Umweltdirektoren-Konferenz. (2010). *Interkantonale Vereinbarung über die Harmonisierung der Baubegriffe IVHB*. <https://www.dtap.ch/bpuk/konkordate/ivhb/>; accessed 12.07.2019.

Beck, J. (2019). *Hyper Reality Pop*. In: Landwehr, D. (Hg.) (2019). *Virtual Reality*, Edition Digital Culture 6. Migros Kulturproduzent. Christoph Merian Verlag.

Beck, H.-E. Zimmermann, N.-E. McVicar T.-R. Vergopolan, N. Berg, A. & Wood, E.-F. (2018). Present and future Köppen-Geiger climate classification maps at 1-km resolution. *Sci Data*. 2018;5:180214. 2018 Oct 30. DOI=10.1038/sdata.2018.214.

Beirão, J. Arrobas, P. & Duarte, J. (2012). Parametric Urban Design: Joining morphology and urban indicators in a single interactive model. In *Digital Physicality - 30th eCAADe Conference, Digital Physicality - Proceedings of the 30th eCAADe Conference - 12-14. September, Czech Technical University in Prague, Faculty of Architecture (Czech Republic)*, pp.167-175.

Benjamin, W. (1929). *San Gimignano*. *Frankfurter Zeitung*. 23.08.1929. In: Kammasch, T. (2020). *Betrachtungen der Architektur. Versuch in Ekphrasis*. *ArchitekturDenken* 11. transcript publishing. Bielefeld.

Bergmann, K.-C. (2018). Macht Feinstaub die Pollen aggressiver? *MMW - Fortschritte der Medizin* 160, 8 (2018). <https://doi.org/10.1007/s15006-018-0259-9>.

Bhatt, V. & Rybczynski, W. (2003). *How the Other Half Builds*. In *Time-Saver Standards for Urban Design*, 1.3-1 – 1.3-12. Edited by D. Watson, A. Plattus and R. Shibley. New York/Chicago/San Francisco/Lisbon/London/Madrid/Mexico City/Milan/New Delhi /San Juan/Seoul/Singapore/Sydney/Toronto: McGraw-Hill.

Bibby, P. Henneberry, J. & Halleux, J.-M. (2020). Under the radar? "Soft" residential densification in England, 2001–2011. *Environment and Planning B: Urban Analytics and City Science*, 47(1), 102–118.

Bieda, A. Bydłoz, J. Parzych, P. Pukanska, K. & Wójciak, E. (2020). 3D Technologies as the Future of Spatial Planning: the Example of Krakow. *Geomatics and Environmental Engineering*. 14. 15. 10.7494/geom.2020.14.1.15.

Bijbecki, F. Stoter, J. Ledoux, H. Zlatanova, S. & Cöltekin, A. (2015). Applications of 3D city models: state of the art review. *ISPRS International Journal of Geo-Information*, 4(4):2842-2889. DOI=<https://doi.org/10.3390/ijgi4042842>.

blueCFD-Core. (2017). provides OpenFOAM 5.x, Paraview 5.4.1, <http://bluecfd.github.io/Core/Downloads/#bluecfd-core-2017-2>; accessed 07.01.2020.

von Borries, F. (2010). *Klimakapseln. Überlebensbedingungen in der Katastrophe*. Edition suhrkamp 2615. Suhrkamp Verlag. Berlin.

- von Borries, F. & Kasten, B. (2019). Stadt der Zukunft, Wege in die Globalopolis. Forum für Verantwortung. Fischer Taschenbuch. Frankfurt am Main.
- Bottazzi, R. (2020). Seeing by Numbers: A Short History of Computer Renderings. In.: Fankhänel, T. Lepik, A. (2020). The Architecture Machine. The Role of Computers in Architecture. Birkhäuser. Basel.
- Boyce, P.-R. (2019). The Benefits of Light at Night. *Building and Environment* 151: 356-367.
- Brahushi, F. Bani, A. & Çela, E. (2011). Air quality assessment of Sharra landfill-Albania. Publication place: 2nd International Conference on Air Pollution and Control (CAPAC-II) September 19-23, 2011 Antalya, Turkey.
- Brand, S. (1968). Whole Earth Catalog. Menlo Park, Calif: Portola Institute. 1968-1970.
- Brantingham, P. Brantingham, P. Song, J. & Spicer, V. (2018). Advances in visualisation for theory testing in environmental criminology. As part of: Bruinsma, G. & Johnson, S. (2018). The Oxford Handbook of Environmental Criminology. Oxford University Press.
- Bridle, J. (2020). New Dark Age: Der Sieg der Technologie und das Ende der Zukunft. C. H. Beck. München.
- Brillembourg, A. Feireiss, K. & Klumpner, H. (2005). The Simple and the Complex. In.: Informal City: Caracas Case. Edited by A. Brillembourg, K. Feireiss and H. Klumpner. Munich/Berlin/London/New York: Prestel.
- Brillembourg, A. Klumpner, H. & Kalagas, A. (2015). The Evolution of Radical Urbanism. In.: Betsky, A. Brillembourg, A. Klumpner, H. Heng Liu, D. (2015). Re-Living the City: UABB 2015 Catalogue. 6th Bi-City Biennale of Urbanism/Architecture from the 4th December 2015 to the 28th February 2016 in Shenzhen, China. Actar Publisher. New York/Barcelona.
- Bydłoz, J. Bieda, A. & Parzych, P. (2018). The Implementation of Spatial Planning Objects in a 3D Cadastral Model. *ISPRS International Journal of Geo-Information*. 7. 153. 10.3390/ijgi7040153.
- Calò, F. & Parise, M. (2009). Waste management and problems of groundwater pollution in karst environments in the context of a post-conflict scenario: The case of Mostar (Bosnia Herzegovina). Publication place: Habitat International. 33. 63-72. 10.1016/j.habitatint.2008.05.001.
- Canton of Vaud, Switzerland. (2018). Official Cadastral Survey.
- Carpo, M. (2017). The Second Digital Turn: Design Beyond Intelligence. MIT press.
- Chaillou, S. (2019). KI und Architektur – der entwerfende Computer. In Arch+ Zeitschrift für Architektur und Urbanismus. Posthumane Architektur. Nr. 236. Arch+ Verlag, Berlin.
- Chamilothori, K. Wienold, J. & Andersen, M. (2019). Adequacy of Immersive Virtual Reality for the Perception of Daylit Spaces: Comparison of Real and Virtual Environments. *The Journal of the Illuminating Engineering Society* 15, no. 2-3: 203-226.

- Chen, L. Liu, C. Zhang, L. & Zhang, Z. (2017). Variation in Tree Species Ability to Capture and Retain Airborne Fine Particulate Matter (PM_{2.5}). *Sci Rep* 7, 3206 (2017) DOI=10.1038/s41598-017-03360-1.
- Chen, Y. Cui, Z. & Hao, L. (2019). Virtual Reality in Lighting Research: Comparing Physical and Virtual Lighting Environments. *Lighting Research & Technology* 51, no. 6: 820-837.
- Citizen Science. (2021). In Oxford English Dictionary. Retrieved from <https://www.oed.com/view/Entry/33513?redirectedFrom=citizen+science#eid316619124>; accessed 28.01.2021
- Citizen Scientist. (2021). In Oxford English Dictionary. Retrieved from <https://www.oed.com/view/Entry/33513?redirectedFrom=citizen+science#eid316597460>; accessed 28.01.2021
- Colman, F. Tuin, I. O'Donnell, A. & Bühlmann, V. (2018). Ethics of Coding: A Report on The Algorithmic Condition. European Commission. Brussels. <https://cordis.europa.eu/project/id/732407/reporting>; accessed: 23.01.2020.
- Commission Internationale de l'Eclairage. (2003). Guide on the Limitation of the Effects of Obstrusive Light from Outdoor Lighting Installations. Vienna: Commission Internationale de l'Eclairage.
- Commission Internationale de l'Eclairage. (2006). Road Lighting Calculations. 3rd Edition. Vienna: Commission Internationale de l'Eclairage.
- Cybernetics. (2021). In Oxford English Dictionary. Retrieved from <https://www.oed.com/view/Entry/46486?redirectedFrom=cybernetics#eid>; accessed 07.02.2021
- Debray, R. (2003). Einführung in die Mediologie. Haupt Verlag. Bern.
- Departements Bau, Verkehr und Umwelt, Kanton Aargau. (2017). Schattendiagramm <https://www.ag.ch/app/DokTabelleFrontend/web/rechtsabteilung/index.php?controller=Download&DokId=266&Format=pdf> accessed 30.07.2020.
- DeVries, T. Holzer, M. & Primeau, F. (2017). Recent increase in oceanic carbon uptake driven by weaker upper-ocean overturning. *Nature* 542, 215–218 (2017).
- Dewi, J. Siahann, U. & Tobing, R.-R. (2015). Parametric simulation as a tool for observing relationships between parcel and regulations in unplanned commercial corridor. *Cities 2015 International Conference, Intelligent Planning Towards Smart Cities*.
- Digital. (2010). In Duden. Das Fremdwörterbuch. 10. Auflage. Dudenverlag. Mannheim. Zürich.
- Dimopoulos, K. (2019). In-World Realism. In conversation with Gerber, A. In.: Gerber, A. Götz, U. (2019). *Architectonics of Game Spaces. The Spatial Logic of the Virtual and Its Meaning for the Real*. Zurich ZHDK University of the Arts. ZHAW School of Architecture, Design and Civil Engineering, Institute of Urban Landscape. transcript Verlag. Bielefeld.

Döllner, J. Baumann, K. & Buchholz, H. (2006). Virtual 3D City Models as Foundation of Complex Urban Information Spaces. 11th International Conference on Urban Planning and Spatial Development in the Information Society. Vienna: CORP - Competence Center for Urban and Regional Development, 2006, 107-112.

Doyle, M.-R. Savić, S. & Bühlmann, V. (2019). Ghosts of Transparency, Shadows cast and shadows cast out. Applied Virtuality Book Series 13. Birkhäuser.

Duguet, A.-M. Klotz, H. & Weibel, P. (1997). Jeffrey Shaw – a users manual. From Expanded Cinema to Virtual Reality. Cantz. Ostfildern.

Dunne, A. & Raby, F. (2013). Speculative Everything. Design, Fiction, and Social Dreaming. The MIT press. Cambridge. Massachusetts. London. England

Efthymiou, D. Farooq, B. Bierlaire, M. & Antoniou, C. (2013). "Agent-Based Indicators Analysis in the Context of Policy Evaluation", in 13st Swiss Transport Research Conference, Monte Verità/Ascona, Switzerland.

Eliasson, O. (2019). Y/our future is now. Fundação de Serralves.

Eliasson, O. (2020). An Exchange of Thoughts. Olafur Eliasson in conversation with Mirjam Varadinis. In: Eliasson, O. (2020). Symbiotic Seeing. Kunsthaus Zürich. Snoeck.

Engelberth, S.-E. Sebastián, C.-E. & Posada Posada, M.-I. (2018). Thermal analysis of urban environments in Medellín, Colombia, using an unmanned aerial vehicle (UAV). Journal of Urban and Environmental Engineering. 11. 142-149. 10.4090/juee.2017.v11n2.142149.

Enz, J.-W. Hofman, V. & Thostenson, A. (2019). Air Temperature Inversions. Causes, Characteristics and Potential Effects on Pesticide Spray Drift. North Dakota State University. <https://www.ag.ndsu.edu/publications/crops/air-temperature-inversions-causes-characteristics-and-potential-effects-on-pesticide-spray-drift>; accessed 11.12.2019.

Epic Games. (2019). Unreal Engine 4.22.

Epic Games. (2020). Unreal Engine 4.28.

Falkeis, A. (2015a). Thinking Out of the Urban Design Toolbox. In.: G. Bast et al. (eds.). Arts, Research, Innovation and Society. DOI=10.1007/978-3-319-09909-5_12. Springer International Publishing. Switzerland. 2015

Falkeis, A. (2015b). Social Design – Public Action. Edition Angewandte. Book Series of the University of Applied Arts Vienna. Birkhäuser Verlag. Basel.

Falkeis, A. (2017). Urbanizing the World. In: Social Design – Urban Change: Arts as Urban Innovation. Edition Angewandte. Book Series of the University of Applied Arts Vienna. Birkhäuser Verlag. Basel.

Fankhänel, T. (2020a). Movement, Time and Architecture. In.: Fankhänel, T. Lepik, A. (2020). The Architecture Machine. The Role of Computers in Architecture. Birkhäuser. Basel.

Fankhänel, T. (2020b). Computers and Architecture. In.: Fankhänel, T. Lepik, A. (2020). The Architecture Machine. The Role of Computers in Architecture. Birkhäuser. Basel.

The Federal Assembly - The Swiss Parliament. (2004). Begriffe und Messweisen in Bau- und Nutzungsvorschriften. Harmonisierung. <https://www.parlament.ch/de/ratsbetrieb/suche-curia-vista/geschaeft?AffairId=20040456>; accessed 12.07.2019.

Federal Council of Switzerland. (2019). Federal Act on Spatial Planning, Spatial Planning Act. Art. 3, Planning Principles, Paragraph 3a. <https://www.admin.ch/opc/en/classified-compilation/19790171/index.html>; accessed: 26.10.2018.

Fotios, S. & Uttley, J. (2018). Illuminance Required to Detect a Pavement Obstacle of Critical Size. *Lighting Research & Technology* 50, no. 3: 390-404.

Fotios, S. Liachenko-Monteiro, A. & Uttley, J. (2019). Evaluation of Pedestrian Reassurance Gained by Higher Illuminances in Residential Streets using the Day-Dark Approach. *Lighting Research & Technology* 51, no. 4: 557-575.

Flusser, V. (1996). *Schriften*. Bollmann Verlag. Mannheim.

Gamma, E. Helm, R. Johnson, R. & Vlissides, J. (1994). *Design Patterns : Elements of Reusable Object-Oriented Software*. Pearson Education Limited. Harlow.

Garber, R. (2018). Präzision, Objektorientierung, Simulation. In *Arch+*, Nr. 233, Norm-Architektur – Von Durand zu BIM.

Gawlikowska, P.-S. Marini, M. Chokani, N. & Abhari S.-R. (2018). A Visualisation and Immersion Dome Experience for Inspired Participation. *J. sustain. dev. energy water environ. syst.*, 6(1), pp 67-77.

Gehl, J. & Svarre, B. (2016). *Leben in Städten: Wie man den öffentlichen Raum untersucht*. Edition Angewandte. Book Series of the University of Applied Arts Vienna. Birkhäuser Verlag. Basel.

Ghose, M.-K. & Majee, S.-R. (2001). Air pollution caused by opencast mining and its abatement measures in India. Publication place: *Journal of Environmental Management*. 2001. 63, 193-202.

Gilgen, S. & Walczak, M. (2017). *Innere Entwicklung Ringstrasse, 4900 Langenthal*. Burgdorf, Berner Fachhochschule Architektur, Holz und Bau.

Girardin, F. (2018). Das Auge der Welt. In: Offenhuber, D. & Ratti, C. (2013). *Die Stadt entschlüsseln: Wie Echtzeitdaten den Urbanismus verändern*. Stadtplanung/Informationstechnologie. Bauwelt Fundamente. Birkhäuser. Basel.

Glanville, R. (1988). *Objekte*. Merve Verlag. Berlin

Goroczny, E.-E. (2018). *Lichtverschmutzung in Metropolen: Analyse, Auswirkungen und Lösungsansätze*. [Light Pollution in Metropolises: Analysis, Effects and Solutions.] Wiesbaden: Springer Vieweg.

- Gouverneur, D. (2015). *Planning and Design for Future Informal Settlements: Shaping the Self-Constructed City*. Abingdon / New York: Routledge.
- Grams, A. (2015). *Spielräume für Dichte*. Dissertation ETH Zurich.
- Greengard, S. (2019). *Virtual Reality*. Cambridge / London: The MIT Press.
- Grieves, M. & Vickers, J. (2017). *Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems*. *Transdisciplinary Perspectives on Complex Systems*.
- Gross, B. Bohnacker, H. Laub, J. & Lazzeroni, C. (2018). *Generative Gestaltung, Creative Coding im Web, Entwerfen, Programmieren und Visualisieren in p5.js*. Verlag Hermann Schmidt. Mainz.
- Gygli, M., Grabner, H., Riemenschneider, H., Nater, F. & Van Gool, L. (2013). *The Interestingness of Images*.
- Hanspal, A. (2018). *Von selbstlernenden Systemen und intelligenten Helfern*. In *Arch+ Zeitschrift für Architektur und Urbanismus. Norm Architektur. Von Durand zu BIM*. Nr. 233. Arch+ Verlag, Berlin.
- Hao, L. Yong, H. Chunsong, L. Jun, Y. & Yonghua, W. (2019). *Characteristics of Surface Solar Radiation under Different Air Pollution Conditions over Nanjing, China: Observation and Simulation*. Publication place: *Advances in Atmospheric Sciences*. 36. 1047-1059. 10.1007/s00376-019-9010-4.
- Hausladen, G. de Saldanha, M. & Liedl, P. (2006). *ClimaSkin, Konzepte für Gebäudehüllen, die mit weniger Energie mehr leisten*. Publication place: Callwey. München. 2006.
- Healey, P. (1992). *Planning through Debate: The communicative Turn in Planning Theory*. *Town Planning Review*. 63. p. 143-162.
- Hegel, G.-W.-F. (1835). *Kunst als Medium der Erkenntnis. Ende der Kunst*. In: *Texte zur Medientheorie* (2002). Reclam Verlag. Stuttgart.
- von Heland, F. Westerberg, P. & Nyberg, M. (2016). *Using Minecraft as a citizen participation tool in urban design and decision making*.
- Hernández-García, J. (2013). *Public Space in Informal Settlements: The Barrios of Bogotá*. Newcastle upon Tyne: Cambridge Scholar Publishing.
- Hirohisa, T. & Inoue, K.-I. (2017). *Environmental pollution and allergies*. *Journal of toxicologic pathology* vol. 30,3 (2017): 193-199. DOI=10.1293/tox.2017-0028.
- Hübner, G. Pohl, J. Schöbel-Rütschmann, S. Kern, S. Gawlikowska, A. & Marini, M. (2018). *Akzeptanz Erneuerbarer Energien: Beteiligung, Visualisierung und Evaluation am Beispiel küstennaher Offshore-Windparks in Mecklenburg-Vorpommern. Entwicklung eines neuartigen Instrumentariums zur optimierten Planungsbeteiligung und Akzeptanzanalyse bei der Umsetzung großer Infrastrukturmaßnahmen im Zuge der Umsetzung der Energiewende. Final Report*. Halle (Saale).

Ikram, M. Yan, Z. Liu, Y. & Qu, W. (2015). Seasonal effects of temperature fluctuations on air quality and respiratory disease: a study in Beijing. Publication place: Natural Hazards. 79. 10.1007/s11069-015-1879-3.

Imaginary. (2000). In *The New Penguin English Dictionary*. First edition. Penguin Books. London.

Imaginary. (2021). In *Oxford English Dictionary*. Retrieved from <https://www.oed.com/view/Entry/91640?redirectedFrom=IMAGINARY#eid>; accessed 28.01.2021

Janser, A. (2019). *Knowledge in Images – Information design today*. Museum für Gestaltung Zürich. Exhibition from 20.09.2019 until 08.03.2020.

Joubert, C. (2020). Large-scale Agent-based Modelling of Contact Robbery using Graphical Processing Units and Reinforcement Learning. <https://istp.ethz.ch/research/uri/projects/abm-robbery.html>; accessed 07.02.2021

Kaganskiy, J. (2017). *The unframed World, Virtual Reality as Artistic Medium*. Haus der elektronischen Künste Basel. Christop Merian Verlag.

Kahneman, D. (2012). *Schnelles Denken, Langsames Denken. Thinking, Fast and Slow*. Penguin Verlag. München.

Kalisch, R.-E. & Schechtman, D. (2016). Diffraction of Urban Crystals, Haifa. In *Lifeobject: Merging Biology & Architecture*. Israeli Pavilion. The 15th International Architecture Biennale Venice 2016. Sternthal. Montreal, Quebec.

Kamalipour, H. & Dovey, K. (2018). Incremental Urbanism. In *Mapping Urbanities: Morphologies, Flows, Possibilities*, 249-267. Edited by K. Dovey, E. Pafka and M. Ristic. Abington/New York: Routledge.

Kamalipour, H. & Dovey, K. (2019). Mapping the Visibility of Informal Settlements. *Habitat International* 85: 63-75.

Kammasch, T. (2020). *Betrachtungen der Architektur. Versuch in Ekphrasis*. ArchitekturDenken 11. transcript publishing. Bielefeld.

Katsouyanni, K. Pantazopoulou, A. Touloumi, G. Tselepidaki, I. Moustris, K. Asimakopoulos, D. Pouloupoulou, G. & Trichopoulos, D. (1993). Evidence for Interaction between Air Pollution and High Temperature in the Causation of Excess Mortality. Publication place: Archives of environmental health. 48. 235-42. 10.1080/00039896.1993.9940365.

Kay, R.-H. (2012). Exploring the use of video podcasts in education: A comprehensive review of the literature. *Computers in Human Behavior*, 28(3), 820-831. <https://doi.org/10.1016/j.chb.2012.01.011>

Knoblauch, H., & Schnettler, B. (2012). Videography: analysing video data as a "focused" ethnographic and hermeneutical exercise. *Qualitative Research*, 12(3), 334-356. <https://doi.org/10.1177/1468794111436147>.

Kim, H. & Lee, J.-K. (2016). Relational Logic Definition of Articles and Sentences in Korean Building Code for the Automated Building Permit System.

Kim, J. (2014). Parametric Urban Regulation Models for predicting development performances. Dissertation Texas A&M University.

Kostenwein, D. (2021). Between walls and fences: how different types of gated communities shape the streets around them. *Urban Studies*. February 2021. DOI=10.1177/0042098020984320.

Kretzer, D.-M. (2020). High-Mast Lighting as an Adequate Way of Lighting Pedestrian Paths in Informal Settlements? *Development Engineering*. DOI=10.1016/j.deveng. 2020.100053.

Kretzer, D.-M. (2021). The Relationship between Public Lighting and Urban Sustainability in Bogotá's Informal Settlements. In *Transitioning to Sustainable Cities and Communities*. Edited by H. Klumpner and K. E. Papanicolaou. Basel: MDPI. [In Review].

Kretzer, D.-M. & Walczak, M. (2020). The impact of vertical densification on public lighting in informal settlements: using virtual environments as an evaluation tool for policy making. *Athens Journal of Architecture*. Athens Institute for Education and Research (ATINER) (to be published).

Kubicek, H. (2010). The Potential of E-Participation in Urban Planning: A European Perspective. In: C. N. Silva, Hrsg. 2010. *Handbook of Research on E-Planning: ICTs for Urban Development and Monitoring*. New York: IGI Global. p. 168-194.

Kuliga, S.-F. Thrash, T. Dalton, R.-C. & Hölscher, C. (2015). Virtual Reality as an Empirical Research tool—Exploring User Experience in a Real Building and a Corresponding Virtual Model. *Computers, Environment and Urban Systems* 54: 363-1 375.

Kunze, A. Dyllong, J. Halatsch, J. Waddell, P. & Schmitt, G. (2012). Parametric building typologies for San Francisco Bay Area: A conceptual framework for the implementation of design code building typologies towards a parametric procedural city model. In *Digital Physicality: Proceedings of the 30th eCAADe Conference, Prague, Czech Republic, 09/2012, Czech Technical University in Prague, Faculty of Architecture, 187-193*.

Landwehr, D. (2019). (Ed.). *Virtual Reality*. Basel: Christoph Merian Verlag, 2019.

Landbook. (2019). <https://www.landbook.net>; accessed 11.07.2019.

Lee, H. Lee, S. Park, S. & Lee, J.-K. (2015). An Approach to Translate Korea Building Act into Computer-Readable Form for Automated Design Assessment. Conference: 32nd International Symposium on Automation and Robotics in Construction, Pages 1-8 (2015 Proceedings of the 32nd ISARC, Oulu, Finland).

Leslie, R.-P. & Rodgers, P.-A. (1996). *The Outdoor Lighting Pattern Book*. New York: McGraw- Hill Publishers.

- Lynch, K. (1989). *The image of the city*. Birkhäuser. Basel.
- Maak, N. (2020). *Eurodrive: Repopulation Utopia*. Publication place: Countryside. A Report. Amo. Rem Koolhaas. Taschen Verlag. Köln.
- Maeda, J. (2001). *Design by Numbers*. MIT press.
- Maheshwari, T. Kupferschmid, J. & Erath, A. (2016). Virtual Reality as a tool to assess perception of safety and comfort for cyclists in Singapor. Great Asian Streets Symposium (GASS 2016), Singapore, Republic of Singapore, December 12-13, 2016.
- Majale, M. (2011). *Enabling Shelter Strategies: Design and Implementation Guide for Policymakers*. Nairobi: UN-Habitat.
- Mamdani, M. (1996). *Citizen and Subject: Contemporary Africa and the legacy of late colonialism*. Princeton, Princeton University Press.
- Mandelbrot, B. (1967). How Long Is the Coast of Britain? Statistical Self-Similarity and Fractional Dimension. *Science* 05 May 1967: Vol. 156, Issue 3775, pp. 636-638. DOI=10.1126/science.156.3775.636.
- Marinčić, N. (2019). *Computational Models in Architecture – Towards Communication In CAAD. Spectral Characterisation And Modelling with Conjugate Symbolic Domains*. Applied Virtuality Book Series 12. Birkhäuser. Basel.
- Marini, M. Chokani, N. & Abhari, S.-R. (2019). Immigration and future housing needs in Switzerland: Agent-based modelling of agglomeration Lausanne. *Computers, Environment and Urban Systems*. 78. 101400. 10.1016/j.compenvurbsys.2019.101400.
- Marini, M. Gawlikowska, A.-P. Rossi, A. Chokani, N. Klumpner, H. & Abhari, S.-R. (2018). Impact of Future Cities on Commuting Patterns: an Agent-Based Approach. *Environment and Planning B: Urban Analytics and City Science*, Vol. 1.
- Martin-Díaz, J. Golijanin, J. Palma, P. Oliva, M. Nofre, J. & Nihad, Č. (2018). The urbanisation on the slopes of Sarajevo and the rise of geomorphological hazards during the post-war period, *Cities*, Volume 72, Part A, 2018, Pages 60-69, <https://doi.org/10.1016/j.cities.2017.07.004>; accessed 18.12.2019.
- Masic, A. Musemić, R. & Dzaferovic, E. (2016). Temperature Inversion Measurements in Sarajevo Valley Using Unmanned Aerial Vehicles. *Proceedings of the 27th DAAAM International Symposium*, pp.0423-0427, B. Katalinic (Ed.), Published by DAAAM International.
- Masic, A. Pikula, B. & Bibić, D. (2017). Mobile Measurements of Particulate Matter Concentrations in Urban Area. Publication place: 10.2507/28th.daaam.proceedings.063.
- Masic, A. Bibić, D. Pikula, B. Dzaferovic, E. & Musemić, R. (2018). Experimental study of temperature inversions above urban area using unmanned aerial vehicle. *Thermal Science*. (00). 250. 10.2298/TSCI180227250M.
- Mathworks. (2019). *MATLAB_R2019a*. Version R2019a.

- McLuhan, M. & Fiore, Q. (2008). *Das Medium ist die Botschaft. The Medium is the Message*. Penguin Books.
- Mertens, K. (2011). *Photovoltaik. Lehrbuch zu Grundlagen, Technologie und Praxis*. Publication place: Fachbuchverlag Leipzig im Carl Hanser Verlag. Leipzig.
- Minsky, M. (1961). Steps toward Artificial Intelligence. *Proceedings of the IRE*, vol. 49, no. 1, pp. 8-30, Jan. 1961, DOI=10.1109/JRPROC.1961.287775.
- Mitchell, W.-J.-T. (2018). *Bildtheorie. [Image Theory.]* Frankfurt am Main: Suhrkamp.
- Model. (2000). In *The New Penguin English Dictionary*. First edition. Penguin Books. London.
- Model. (2021). In *Oxford English Dictionary*. Retrieved from <https://www.oed.com/view/Entry/120577?rskey=PEBkEQ&result=1&isAdvanced=false#eid>; accessed 28.01.2021
- Molina, L. & Molina, M. (2002). *Air Quality in the Mexico Megacity: An Integrated Assessment*. Publication place: Springer Science+Business Media Dordrecht. 10.1007/978-94-010-0454-1.
- De Monchaux, N. (2010). *Local Code Real Estates. Architectural Design*.
- Morello-Frosch, R. (2004). Separate but unequal? Residential segregation and air quality in U.S. metropolitan areas, Publication place: *Epidemiology*: July 2004 - Volume 15 - Issue 4 - p S134.
- Morosini, R. & Zucaro, F. (2019). Land use and urban sustainability assessment: a 3D-GIS application to a case study in Gozo. *City Territ Archit* 6, 7 <https://doi.org/10.1186/s40410-019-0106-z>.
- Moss, P. Cameron, C. & Coram, T. (2007). *Research Unit, Institute of Education, University of London: Care Work Europe (Horst Niesyto, Peter Holzwarth und Björn Maurer: Interkulturelle Kommunikation mit Foto und Video. München 2007, Verlag kopaed)*.
- Narro, N. Ricardo, A. & Yuya, K. (2020). *Decomposition of density into their components: Analysis for the case of Japan*. MPRA Paper 100322, University Library of Munich, Germany.
- Natapov, A. & Fisher-Gewirtzman, D. (2017). *Cities as Visuospatial Networks*. In: Stamatina Th. Rassia, Panos M. Pardalos (Ed.). *Smart City Networks, Through the Internet of Things*. Springer Optimization and Its Applications 125. Springer Verlag.
- Negroponte, N. (1973). *The Architecture Machine, Toward a More Human Environment*. MIT press. Cambridge.
- Neufert, E. (2019). *Bauentwurfslehre. 42. [Building Design Theory.]* Wiesbaden: Springer Vieweg.
- Neuhaus, F. Stark, & H.-J. Drilling, M. (2015). *ePartizipation demokratischer Stadtentwicklung*. Fachhochschule Nordwestschweiz FHNW. Hochschule für Architektur, Bau und Geomatik. Muttenz.
- Niquille, S. (2018). Was will die grafische Benutzeroberfläche. In *Arch+*, Nr. 233, Norm-Architektur – Von Durand zu BIM.

Oberzaucher, E. (2017). Die vielen Herausforderungen an die Stadtplanung. In *Book Homo Urbanus, Ein evolutionsbiologischer Blick in Die Zukunft der Städte*. Springer, pp. 201–207, pp. 227-231

Oberzaucher, E. (2017). Homo urbanus – evolutionary considerations for the city of future. Paper presented at Institut für Kunst und Gesellschaft, Cross-Disciplinary Strategies, University of Applied Arts in Vienna, 15.10.2019.

Official Journal of the European Union. (2008). Directive 2008/50/ec of the European parliament and of the council of 21 may 2008 on ambient air quality and cleaner air for Europe. Publication place: <https://eur-lex.europa.eu/legal-content/DE/TXT/?qid=1419251316048&uri=CELEX:32008L0050>; accessed 09.12.2019.

Official Journal of the European Union. (2016). RICHTLINIE (EU) 2016/2284 DES EUROPÄISCHEN PARLAMENTS UND DES RATES vom 14. Dezember 2016 über die Reduktion der nationalen Emissionen bestimmter Luftschadstoffe, zur Änderung der Richtlinie 2003/35/EG und zur Aufhebung der Richtlinie 2001/81/EG. Publication place: <https://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX%3A32016L2284&from=EN>; accessed 09.12.2019.

Paglen, T. (2019). From "Apple" to "Anomaly" (Pictures and Labels) Selection from the ImageNet dataset for object recognition. Publication accompanying Exhibition at Barbican London. The curve commission. From 26. Sep 2019 until 16. Feb 2020.

Patterson Z. Darbani M.-J. Rezaei A. Zacharias J. & Yazdizadeh A. (2016). Comparing text-only and virtual reality discrete choice experiments of neighbourhood choice. *Landscape and Urban Planning Journal* 157 (2017) 63–74.

Pedercini, P. (2019). *Invisible (Game) Cities*. In conversation with Gerber, A. In.: Gerber, A. Götz, U. (2019). *Architectonics of Game Spaces. The Spatial Logic of the Virtual and Its Meaning for the Real*. Zurich ZHDK University of the Arts. ZHAW School of Architecture, Design and Civil Engineering, Institute of Urban Landscape. transcript Verlag. Bielefeld.

Percept. (2021). In *Oxford English Dictionary*. Retrieved from <https://www.oed.com/view/Entry/140554?rskey=ox2Lsq&result=1#eid>; accessed 28.01.2021

Pias, C. (2003). Zeit der Kybernetik – Eine Einstimmung. In. *Cybernetics, Kybernetik. The Macy-Conferences 1946-1953*. Bd. 1 Transactions/Protokolle. Diaphanes Zurich.

Pieterse, E. & Parnell S. (2014). *Africa's urban revolution*. UCT Press. Cape Town.

Reichardt, J. (1968). *Cybernetic Serendipity, The Computer and the Arts*. Studio International Special Issue. Frederick A. Praeger Publishers. New York. Washington.

Piplas, H. Brillembourg, A. & Klumpner, H. (Ed.) (2019). *Reactivating Sarajevo's (Dis)Continues Urbanism*. In: *City Action Lab, Integrated Urban Toolbox for Post-Socialist Central Eastern European Cities*. Urban Think Tank. Publication place: Swiss Federal Institute of Technology, Chair of Architecture and Urban Design.

QGIS Development Team. (2017). *Q-GIS 2.18.2 Las Palmas*.

- QGIS Development Team. (2018). Q-GIS 3.4.8 Madeira.
- Rat für Raumordnung. (2019). Megatrends und Raumentwicklung Schweiz, Bern.
- Ravindra-Prasad, D. & Malla-Reddy, A. (1994). Environmental Improvement of Urban Slums: The Indian Experience. Hyderabad: Booklinks Corporation.
- Rheingold, H. (1992). Virtuelle Welten, Reisen im Cyberspace. Rowohlt Verlag. Reinbek.
- Ries, M. (2020). Schaukel über jede Physik hinaus. Virtual Reality und die Annahme eines Numerisch-Unbewussten. In.: Springerin Magazin. Post-Anthropozän. Issue 03. Autumn 2020. Vienna.
- Robert McNeel & Associates. (2017a). GhPython Add-on for Grasshopper. 0.6.0.3.
- Robert McNeel & Associates. (2017b). Grasshopper 0.9 for Rhino 5.0. 0.9.76.
- Robert McNeel & Associates. (2017c). Rhinoceros 5.0. Version 5 SR14.
- Roudsari, M.-S. (2019a). Butterfly, Version 0.0.05, <https://www.food4rhino.com/app/ladybug-tools>; accessed 07.01.2020.
- Roudsari, M.-S. (2019b). Ladybug, Version 0.0.68, <https://www.food4rhino.com/app/ladybug-tools>; accessed 07.01.2020.
- Roudsari, M.-S. (2019c). Honeybee, Version 0.0.65, <https://www.food4rhino.com/app/ladybug-tools>; accessed 07.01.2020.
- Rowland, I. (1999). Vitruvius. Ten Books on Architecture. Cambridge. Cambridge University Press.
- Rozenberg, H. (2019). Bauen ohne Diskriminierung. Eine Architektursprache des Post Binären. In Arch+ Zeitschrift für Architektur und Urbanismus. Posthumane Architektur. Nr. 236. Arch+ Verlag, Berlin
- Sager, F. Mavrot, C. Hinterleitner, M. Kaufmann, D. Grosjean, M. & Stocker, T.-F. (2020). Utilization-focused scientific policy advice: a six-point checklist. *Climate Policy*. 20:10, 1336-1343. DOI=10.1080/14693062.2020.1757399
- Saprykin, A. Chokani, N. & Abhari, S.-R. (2019). GEMSim: A GPU-Accelerated Multi-Modal Mobility Simulator for Large-Scale Scenarios. *Simulation Modelling Practice and Theory*. 94. 10.1016/j.simpat.2019.03.002.
- Schaller, C. (2018). Parametrisches (Geo)Design für Testplanungen, Vorgehensmodell zur Unterstützung von Planungen zur inneren Verdichtung. Master Thesis Paris Lodron-University Salzburg.
- Schechtner, K. (2017). Big Data for Urban Change – Debunking the Myth & a Way Foreword. In: Social Design – Urban Change: Arts as Urban Innovation. Edition Angewandte. Book Series of the University of Applied Arts Vienna. Birkhäuser Verlag. Basel.

Schnabel, M.-A. Zhang, Y. & Aydin, S. (2017). Using parametric modelling in form-based code design for high-dense cities. International High-Performance Built Environment Conference – A Sustainable Built Environment Conference 2016 Series (SBE16), iHBE 2016.

Schneider, P. & Fankhänel, T. (2020). Architectural Software Timeline. In.: Fankhänel, T. Lepik, A. (2020). The Architecture Machine. The Role of Computers in Architecture. Birkhäuser. Basel.

Schneidewind, U. (2018). Die Grosse Transformation. Eine Einführung in die Kunst gesellschaftlichen Wandels. Forum für Verantwortung. Fischer Verlag. Frankfurt am Main.

Service du Développement Territorial - SDT. (2016). Project d'Agglomération Lausanne-Morges - PALM. Lausanne, Switzerland.

Shaw, J. (1992). Virtual Reality: A new medium for the artist? in: Virtual Reality International 92, Impacts and Applications, Ed. Feldman, Tony, Meckler, London, pp. 65-68.

Silva, A. (2006). Imaginarios urbanos. Arango Editores. Bogotá.

Sirianni, C. Girourd, J. (2012). The civics of urban planning. Chapter 32. As part of: Weber, R., Crane, R. (2012). The Oxford Handbook of Urban Planning. Oxford University Press.

Smid, M. Russo, S. Costa, A.-C. Granell, C. & Pebesma, E. (2019). Ranking European capitals by exposure to heat waves and cold waves, Urban Climate, Volume 27.

Smith, A. (1776). An Inquiry into the Nature and Causes of the Wealth of Nations. 1st edn 1776. Oxford.

Socher, R. (2019). Künstliche Intelligenz wird ganze Volkswirtschaftlichen effizienter Machen. Interview with Langer, M.A. In.: Neue Zürcher Zeitung, 21.01.2020. Zurich. <https://www.nzz.ch/wirtschaft/der-bias-ist-das-groesste-problem-bei-der-kuenstlichen-intelligenz-ld.1528242>; accessed: 23.01.2020.

Spacewalk. (2019). <http://www.spacewalk.tech>; accessed 11.07.2019.

Stachowiak, H. (1973). Allgemeine Modelltheorie, 1973, S. 131-133.

Stalder, F. (2019). Das tiefste Schwarz. KI als soziale Macht. In.: Entangled Realities Living with Artificial Intelligence. HeK (Haus der elektronischen Künste Basel). Christoph Merian Verlag Basel.

Steadman, P. (2016). Research in architecture and urban studies at Cambridge in the 1960s and 1970s: what really happened, The Journal of Architecture, 21:2, 291-306, DOI=10.1080/13602365.2016.1165911

Steyerl, H. (2020). I will survive. Kunstsammlung Nordrhein-Westfalen. Centre Pompidou. Spector Books.

Swiss Federal Office for Statistics. (2015a). Eidgenössisches Gebäude- und Wohnungsregister. Bern, Switzerland.

Swiss Federal Office for Statistics. (2015b). Szenarien zur Bevölkerungsentwicklung der Schweiz 2015 – 2045.

Swiss Federal Office for Statistics. (2018). Bevölkerung / Bevölkerungsstand und -entwicklung 2000 – 2018; https://www.atlas.bfs.admin.ch/maps/13/de/14459_72_71_70/23027.html; accessed: 22.07.2020.

Taubenböck, H. Kraff, N.-J. & Wurm, M. (2018). The Morphology of the Arrival City - A Global Categorization based on Literature Surveys and Remotely Sensed Data. *Applied Geography* 92: 150-167.

Tellis, G.-J. (2009). Generalizations about advertising effectiveness in markets. *Journal of Advertising Research*, 49(2), 240-245. <https://doi.org/10.2501/S0021849909090357>.

Theodosis, L. (2017). Die Human Community in Constantinos Doxiadis urbanisierter Welt. In *Arch+*, Nr. 230, Architekturen der Globalisierung.

Turan, K. Torlak, M. & Hadžiabdić, M. (2012). Wind resource assessment in complex terrain with limited data. Publication place: 7th International Conference of the Croatian Society of Mechanics, Zadar, Croatia.

Turetsky, M.-R. Abbott, B.-W. Jones, M.-C. Anthony, Katey W. Olefeldt, D. Schuur, E.-A.-G. Koven, C. McGuire, A.-D. & Grosse, G. (2019). Permafrost collapse is accelerating carbon release. Publication place: *Nature*. Vol 569. 2. May 2019. Springer.

Turing, A.-M. (1937). On Computable Numbers, with an Application to the Entscheidungsproblem. *Proceedings of the London Mathematical Society*, s2-42: 230-265. DOI=10.1112/plms/s2-42.1.230.

UN-Habitat. (2003). *The Challenge of Slums: Global Report on Human Settlements 2003*. London/ Sterling, VA: Earthscan.

United Nations. (2015). Sustainable Development Goals. Retrieved from: www.un.org/sustainabledevelopment/cities/. [Accessed 18 April 2019].

Valencia-Romero, A. & Lugo, E.-J. (2017). An immersive virtual discrete choice experiment for elicitation of product aesthetics using Gestalt principles. *Design Science Journal* vol3 3, e11. Cambridge University Press.

Vega, A. Weibel, P. & Zielinski, S. (2018). DIA-LOGOS, Ramon Llull's Method of Thought and Artistic Practice. ZKM Karlsruhe.

Vertov, D. (1923). Kinoki – Umsturz. In *Texte zur Theorie des Films (1998)*. Reclam Verlag. Stuttgart.

Vrachliotis, G. (2018). Architekturmaschine, Individualisierungssysteme. In *Arch+ Zeitschrift für Architektur und Urbanismus*. Datatopia. Nr. 234. 36-43. Arch+ Verlag, Berlin.

Wahbeh, W. Kunz, D. Hofmann, J. & Bereuter, P. (2020). DIGITAL TWINNING OF THE BUILT ENVIRONMENT – AN INTERDISCIPLINARY TOPIC FOR INNOVATION IN DIDACTICS, *ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci.*, V-4-2020, 231-237, <https://doi.org/10.5194/isprs-annals-V-4-2020-231-2020>.

Walczak, M. (2019). Qualitative visualisation of quantitative urban models impacting policy decision making: A case study of urban infrastructure interventions. *Angewandte Vienna. Conference Paper In.: 3. Doktorand_innen Symposium der Architektur. Kunstuniversität Linz. 17. and 18. October 2020.* https://www.ufg.at/fileadmin/media/kunstforschung/PhD/aktuelles/2019/1019_Reader_Dok-Symposium_Architektur.pdf; accessed: 17.01.2020.

Walczak, M. (2021a). A multi-dimensional spatial policy model for large-scale multi-municipal Swiss contexts. *SAGE Journal Environment and Planning B: Urban Analytics and City Science.* <https://doi.org/10.1177%2F2399808320985854>.

Walczak, M. (2021b). Airquality is the result of the new 3D's paradigm: Daylight, densification and domain. In *Transitioning to Sustainable Cities and Communities*, edited by Hubert Klumpner and Klearjos Eduardo Papanicolaou. Basel: MDPI. [In Review].

Wang, H. (2017). *A Web3D Forest Geo-Visualisation and User Interface Evaluation.*

Ward, P.-M. (1982). The Practice and Potential of Self-Help Housing in Mexico City. In *Self-Help Housing: A Critique*, 175-208. Edited by P. M. Ward. London: Mansell Publishing Limited.

Weibel, P. (2003). *Die Beschleunigung der Bilder.* In *der Chronokratie.* Benteli Verlag, Bern. ZKM Karlsruhe.

Weibel, P. (2019). *Kunst und Medien. Enzyklopädie der Medien.* Hatje Cantz. Universität für angewandte Kunst und Wien. ZKM Karlsruhe.

Weizenbaum, J. (1978). *Die Macht der Computer und die Ohnmacht der Vernunft.* suhrkamp taschenbuch wissenschaft. Frankfurt am Main.

Weizenbaum, J. Haefner, K. & Haller, M. (ed). (1990). *Weizenbaum contra Haefner, Sind Computer die besseren Menschen? Pendo-profile.* Zurich.

Weizman, E. (2019). *Forensic Architecture: Violence at the Threshold of Detectability.* Zone Books.

Wiener, N. (1948). *Cybernetics or Control and Communication in the Animal and the Machine.* MIT press. Cambridge.

Wook, C.-B. (2018). Share complex architectural information. Improvement of land utilization efficiency. Published online in: <http://www.segye.com/newsView/20181125001702>; accessed 12.07.2019.

Yilmaz, A. Kemec, S. Duzgun, S. & Cakir, M. (2014). Cognitive Aspects of Geovisualisation: A Case Study of Active and Passive Exploration in a Virtual Environment. In: *Thematic Cartography for the Society* p.157.

Zafiris, E. (2019). Ambiguity and information in the context of "Natural Communication": An obstacle-oriented galoisian standpoint. In.: Doyle M. R., Savić S., Bühlmann V. (2019) *Ghosts of Transparency, Shadows cast and shadows cast out.* Applied Virtuality Book Series 13. Birkhäuser.

Zendehbad, M. Chokani, N. & Abhari, S.-R. (2019). Multi-scale measurements in wind farms in complex and flat terrain. Publication place: Proceedings ASME Turbo Expo 2015: Turbine Technical Conference and Exposition GT2015, Montreal, Canada, June 15-19, 2015.

Zhang, Y. & Schnabel, M.-A. (2017). Workflow of Data Integrating and Parametric Modelling in Urban Design Regulation. Back to the Future: The Next 50 Years, (51st International Conference of the Architectural Science Association (ANZAScA), Architectural Science Association (ANZAScA), pp. 139–148.

