THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

# Staging urban emergence through collective creativity:

## Devising an outdoor mobile augmented reality tool

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# Abstract

## Staging urban emergence through collective creativity:
## Devising an outdoor mobile augmented reality tool

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The unpredictability of global geopolitical conflicts, economic trends, and impacts of climate change, coupled with an increasing urban population, necessitates a more profound commitment to resilience thinking in urban planning and design. In contrast to top-down planning and designing for sustainability, allowing for emergence to take place seems to contribute to a capacity to better deal with this complex unpredictability, by allowing incremental changes through bottom-up, self-organized adaptation made by diverse actors in the proximity of various social, economical and functional entities in the urban context.

The present thesis looks into the processes of creating urban emergence from both theoretical and practical perspectives. The theoretical section of the thesis first looks into the relationship between the processes and the qualities of a compact city. The Japanese city of Tokyo is used as an example of a resilient compact city that continuously emerges through incremental micro-adaptations by individual actors guided by urban rules that ‘let it happen’ without much central control or top-down design of the individual outcomes. The thesis then connects such rule-based emergent processes and the qualities of a compact city to complex adaptive system’s (CAS) theory, emphasizing the value of incremental and individual multiple-stakeholder input. The latter part of the thesis focuses on how to create a platform that can combine the bottom-up, emergent, rule-based planning approaches, and collective creativity based on individual participation and input from the public. This section is dedicated to developing a tool for a collaborative urban design using outdoor mobile augmented reality (MAR) by *research-through-design* method.

The thesis thus has three parts addressing the topics: 1. urban planning processes and resulting urban qualities concerning compact city – i.e., density and diversity; 2. the processes of urban emergence, which generates complexity that renders urban resilience from the urban planning theory perspective; 3. developing a tool for non-expert citizens and other stakeholders to design and visualize an urban neighborhood by simulating the rule-based urban emergence using outdoor MAR. The results include a proposal for a complementary hybrid planning approaches that might approximate the CAS in urban systems with qualities that contribute to urban resiliency. Thereafter, the results describe specifications and design criteria for a tool as a public collaborative design platform using outdoor MAR to promote public participation: Urban CoBuilder. The processes of developing and prototyping such a tool to test various urban concepts concerning identified adaptive urban planning approaches are also presented with an assessment of the MAR tool based on focus group user tests. Future studies need to better include the potential of crowdsourcing public creativity through mass participation using the collaborative design tool and actual integration of these participatory design results in urban policies.

*Keywords: Compact city, Urban resilience, Emergent processes, Complex adaptive systems, Urban Rules, outdoor mobile augmented reality, collaborative design, research-through-design*

# List of Appendices and publications

**Appendix 1:**

Lim, H. K*., & Kain, J.-H. (2016). Compact Cities Are Complex, Intense and Diverse but: Can We Design Such Emergent Urban Properties? Urban Planning, 1(1), 95. https://doi.org/10.17645/ up.v1i1.535

*Paper 1*

** This paper was published under the author's former initial and last name, H.K. Lim.*

**Appendix 2:**

Imottesjo, H., & Kain, J.-H. (2018). The Urban CoBuilder – A mobile augmented reality tool for crowd-sourced simulation of emergent urban development patterns: Requirements, prototyping and assessment. Computers, Environment and Urban Systems, 71, 120–130. https://doi.org/10.1016/j.compenvurbsys.2018.05.003

*Paper 2*

**Appendix 3:**

Imottesjo, H., Thuvander, L., Billger, M., Wallberg, P., Bodell, G., Kain, J-H., & Nielsen., S. A. (Submitted). Iterative prototyping of Urban CoBuilder: Tracking methods and user interface of an outdoor Mobile Augmented Reality tool for co-designing

*Paper 3*

**Appendix 4:**

Mechanisms and outcomes of 'rule-based-planning system' vs 'designed-form-based-planning system': adaptabilities and incremental changes in regard to densification

*Board game/Documentation*

**Appendix 5:**

Urban CoMapper

*Mobile web-app/Documentation*

## Appendix 6:

Urban CoBuilder

*Outdoor mobile augmented reality smartphone app/Documentation*

# List of Abbreviations

*(in alphabetical order)*

| | |
|---|---|
| ABM: | agent-based modeling |
| AR: | augmented reality |
| BCR: | building coverage ratio |
| CAS: | complex adaptive systems |
| FAR: | floor area ratio |
| GIS: | geographical information system |
| GPS: | global positioning system |
| ICT: | information and communications technology |
| IMDB: | internet movie database |
| MAR: | mobile augmented reality |
| SES: | social-ecological system |
| SLAM: | simultaneous localization mapping |
| UCM: | Urban CoMapper |
| UI: | user interface |
| UWB: | ultra-wideband |
| UX-I: | user experience and interface |
| VR: | virtual reality |

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Thank you!!

# Contents

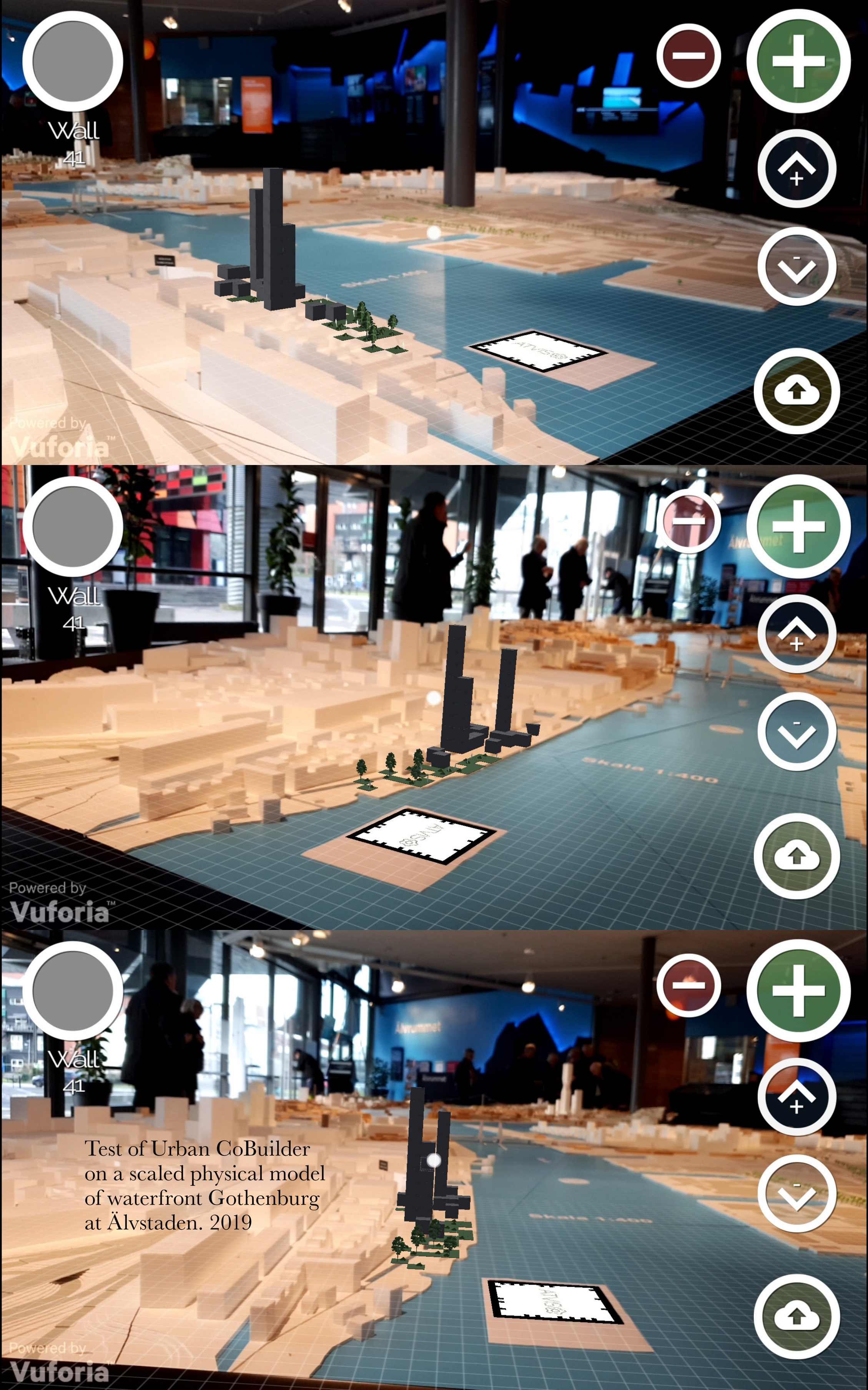
Urban CoBuilder at Student workshop during Social Inclusion Course, Department of Architecture and Civil Engineering, Chalmers University of Technology: Hammarkullen, 27th of September 2017

Student workshop, 27th of September 2017
Setting up the mobile augmented reality tracking markers

Student workshop, 22th of October 2018
Setting up the mobile augmented reality tracking markers for 1:1 scale projection

Screenshots of Urban CoBuilder in use: Top image shows its use as a 1:1 scale design app and the bottom image shows a tabletop version scaled-down model. The images were taken during the student workshop at Hammarkullen, 2018.

The top image shows 1:1 scale urban modeling on-site during the test of Urban CoBuilder as a semi-pilot system and the bottom image shows scaled-down urban model tested and presented during 75% PhD seminar in 2017.



Test of Urban CoBuilder
on a scaled physical model
of waterfront Gothenburg
at Älvstaden. 2019

# Chapter 1.

# Introduction

## 1.1 Approaching the thesis

This thesis adopts a mix of theory-driven and design-driven research approaches in order to identify urban planning systems and development processes that promote urban adaptability and resilience and to investigate methods and develop tools for supporting the identified development processes.

The inspiration and starting point for this Ph.D. project were acquired from the praxis in the field of architecture in Tokyo, where the author worked as an architect for three years prior to starting the doctoral studies. Tokyo is a megacity that has been withstanding natural and human-made catastrophes throughout history and the examples collected from the professional practice of the author in the city has contributed strongly to the direction taken in the exploration into planning theory and urban theory.

Even though this is a compilation thesis, it was initially prepared as a monograph investigating theoretical aspects concerning how different planning systems and procedures relate to ambitions for more compact cities. However, with the practical experience from the field of architecture in Tokyo as a guiding example, an increasing interest in the rule-based planning approach led the focus to shift towards urban development processes taking place in a context of urban complexity, adaptability, self-organization, and resilience. This also led to that, during the latter half of the Ph.D. project, the focus turned towards the more practical aspects of developing planning tools in response to the findings from the first half. Due to the time constraints of a Ph.D. project, the scope of the second half of the thesis is limited to an iterative process of design, prototyping, and assessment of the tools, with no extensive user testing from application in a broader test case.

The shift from studying planning systems and planning theory to design-driven tool development entailed changing the writing format from monograph to a compilation of published journal articles and developed planning tools. The reader might be able to feel the change in writing style and the pace of the storyline throughout the thesis, even though the logic of the interplay between the theoretical aspects and the practical work is consistent. Also, in the thesis, this interplay is presented as a straightforward shift from theory to design while, in reality, it entailed a significant amount of moving back and forth between literature studies and research-by-design linked to tool development.

The expansiveness of the thesis, integrating theory and practice, might put some strain on the readers depending on their interest and expertise in the fields of urban planning and interactive design. The author suggests that readers with more specified interests in either field selectively focus on the relevant chapters but would also like to emphasize the importance of following the flow of the logic presented in areas of less apparent personal interest.

## 1.2 Structure of the thesis

The thesis consists of in total of seven chapters. Following the current chapter of introduction, Chapter Two establishes the wider societal problems, followed by state of the art identifying three main knowledge gaps. The chapter concludes with defining the overall aim of the thesis and three main research questions, each linked to one of the knowledge gaps.

Chapter Three provides a deep description of the actual starting point and inspiration for the Ph.D. project: how the Japanese planning system engages with urban development that supports urban resilience, supplemented by an example from the author's own praxis from working as an architect in Japan.

Chapter Four describes the methods applied to answer the three main research questions: comparative studies, literature review, and research-through-design.

Chapter Five presents the results responding to the research questions in three sub-chapters, where results linked to the research questions one and three are based on empirical studies and results for research question two are based on theory development.

Chapter Six discusses the results by reconnecting them to the literature. The chapter is divided in three sections connected to the three objectives developed in the Chapter one.

Finally, the concluding Chapter Seven starts with thoughts on the applied research methods and the limitations of the conducted research, and reflects on these limitations and what future research is needed in order to address the remaining challenges.

# Chapter 2.

# Background and state of the art

## 2.1 Two degrees Celsius, climate refugees and unforeseeable future urban challenges

Recently published research points to a mere 5% probability of containing the rise of the global average temperature to below two degrees Celsius by the year 2100 (Raftery, Zimmer, Frierson, Startz, & Liu, 2017). Containing the temperature rise to below 2 degrees Celsius, or even better to below 1.5 degrees, was postulated in the 2015 Paris Agreement (UNFCCC, 2015) as sustainable, even though the unpredictability of climate change is more substantial than simply pinpointing how many degrees of temperature rise is below the threshold for catastrophic consequences (Shaw, 2017). Therefore, research speculating that we might actually face a rise in the range of 2.0-4.9 degrees Celsius instead of below 2.0 (Raftery et al., 2017; Steffen et al., 2018), coupled with the 'cascade effect,' one factor triggering others to change, further obscures our insight into the tangible scenarios relating to a sustainable future. Even though many other studies on climate change and global warming challenge policymakers to take more stringent measures (Nordhaus, 2016; Aengenheyster, Feng, van der Ploeg, & Dijkstra, 2018; King et al., 2018), we might be seeing various ecosystems already on the verge of a tipping point (Mouritsen, Sørensen, Poulin, & Fredensborg, 2018).

In addition to uncertainties of the impact of climate change, due to the collapse of ecosystems,' extreme weather conditions, changes in agroforestry patterns, and economic instability (Bovari, Giraud, & Mc Isaac, 2018), the number of climate refugees – i.e., the global population that is displaced as a result of climate change – is predicted to amount to some 200 million by 2050 (Sen Roy, 2018). Rising water levels, as well as increased flooding, droughts, and desertification, can lead to an acceleration of the forced global migration of displaced populations. Combined with an already forecasted urban population growth of 2.5 billion by 2050 (UN, 2018), the unpredictability of future climate change will place existing urban structures under high stress. The population dwelling in informal settlements, so-called 'slums,' is expected to rise from 800 million in 2018 to about 3 billion in 2030 (UN-Habitat, 2016). Since global climate change and impacts are felt considerably more by those living on the urban fringes in informal settlements without proper infrastructure for transportation, sanitation, or essential public services (UN-Habitat, 2019), UN prognoses 3 billion people will need adequate housing by 2030 (UN-Habitat, 2016).

The future has always been unpredictable. However, with increasing insecurity surrounding climate change and its impact, 30 years into the future from now seems a bit more unpredictable than the future, as seen 30 years ago. The uncertainty and unpredictability of the complex outcomes of climate change sound dreary, but in a more positive light, they also indicate the potential for future cities to be drivers of change that may have a positive impact (Ahern, 2011). Accommodating about 70% of human lives by 2050 (UN-Habitat, 2019), the cities built now can indeed enhance not only environmental and climatic resilience, but also social, political, and economic resilience for future generations. Thus, the challenges lie not only in dealing with current urban challenges but also in accommodating unforeseeable future challenges.

## 2.2 Compact city and climate change

It is apparent that to contain the global temperature rise to below 2 degrees Celsius (and if possible even to 1.5 degrees) compared to the pre-industrial level, radical measures need to be taken right now rather than later to reduce carbon emission to net zero by the middle of the century (IPCC, 2018).

Likewise, from here on, radical measures need to be implemented regarding future urban development projects to reduce further land consumption for urbanization in the face of increasing urban populations, as well as to provide adequate housing to migrating populations, alleviating the potential burden of climate change on the unfortunate masses of the urban poor (UN-Habitat, 2019). There is currently a disproportionate increase in land consumption compared to population growth: 5% population growth to 30% land use (Rode et al., 2017). In conjunction with the continuous decrease in urban population density (Seto et al., 2014; Oueslati, Alvanides, & Garrod, 2015; Güneralp et al., 2017), this indicates an ongoing urban sprawl globally. Urban sprawl is characterized by low-density housing, auto dependence, and separated land uses (Brueckner, 2000; Ewing, Pendall, & Chen, 2003 from Seto et al., 2014), and is argued to have a stronger correlation to increased transport-related CO2 emission than the increase in GDP per capita or even population growth (Bart, 2010). Estimating that 65% of all land will be urbanized by 2030 and considering the 'irreversibility' of such scale of investment (Seto et al., 2014), a re-thinking of future infrastructural development plans for the future urbanization is necessary.

Furthermore, the cost of investing in and maintaining infrastructure in high population-density urban areas compared to sprawling areas has been estimated to be 76% less (Halifax Regional Municipality, 2005). In fact, sprawl has been estimated to cause 10% larger annual public services deficits and a 10% increase in road lane length in various urban development scenario simulations done for the period 2000-2025 in the US (Burchell & Murkherji, 2003). Other international studies also indicate savings on the costs of infrastructure and operation, with as much as 38% or 60% savings in case cities in high population-density areas (SGS Economics and Planning, 2016). The development of infrastructure for servicing urban development in greenfields costs two to four times more than for infill development, with significant added ongoing cost burdens relating to transport for each new greenfield block over 50 years (SGS Economics and Planning, 2016).

Even though the data are contradicting with regard to the reduced environmental impact from compact city urban forms (Heinonen & Junnila, 2011; Gugger & Kerschbaumer, 2013), studies looking beyond simple measures of urban compactness, such as 'population density, connectivity, proximity to jobs and services, and diversity and intensity of urban activities' (Ramaswami, Russell, Culligan, Sharma, & Kumar, 2016, p. 940) and into the complexity of such, including ‘self-similarity across scales (from blocks to neighborhoods to cities) and patterns of social segregation’ (Ramaswami et al., 2016, p. 940) find that ‘an optimally dense urban form, with a high intensity of diverse co-located activities, creates opportunities for systemic multisector infrastructure interventions, yielding the highest-efficiency gains’ (Ramaswami et al., 2016, p. 942).

## 2.3 Local context

Even though calculations indicate a need to reduce passenger transport by 20% by 2030 in order to achieve climate objectives in the Gothenburg region, the Swedish Transport Administration predicts a 25% increase in private car use from 2010 to 2030 (Boberg et al., 2014). With a projection of population growth by 10,000 per year (Cullberg, Montin, & Tahvlizadeh, 2014), smart development plans, not only for housing the incoming populations but also for providing the infrastructure to eventually reduce private car use, are necessary for the long run. In addition to these challenges, Gothenburg faces an additional challenge as a coastal town with central districts on the waterfront. A report from 2012 (Bergström, 2012) expects the sea level to rise 70 cm above the current sea level by 2100, entailing a high risk of flooding, not least due to the extreme storms with higher rainfall expected as a consequence of climate change. The high-water levels and flooding will affect the central city area around the Göta Älv river, where both new urban regeneration development plans and old town structures are concentrated (Cullberg et al., 2014; Blomquist, 2015, see Figure 1).

The city has suggested infrastructure development in this core urban area, including a storm barrier structure or long dikes along the riverbank, as a response to the prognosis of higher flood risk due to future climate change, and to secure the waterfront development to create a more connected city along with compact city policy guidelines. The implementation of infrastructural changes on this scale will undoubtedly impact both the existing and future urban conditions of the city, highlighting the importance of considering the irreversibility pointed out by Seto et al. (2014). All in all, such problems necessitate focused efforts to develop smarter and less environmentally impactful approaches to traffic and material flows (UNEP, 2013; Lehmann, 2016), and through intensification rather than through continued urban sprawl (Brueckner, 2000; Ewing et al., 2003 from Seto et al., 2014; Bart, 2010).

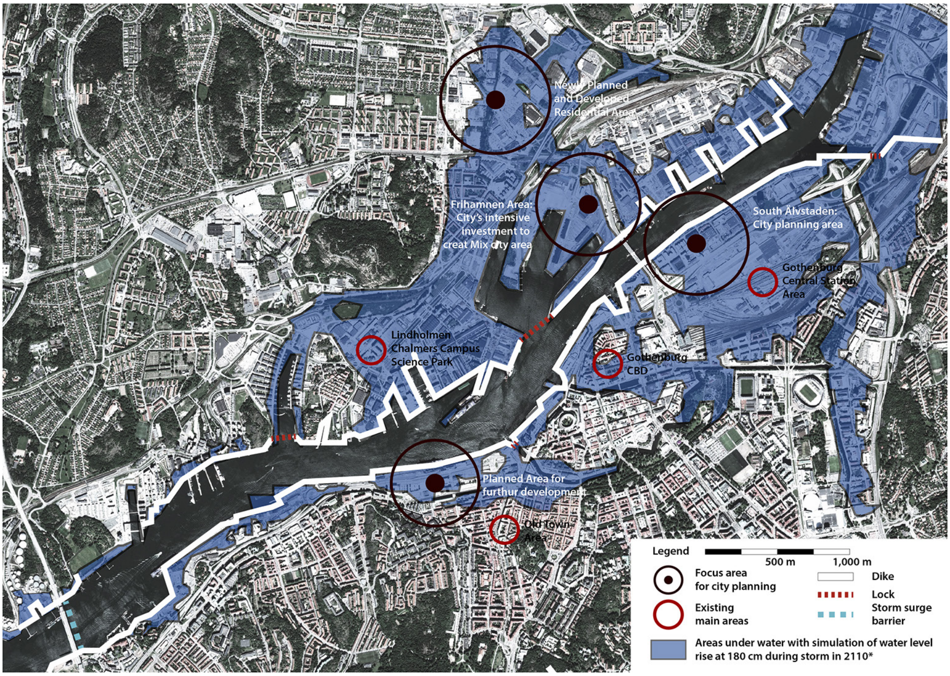


*Figure 1. Rising water level and flooding prognosis for Gothenburg city*

## 2.4 Research and policies on the compact city: What makes and breaks a compact city?

Globally, compaction of urban areas and prevention of dispersed urban fringes to mitigate future adverse scenarios caused by climate change and urban migration are promoted through policies (European Commission, 2011; UN-Habitat, 2011, 2014, 2015; OECD, 2012) and in research (Burchell

& Murkherji, 2003; Halifax Regional Municipality, 2005; Bart, 2010; Seto et al., 2014; SGS Economics and Planning, 2016). In Gothenburg, reflecting research on the advantages of the compact urban form, e.g., the urban development policy Rivercity Gothenburg (2012) denounces urban sprawl and actively promotes compact urban development for creating a more connected, walkable, and diverse urban-scape instead of a segregated, sprawled, and car-oriented cityscape. According to the policy document, this kind of development is intended to foster social inclusiveness, as well as green and dynamic urban growth through better accessibility, liveability, and higher density. It regards good accessibility to various services, trades, culture, and transportation infrastructure as a way to increase attractivity and liveability for city dwellers (Rivercity Gothenburg, 2012; Gothenburg City Council, 2014).

Turning our eyes to the broader international context, compact city policies from the UN, the OECD, and the European Commission all promote this dense urban form for thwarting further land consumption, decreasing impact on the environment (EEA, 2015), boosting social diversity (UN-Habitat, 2015), and promoting urban functional mixed-use (OECD, 2012). Even though most of these policies seem to consider the compact city as a solution to many ills – reducing environmental impact including CO2 emission and energy use (OECD, 2012); enabling social, cultural and political dynamics (European Commission, 1990); and promoting health, social cohesion, better economy and efficient use of resources (UN-Habitat, 2014; 2015), to name a few – the definition of this compact city concept remains fuzzy (Neuman, 2005).

While policies agree that a compact city is dense and diverse, and has excellent infrastructure networks (European Commission, 2011; OECD, 2012; UN-Habitat, 2015), it is less common to declare quantifiable objectives clearly. The difficulties in assessing and simplifying the precise boundaries and conditions of the terms make it rather inefficient to set target values for such parameters (Churchman, 1999; Manaugh & Kreider, 2013) to support implementation. Without taking into account local cultures and urban contexts (Williams, 2004; Roberts, 2007; Bardhan, Kurisu, & Hanaki, 2015), efforts to implement compaction and density measures can result in either superfluous compact city guidelines in already dense cities, or dismiss some of the local values, e.g., high regard for open space or a low- density residential urban form for families with children.

Heterogeneous indexes to measure the density (Churchman, 1999; Manaugh & Kreider, 2013; Lee, Kurisu, An, & Hanaki, 2015) and diversity (Manaugh & Kreider, 2013) in various regions, and carried out in different practices, complicate the enforcement of global policy guidelines that can be quickly adopted and implemented. For instance, regarding calculating mixed urban functionality based on proportions of the functions found in a given area, such a number could indicate the same level of mixed-use for areas consisting of large commercial and residential blocks on the one hand and those with a smaller urban grain, where each building has a shop on the ground floor, on the other (Manaugh & Kreider, 2013) (see Figure 2). Not surprisingly, given the elusiveness of the definition, research on the compact city presents contradictory results concerning its strengths and weaknesses (Jenks, Burton, & Williams, 1996).

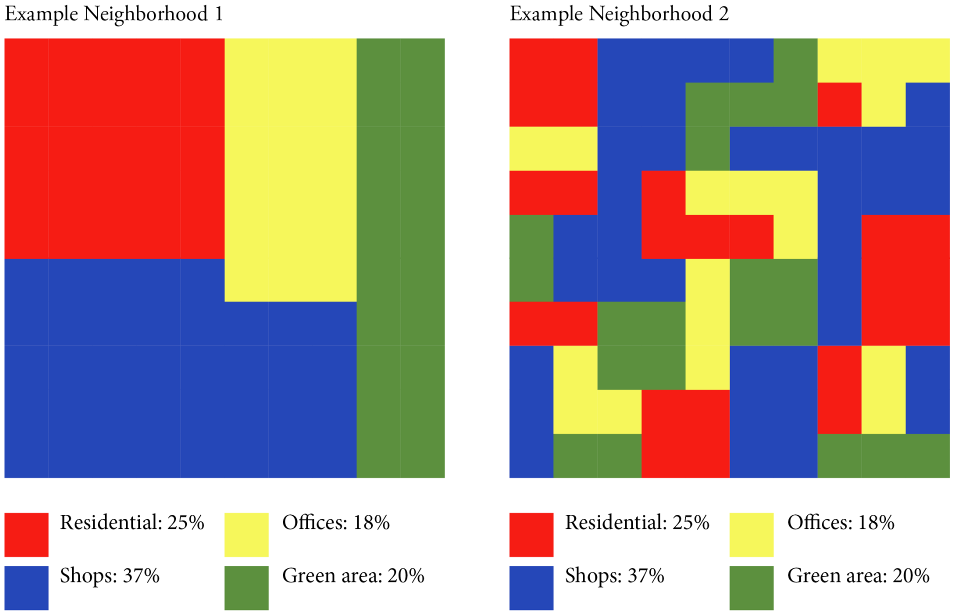


*Figure 2. Figure illustrates how the proportion of mix-use in a neighborhood can be described based on the size of the analyzed area*

Additionally, in already highly populated cities, the understanding of compact city form needs to be accompanied by other complex urban factors, such as the socio-economic, climatic and cultural elements of the location, to maximize the contribution to lessened environmental impacts (Chen, Jia, & Lau, 2008; Lu, Xiao, & Ye, 2016). Furthermore, with the lack of consensus on how to define and measure density, studies show inconclusive results in relation to reduced carbon emission (Heinonen & Junnila, 2011), neighborhood satisfaction (Bramley & Power, 2009), psychological health (Haigh, Ng Chok, & Harris, 2011), the consumption of energy and goods (Heinonen & Junnila, 2011), and ecological footprint (Gugger & Kerschbaumer, 2013). Thus, without having plausible global methods for defining how to measure urban density and diversity: how can we achieve the resilient kind of compact city that delivers increased walkability through mixed-use (Badland et al., 2012; Choi & Sayyar, 2012; Oyeyemi et al., 2013; Eom & Cho, 2015), heightened citizen trust and engagement in the neighborhood (Rogers, Gardner, & Carlson, 2014; Eom & Cho, 2015), better quality of public transportation (Frank & Pivo, 1994; Rode et al., 2017), shortened commuting distances (Boussauw, Neutens, & Witlox, 2012), and social cohesion (Burton, 2001; Mardiah, 2015), while at the same time supporting reduced resource consumption, carbon emission, and ecological footprint per capita (Newman, 2006; Dodman, 2009)?

So, what makes a great city? According to Glaeser (2011, p. 223), ‘successful cities always have wealth of human energy that expresses itself in different ways and defines its own idiosyncratic space.’ Glaeser credits urban density as the creator of a constant flow of information that lets humans, as social beings, interact with and learn and share from each other. Likewise, Glaeser argues that the idiosyncrasies that characterize those successful urban spaces contribute to attract people with all kinds of backgrounds and interests, thus providing opportunities for collaborations between diverse people so that cultural and technological innovations can flourish, such as in 5th century B.C. Athens and in the rise of Silicon Valley.

Garvin, another city proponent, adds ‘(it) is not about the most beautiful, convenient, or well-managed city; it isn't even about any "city." For me, it is about what we can do to make a city great' (2016, p. xvii). According to Garvin, an accessible and open public realm delivering a multitude of opportunities for small-scale transformations by residents' simple interventions can attract more people, and likewise, generations of urban dwellers reshaping, creating new demands and governments supporting those changes would make a recipe for a great city.

Both these perspectives from city proponents strongly regard the human social interactions that emerge in a place as the base of valuation of the place. In other words, we can contemplate a city as a dynamic, transient (Garvin, 2016) and ever-changing (Glaeser, 2011) system of human social process (Neuman, 2005) with a certain degree of plasticity. We could thus refrain from evaluating cities as static artifacts (Alexander, 1965), and approach them as agglomerations of diverse humans in proximity of each other; interacting, exchanging and sharing material and immaterial things/objects/beings rather than the spatial form that contains them.

Proximity and diversity of people seem to generate complex networks among them, which in turn contribute to creating knowledge spillover and innovativeness (Carlino, Chatterjee, & Hunt, 2007; Bettencourt, 2013), by sustaining information flows that maintain collective creativity (Kanter, 1988). According to Kanter (1988), innovation needs activation of cross-fertilization of ideas through structural integration, and this happens when there is close proximity between demands and solutions, and a diversity of ideas and cultures, and with the added benefit of flexibility that can be observed in organizations composed of smaller units. This theory seems to be supported by research relating to the efficiency of groups of diverse backgrounds (Hong & Page, 2004), where an experiment showed higher proficiency for completing a task in groups with participants of diverse backgrounds with various knowledge levels relating to the given tasks, than in groups of participants with expertise in the task but with similar backgrounds.

In an urban spatial context, this diversity would translate into the integration of a variety of demographics, heterogeneous urban grains, and functions in different scales through mixed land use (Glaeser, 2011), allowing for mutation of businesses through combinatory and divisionary processes (Bettencourt, Lobo, Strumsky, & West, 2010; Bettencourt & West, 2010; Bettencourt, 2014; Youn et al., 2016). Such multifarious scales of business types in proximity of each other are seen not only to generate better economic output (Quigley, 1998), but also to create more resilient urban conditions by supplying a redundancy of functions (Bettencourt & West, 2010). Such a condition presents diverse and complex responses to disturbance situations through increased complexity (Bristow, 2010; Glaeser, 2011; Offenhuber & Ratti, 2014), a resilience that is needed in unpredictable situations (Holland, 1992; Ahern, 2011).

If we consider social processes as the main driving force shaping a city that shows the positive qualities of a compact city, developing a design template for a perfect compact city urban form seems to be unachievable. If we wish to achieve the promised benefits of such an urban form, we probably need to curb our ambition to approach a compact city as a design or a plan achieved by implementing quantifiable targets for density or diversity. Instead, it might be more effective to explore urban systems that support development processes that lead to a type of urban agglomeration that bespeaks of relations and proximity between diverse urban components and people (Neuman, 2005; Glaeser, 2011; Bettencourt, 2013).

### ***The 1st Knowledge Gap:***

Policies promote the compact city for its supposed benefit, such as walkability promoting public health, social engagement in the neighborhood and cohesion and higher quality of public transportation, while at the same time supporting reduced resource consumption, carbon emissions, and the ecological footprint per capita. However, it is still contested in research whether this actually is the case. These contradicting views regarding the purported benefits seem to stem from whether the focus is on the qualities of the density-based urban form or on the processes of 'becoming' a compact city, which often pays attention to interactions and diversity. In the latter case, 'proximity' rather than density is often used to describe the 'compact city' qualities. Either way, cities are increasingly being guided by policy lines promoting the planning and designing of a 'compact city,' as seen in the case of Gothenburg. However, a knowledge gap appears to remain regarding how urban development and planning approaches and processes affect the qualities of a compact city, such as diversity and density.

## 2.5 Urban emergence and resilience in an urban planning context

Neuman (2005, p. 22) argues that a 'form is both the structure that shapes process and the structure that emerges from a process' and 'is an outcome of evolution' (Neuman, 2005, p.23). From this perspective, it seems that the urban evolutionary processes that enable the emergence of compact city urban form need further attention. One way to understand such emergence is by applying Gunderson and Holling's concept of evolutionary resilience to the urban context (Davoudi et al., 2012). According to Gunderson and Holling (2002), evolutionary resilience is about the ability of a system to not only bounce back to the previous state before a disruptive shock but to extend its capacity by self-organization. Applying this to the urban context, compact city qualities that can provide complex and diverse responses in unpredictable challenges (Bristow, 2010; Glaeser, 2011; Offenhuber & Ratti, 2014), would best emerge through a process of adapting and learning.

Urban research has thus become increasingly engaged in identifying and developing urban planning and designing approaches that enable such diverse interaction between stakeholders to provide self-organized adaptability and resilience (Innes & Booher, 2010; Batty, 2011; Batty & Marshall, 2012; Portugali, 2012). Such processes typically involve multiple-stakeholder inclusion where urban macro structure emerges through incremental changes exceeding the potential of centralized, top-down master planning and designing to provide such responses (Neuman, 2005; Innes & Booher, 2010; Batty, 2011; Portugali, 2012; Bettencourt, 2013).

Proponents of participatory planning in support of multiple-stakeholder inclusion has a long history, such as Sherry Arnstein's 'ladder of citizen participation' (Arnstein, 1969). To deal with the complexities in urban planning, collaborative/communicative planning theories argue that communication and deliberation between the stakeholders should be the center of policymaking (Healey, 1992, 2002, 2007; Innes & Booher, 1999, 2010). As opposed to centralized, top-down planning, decentralized multiple-stakeholder participation based on dialogue is promoted (Healey, 1992, 2002, 2007; Innes & Booher, 1999, 2010; Fainstein, 2000). Susan Fainstein (2000) argues that collaborative/communicative planning, by converging pragmatism and communicative rationality, provides action plans for the planners by positioning the planner as a 'negotiator and intermediary among stakeholders' (Fainstein, 2000 p. 454) forging consensus between perspectives.

However, this consensus-based approach has been critiqued for ignoring issues relating to power (Yiftachel & Huxley, 2000; Flyvbjerg & Richardson, 2002; Hillier & Gunder, 2003) and for ignoring problems linked to the maintenance of consensus (Allemendinger & Haughton, 2012). Furthermore, consensus itself might not always be rational or achievable and may also eliminate potential alternative solutions (Mouffe, 2000, 2013; McAuliffe & Rogers, 2019) by limiting the diversity of solutions made by individual stakeholders since agency is handed over to the consented solution (Imottesjo & Kain, 2018). Fainstein (2000) summarizes the challenges of turning this theoretical approach into practice as 'the gap between rhetoric and action' (p. 460), the lengthy time required for the participatory processes, difficulties in framing alternatives when planners desist from agenda-setting, and potential conflicts between the aim and outcome.

Complexity science and agent-based modeling (ABM) provides another perspective on how to understand bottom-up and self-organized adaptability in planning (Clarke, 2014; Crawford, 2016; Imottesjo & Kain, 2018). In contrast to collaborative/communicative planning, ABM suggests computer simulation methods to generate bottom-up, self-organized emergent urban patterns based on imposed urban rules and individual agent's reaction and adaptation (Crooks, Castle, & Batty, 2008; Sant et al., 2009, 2010; Batty, 2009, 2011; Portugali, 2012), where an 'agent' is defined as 'a behavioral unit, such as a person, household, business, landholder, or farmer' (Clarke, 2014, p. 1218). Advocates of ABM maintain that the agency lies (or should lie) in individual agent's hands, each adapting to an environment that is changing due to other agents' decisions but still abiding by the rules implemented for the simulation (Crooks et al., 2008; Clarke, 2014; Millington & Wainwright, 2017). However, ABM tends to ignore that human motivations are not always rational or straightforward (Bithell, Brasington, & Richards, 2008; Kennedy, 2012; Tan & Portugali, 2012). Another weakness is that, depending on the scale that is used for the computer simulation, there is a necessity to reduce the complexity of real-life context into a type of simpler abstraction (Batty, 2005; Mayer, 2009; Heppenstall, Malleson, & Crooks, 2016).

***The 2nd Knowledge Gap:***

Research about the 'compact city,' even though contrasting perspectives exist, seems to support that its complexity and resilience qualities are of importance. If we focus on the processes of the emergence, or of the 'becoming' of a 'compact city,' the process that support diversity of individual agents networking and interacting in close proximity in a bottom-up direction seems to give rise to its resilient characteristics. These processes of interaction appear to enable faster adaptation through a continuous division and recombination of businesses, ideas and groups, enabling complex responses to complex problems. Here, the insufficiencies within both abovementioned approaches to self-organized adaptability and resilience in planning suggest that more knowledge is needed to facilitate multi-stakeholder inclusion in contexts of urban emergence (Flyvbjerg & Richardson, 2002; Batty & Marshall, 2012; Millington & Wainwright, 2017), potentially building on the strengths of both approaches and avoiding some of the pitfalls. In other words, there is a gap in knowledge relating to how urban planning theory discusses processes of emergent urban development leading to urban resilience.

## 2.6 Visualization and mobile augmented reality

Another issue linked to this pursuit of multiple stakeholder inclusion in urban planning and design processes concerns the communication between urban planners and non-expert citizens, where effective participation depends on tools for stakeholder input (Kallus, 2016). Available tools for communication of what the future built environment will look like are often based on visualized representation, including plans using architectural symbols, 2D image renderings, or 3D physical scale models. These image-based representations might be interpreted in different ways by the non-experts (Bates-Brkljac, 2009) when comparing them to the actual environment on-site, creating misunderstandings (Wergles & Muhar, 2009). Recently, various immersive visualization technologies, especially mixed-reality (MR) technologies, such as virtual reality (VR) and augmented reality (AR), have been developed and adopted to bring in the many types of contextual urban information that need to be presented in representations of the built environment (Hanzl, 2007; Ashraf Khan & Dong, 2011; Gordon & Manosevitch, 2011; Sørensen, 2013; Billger, Thuvander, & Wästberg, 2017). Especially with VR technologies, incorporation of Building Information Modeling (BIM) has been used to provide end-users with experiences of the design of the built environment immersed in the 3D modeled space. This has facilitated better communication between designers and users (Shi, Du, Lavy, & Zhao, 2016). In the urban scale, simulation of environmental big data, such as heat, shades, or noise in the virtual environment aid non-expert stakeholders to perceive information of urban qualities through immersive visualization based on smart city technologies (Jamei, Mortimer, Seyedmahmoudian, Horan, & Stojcevski, 2017).

However, the perception of the built environment includes not only the visual qualities of a place but also ‘auditory, olfactory, haptic and kinetic experiences’ (Wergles & Muhar, 2009, p. 177) from being in the affected space. As relying solely on the visualized representation could be limiting when communicating information about the urban environment (Pizarro, 2009; Pallasmaa, 2012), bringing in ‘immersivity, interactivity and multi-sensoriality’ (Piga & Morello, 2015, p. 4) in the representations of urban conditions and the environment might support effective and enhanced citizen's engagement.

As a result, efforts have been made to use the AR technologies for collaborative design and for communicating architecture and built environment, for example using table-top scale modeling with head-mounted displays (Moeslund et al., 2004; St-Aubin et al., 2010) and on-site projection of built objects for evaluation by stakeholders (Sørensen, 2013, Allen, Regenbrecht, Abbott, 2011, Gill & Lange, 2015). Especially, the combined use of mobile technologies and AR technologies enable outdoor mobile augmented reality (MAR) technology on widely available devices, such as smartphones (Chatzopoulos, Bermejo, Huang, & Hui, 2017), allowing pervasive participation and citizen engagement on urban issues using pervasive smart technologies (Parker, Tomitsch, Kay, & Baldauf, 2015). In addition, technological developments have provided new and increasing opportunities with functions embedded into smartphones, such as camera, a global positioning system (GPS), and gyroscope, which provides easy access of advanced digital tools to the broader public in support of civic engagement (Parker et al., 2015; Chatzopoulos et al., 2017). Such technologies provide ample opportunities to collect data from stakeholders regarding their responses, opinions, and proposals for the design and use of urban space (Allen et al., 2011). However, remaining technical obstacles, such as inaccurate positioning of the augmented objects outdoors (Karlekar et al., 2010; Carozza, Tingdahl, Bosché, van Gool, 2014) contribute to the lack of use of outdoor AR when engaging the public in urban design processes (Gordon & Manosevitch, 2011; Billger et al., 2017).

***The 3rd Knowledge Gap:***

As argued above, supporting efficient bottom-up input of diverse stakeholders during urban design and planning processes can be seen as critical, fostering the complexities that render a city resilient. The use of AR and visualization seems to have significant potential for triggering, facilitating, and visualizing such bottom-up processes. AR, and especially MAR, would support citizens to make decisions on-site based on perceptions of environmental aspects, such as noise, air quality, and crowdedness. AR/MAR also bring possibilities to collect and aggregate the diverse input from many citizens. However, there are still many challenges linked to the use of AR/MAR tools and a need for further research and development regarding AR/MAR tools, which may enable citizens to engage in experiencing, visualizing, and collaboratively designing urban environments.

## 2.7 Aim and research questions

Based on the state of the art and the identified knowledge gaps, this thesis aims to contribute to research concerning how processes of incremental bottom-up urban planning and design involving citizens could be facilitated in support of emergent urban resilience in the context of urban compactness. The first objective linked to achieving this overarching aim is to understand the relationship between different urban planning approaches and the processes and the outcomes of those from the perspective of qualities of compact urban form. The second objective is to understand how the complexity that renders urban resilience is maintained through urban emergence and how this process can be understood from an urban planning theory perspective. Finally, the third objective is to understand how an AR/MAR tool can be devised, which would potentially trigger processes of urban emergence based on non-expert citizen input.

Founded on these objectives, three main research questions are formulated as follows:

> ***Research Question 1:***
> *What are the differences in the physical outcomes of different planning approaches in relation to compact city urban characteristics, such as density and diversity?*
>
> ***Research Question 2:***
> *How can processes of emergent urban development be understood from an urban planning research perspective?*
>
> ***Research Question 3:***
> *What AR and/or MAR tools can be developed to stage urban emergence by supporting citizens to visualize and collaboratively design on the neighborhood scale, and then aggregate people's ideas and views?*

# Chapter 3.

## Point of departure: Example of Tokyo regarding urban resilience and urban process

## 3.1 From a rumble to a mega compact city through plot-by-plot 'self-reconstruction.'

If we assume that the answer to the resilient compact city lies in the process of how a city becomes resilient and compact through adaptation and interaction: how can such a process be replicated from an urban planning perspective to create this kind of emerged compact urban form?

Looking from the urban resilience point of view, we can find some cities that have been rebuilt after near-total destruction by either natural or human-made catastrophe and have started thriving again less than two decades after the event. Then again, other cities that have flourished in the past now face significant decline without any signs of recuperation after just a single local industry has closed down. Even though urban resilience has many faces and definitions (Meerow, Newell, & Stults, 2016), looking at cities that have time after time rebuilt themselves after total devastation might give us some clues as to what makes them resilient, as per the dictionary definition of resilience: 'the capacity to recover quickly from difficulties; toughness' (Resilience, 2019).

Tokyo, a mega compact city with a population density of 6,158 persons per square kilometer (2015 estimation from Tokyo Metropolitan Government, 2019), is the embodiment of a thriving compact city that has resurrected itself time and again from being 'ground zero' after both nature and humans have wreaked havoc on the city. Currently, home to 13,49 million people (2015 estimation from Tokyo Metropolitan Government, 2019), the city manages to maintain the seventh place on the Global Liveability Index, published annually by the Economist Intelligence Unit (2018). This index is based on stability, healthcare, culture, environment, education, and infrastructure. According to an OECD report (2017), Japan has the lowest per-capita land consumption among OECD countries. Keeping cities compact would have attributed to this low consumption of developed land and the maintenance of a high share of forested areas nationwide.

We can examine some of the recent impactful natural and human-made crises from which Tokyo, as a city, has bounced back. Historically, Tokyo has been subjected to a multitude of disasters, due to its geolocation on the so-called Pacific Ring of Fire, that is, the most active earthquake belt on the planet. It holds the top position on Lloyd's city risk index (Ruffle et al., 2018). According to Lloyd's, the risk is not only assessed based on a city's geolocation but also its proximity to the sea with the accompanying risks of a tsunami, tropical windstorm, and flood. Politically, due to Tokyo's proximity to the Korean peninsula, with fluctuating political stability, regional conflict is also a risk factor. The high-cost approximation of these potential risks is ascribable to the high population density of the area, where certain risks would impact a substantial number of people, causing significant economic damage (Ruffle et al., 2018). Still, the greater economic output due to the region's high population density and a more significant loss of economic output when a risk impacts are two sides of the same coin. Therefore, it is in our interest to explore the approaches this city has taken to restore itself from such high-cost disasters by looking into some of the risk factors that have materialized in the past.

### ***Natural disaster***

The Great Kanto Earthquake of 1923 could be seen as a case of natural calamity, in which the ravaging fires caused by the earthquake resulted in 140,000 casualties and 300,000 destroyed houses (Tokyo Metropolitan Government, 2019). Amidst the gloom, due to budget limitations, the national and regional reconstruction measures had no choice but to guide their focus and channel the limited resources into developing and preparing major road arteries to provide improved infrastructure, while leaving the rest of the reconstruction projects out of focus and under local autonomy (Akimoto, 2012). This lack of central planning for disaster reconstruction prompted a bottom-up, self-organized, neighborhood-by-neighborhood regeneration of the city through civilian efforts to rebuild, building-by-building, on the ruins where previous buildings had been situated. The urban structural outcome of this bottom-up rebuilding effort turned out to be more or less unaltered from that of the pre-disaster structure (Hein, 2010; Okata & Murayama, 2011). According to the Tokyo Metropolitan Government's account, by 1935, approximately a decade later, Tokyo had already recouped its population, which had increased from 3.7 million in 1920 to 6.37 million (see Figure 3), matching the populations of London and New York at the time. By then, major infrastructure including subway lines, an airport, and the Tokyo port had also been completed.

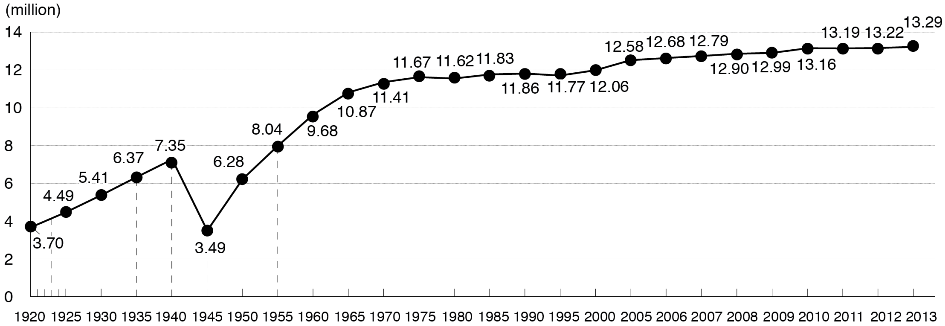


*Figure 3. Population changes in Tokyo*

### *Human-made disaster*

About 20 years after the Great Kanto Earthquake, another unfortunate event hit the city. This time, it involved the Bombing of Tokyo in 1945 during World War II, which caused the city's population to drop to half of that in 1940, from 7.35 million to 3.49 million. Not unlike the previous restoration process in response to the Great Kanto Earthquake, the rebuilding of the city after the war followed the principles of self-reconstruction, encouraged by the government for a quick return to normal by providing shelter to citizens. Once again, this type of quick, bottom-up self-reconstruction mimicked the pre-disaster urban layout and framework (Pernice, 2014), leaving the urban form altered only minimally from the structure before the bombings. This process of empowering the local autonomy further sped up the decentralization, transferring the authority of 'Toshi-keikaku' – directly translated as 'city planning' to local prefectures and municipalities by 1968. This trend of decentralization continued into the year 2000, with the delegation of even more power from prefectures to municipalities (Akimoto, 2012). However, the Japanese context of city planning is defined, in the Toshi-keikaku Act of 1919, as a 'legally binding map for planned important facilities'. This definition lacks the concept of 'planning,' as 'plan-making does not necessarily mean planning' (Akimoto, 2012, p. 1). Although a new type of plan, 'sougou-keikaku,' prepared in the Local Autonomy Law of 1947 and the City Planning Acts of 1968, embraced the international trend of the 'planning' concept – i.e., 'assembling actions into some orderly sequence' (Hall, 2002;1, according to Akimoto, 2012, p. 3) for 'deliberately achieving some objectives' (Hall 2002;1, according to Akimoto, 2012, p. 3) – still, neither new law actually used the Japanese term meaning 'planning' or defined the 'planning process'. Subsequently, this led to planning documents containing no clear idea of either 'planning' or 'planning process' (Akimoto, 2012).

In place of the act of 'planning' as defined by Akimoto, the practice of local community-rebuilding efforts continued to be effectuated even after the Great Hanshin-Awaji Earthquake in 1995. Recently, this community-building effort has been termed 'Machi-zukuri,' meaning town-building as a form of neighborhood development. This refers to 'a variety of activities where residents, working together or in cooperation with the local government, make the place where they live and conduct their day-to-day business into one that is attractive, pleasant to live in, and appropriate for the area' (Toshi-keikaku Yōgo Kenkyū-kai, 1998: 410; From Evans, 2002, p. 447).

This lack of large-scale design planning and comprehensive urban master planning can be argued to be the backbone of livable, multi-functional neighborhoods that include inspiring features involving sustainability and community planning (Hein, 2010). Hein (2010) gives an example of turning a centralized design control mechanism into something more practical and generative so that the means of facilitation for future adaptation are available to the local communities without centralized management. This example relates to the concept of European building frontage lines, which was initially used as a design control instrument for street frontage. When this was introduced and replicated in the Japanese Urban Building Law of 1919, an adaptation of the concept into the Japanese context was made, and the lines were instead drawn in the interior of urban blocks to provide internal access within the deep urban blocks (see Figure 4). According to Hein (2010), this had helped to maintain the population density in the city after the Great Kanto Earthquake by rendering the blocks usable in depth. In this way, a design control instrument was turned into a generative instrument and opened up the capacity of the urban blocks for future adaptation by the locals.

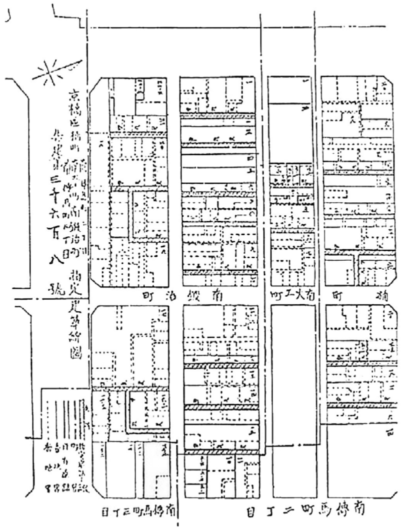


*Figure 4. The lines drawn inside urban blocks to provide future adaptability of the block for densification. Image is taken from Hein (2010), Original source: Yorifusa Ishida and Koshi Ikeda, 'Kenshiku sen' keikaku kara chiku keikaku he no tenkai (Tokyo: Tokyo-tori)*

These fragments of practices – i.e.,the lack of modernistic city-wide masterplanning; the adaptation of design control rules and regulations into more pragmatic rules based on the local context; and the incremental, self-organized, small-scale restoration – hand-in-hand allowed Tokyo to swiftly recover by approximating the pre-disaster urban structure (Okata & Murayama, 2011). Okata and Murayama (2011) further speculate that if more comprehensive and strict planning had been in place, the city would not have had the means to grow as quickly to accommodate the massive population growth.

## 3.2 The great urban patchwork of tiny pieces

The chaotic look of Tokyo, stemming from the lack of planning and design control, can also, in part, be attributed to the size of the urban plot parcels. When individual parcel sizes are small and can be individually modified and transformed, a more diverse output is generated as a whole. After World War II, major agrarian land reform was initiated by the US occupation force, passing the Japanese agrarian reform of 1947. The implementation of this land reform contributed to reassignment and redistribution of farmland from landlords to tenant farmers – i.e., from the hands of the renters to the operating farmers (McDonald, 1997) – leading to the generation of piecemeal mixed-building type development (Kawagoe, 1999). According to Hewes (1950 from McDonald 1997), this reform allowed three million households to purchase some land, and six million farm families to gain smallholdings of an average of less than 1 ha per family. With the demand to urbanize and industrialize during the modernization process, the previously strict Agricultural Land Law of 1952, which prohibited the conversion of farmland into other land, was eased with subsequent revisions of the law in 1970, 1980 and 1991, making it possible to change the land-use type, as well as to sell and purchase the farmland (McDonald, 1997).

In Tokyo, as much as 46% of land parcels owned privately are smaller than 100 m$^2$, and 32% are between 100-200 m$^2$ (Kishii et al., 2007, see Figure 5). Apart from the division of farmland into smaller units, there are many other reasons to further subdivide parcels in densely populated areas, including inheritance and land-use type (Okata & Murayama, 2011) and shape of the parcels (Osaragi, 2014).

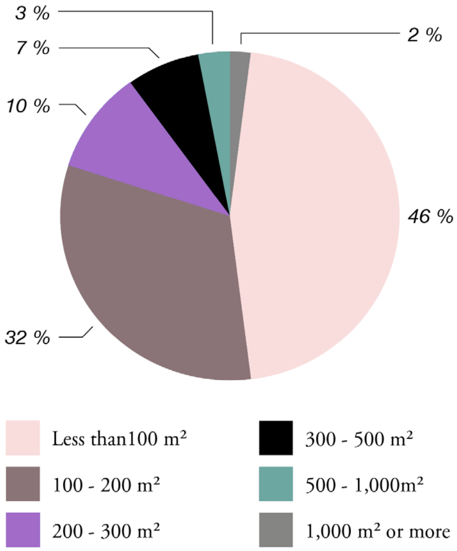


*Figure 5. Sizes of privately-owned land parcels in Tokyo*

Even though this type of fragmentation can be seen as problematic for large-scale urban improvements and developments (Kishii et al., 2007), the possibility of individual development allowing smaller incremental changes can also be seen as contributing to fast adaptation during times of rapid growth and change (Hein, 2010; Okata & Murayama, 2011).

Compared to large-scale development plans, small-scale developments are preferred, not only for the predisposition to fast structural adaptation but also for qualities such as 'spatial intimacy and community cohesion' and the disposition to incremental 'scrap and rebuilding' within the complex urban fabric (Tsukamoto & Almazán, 2006, p. 4). The juxtaposition of old and new on the neighborhood scale further emphasizes the already existing urban functional diversity found in these neighborhoods. Small heterogeneous businesses making up the bottom two-thirds of the Japanese social and economic pyramid (Patrick & Rohlen, 1986) reflect this diversity found in small scale. These small-scale businesses typically include family businesses operating in residential units within the neighborhoods (Patrick & Rohlen, 1986; Echanove & Srivastava, 2011). It is also noteworthy that this juxtaposition of mixed-style development seems to foster less demographic class segregation on the urban neighborhood scale (Fujita & Hill, 2012), promoting a mix of people with diverse socio-economic backgrounds in close proximity in the dense urban context.

As described in this chapter, the city of Tokyo has shown resilience through historical catastrophic events, allowing a capacity to withstand economic and demographic collapses through decentralized, bottom-up, self-organized restoration efforts (Akimoto, 2012; Pernice, 2014). The lack of central master planning and urban design, as well as the building-by-building restoration by local communities, has left the cityscape almost unaltered from the incrementally developed urban form through time and space, exhibiting characteristics of small-scale and diverse urban plots that juxtapose old and new (Tsukamoto & Almazán, 2006; Hein, 2010; Okata & Murayama, 2011; Pernice, 2014). These urban qualities are the very qualities discussed in research in regard to what makes a compact city a resilient urban form (Bettencourt & West, 2010; Bristow, 2010). They permitted the city to bounce back and adapt by supplying the complexity needed to provide diverse responses during times of disturbance (Bristow, 2010; Glaeser, 2011; Offenhuber & Ratti, 2014). In the following sections, we will delve in detail into how this system of individual adaptation without centralized master planning and urban design is maintained.

## 3.3 The roofscapes of Tokyo

*Figure 6. Roofscape of Tokyo, Ebisu (Source: Photographer Matt Kieffer, https://www.flickr.com/photos/mattkieffer/)*

'Do you know why the rooflines look so crazy in Tokyo?' was one of the first questions asked of the author during a job interview at an architecture office in Tokyo. The senior architect continued to claim that architectural design freedom in Japan was greatly limited and that there was no aesthetical wholeness when it comes to city planning and design, all thanks to too many rules, with which all architects had to comply. 'When you're at school, you have these dreams of designing something beautiful and original, but you soon understand that the rules design the buildings, not you.' He added, 'You just use the rules to whatever shadow direction you have, and how far your building is from the road and neighbor, then you have everything already made for you. Space is always too small, you can't lose anything, so you just use the maximum possible area to build.' Well, these were not the exact words, but the spirit of what he meant is nonetheless expressed here.

So, what are these rules that – without a master plan defining an aesthetical wholeness – not only can design individual buildings but also can generate an urban form based on light directions, nearby roads, and neighboring buildings? The roof shapes of buildings in Tokyo (see Figure 6) are not designed based on any central guidelines on design aesthetics for the city as a whole. Instead, the roof patterns emerge from simple rules, such as the slant plane restriction rules (Hasegawa, 2013) that control roof angles depending on a number of local conditions, and the shadow restriction rules that dictate how much shadow a building is allowed to cast upon adjacent properties and roads, and for how much time (Hasegawa, 2013). If a building is torn down, and two adjacent land parcels are merged, then the new building on the larger plot, with its new neighboring properties and road systems, will have a new roof shape that adapts to the changed environmental situation of the site. Accordingly, the macro roofscape system in Tokyo emerges from a micro-scale choreography of the light and shadow and the surrounding neighborhood conditions.

## 3.4 Design process based on urban rules

To aid the understanding of how these rules are practically implemented, we will use an example site as an illustration[1], following the rules assigned to this specific site step-by-step until the final roof shape can be determined. First, we need to identify the land-use zoning category to which the site belongs. Figure 7 shows the detailed land-use zoning of the Meguro ward in Tokyo. We can identify the division of the ward into eight zoning categories. On the map, our example site is also indicated with an arrow.

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[1] *The illustrations used in this section have been modified and reworked from analyses done by the author during work at Albert Abut Architecture in Tokyo.*

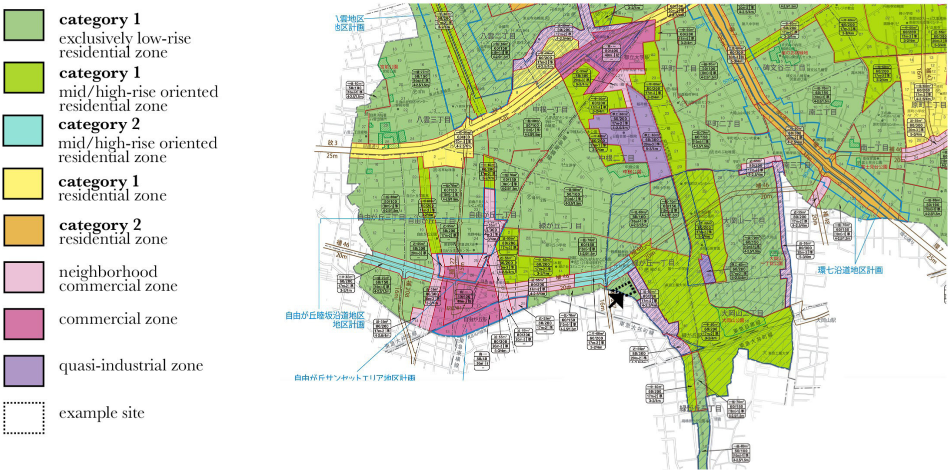


*Figure 7. Detailed zoning plan of the selected area in Meguro ward (Meguro City, 2016)*

If we zoom into the example case site (see Figure 8), we find that the site belongs to Zoning Category 1: Exclusively low-rise residential zone (darker green in the legend).

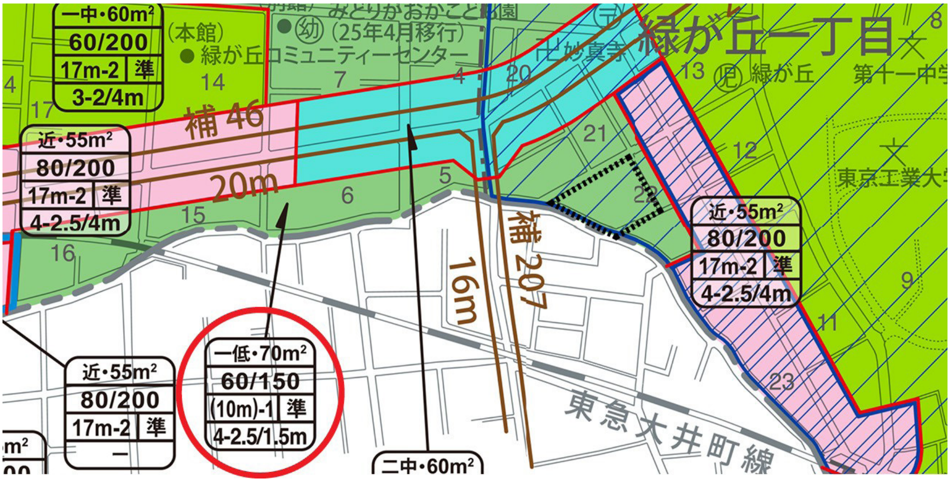


*Figure 8. Detailed zoning plan of the selected area in Meguro ward (Meguro City, 2016)*

A codified zoning tag is assigned to each bundle of sites according to their land-use zoning category and lists a number of attributes that need to be complied with when designing a building on the site.

The information specified in the tag (see Figure 9) includes:

1. Land-use zoning category,
2. Minimum allowed land parcel size,
3. Building coverage ratio (BCR): (building footprint area/site area) x100,
4. Floor area ratio (FAR): (total floor area/site area) x100
5. Height restriction,
6. Type of fire protection area,
7. Shadow control duration and length, and
8. Shadow measurement height from the ground.

The building shape is primarily affected by Points 3, 4, 5, 7 and 8, which control the building's proportion, height, and volume, depending on the duration and length of the shadow.

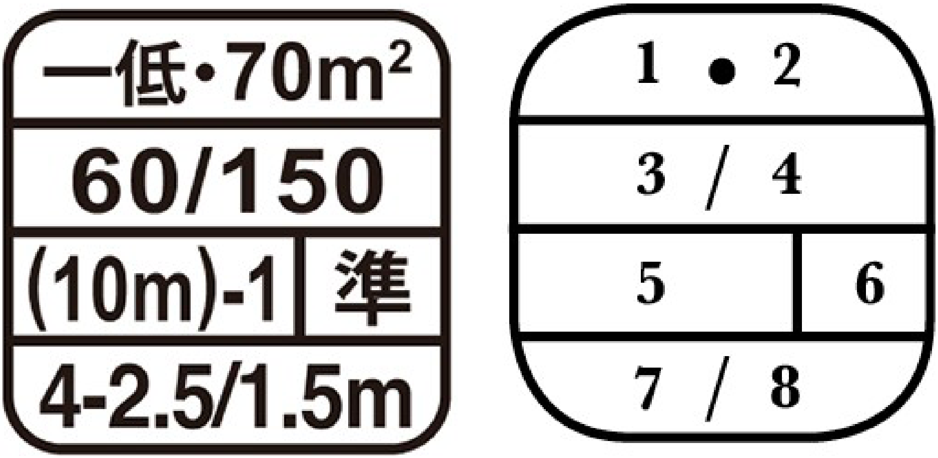


*Figure 9. Codified zoning tag*

Second, we need to consider the setback distance rules. Such rules were introduced in the 1987 revision of the Building Standard Law (Sorensen, Okata & Fujii, 2010), and prescribe where to position the building in relation to the site boundary depending on the width of the adjacent road. With this rule, if an adjacent road is less than four meters wide, as is often the case with the old road system, a setback line should be drawn so that the road width and the setback lines from the site boundaries on both sides of the road will add up to four meters (see Figure 10).

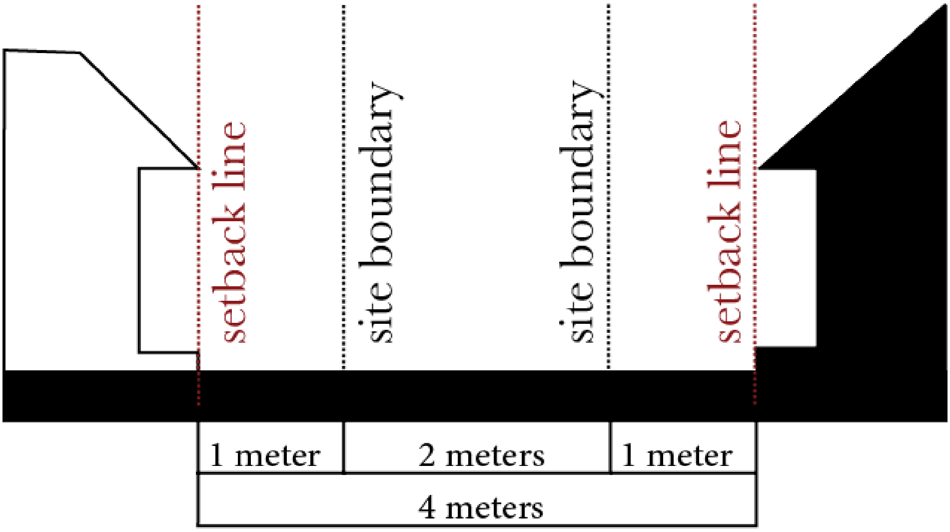


*Figure 10. Setback lines*

As can be seen in Image 4, due to the old road type which is narrower than four meters, one-meter setback lines were added to the properties on both sides of the road, which places the edges of the facing buildings four meters from each other. Figure 11 shows the interpretation of this rule on the example site. Roads A, B, and C are less than four meters wide, and setback lines were drawn as compensation, indicated by the red chain-dotted lines. Road D is wider than four meters, so no setback line was needed.

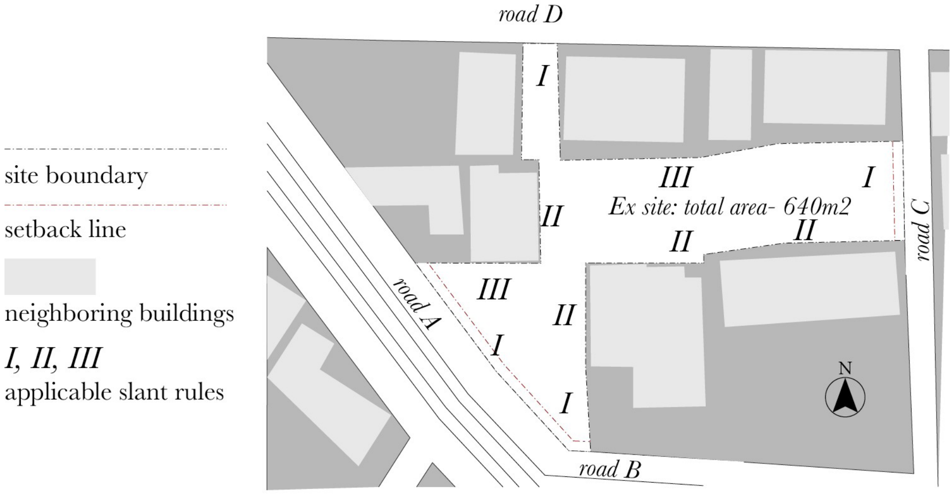


*Figure 11. Setback lines on the example case site (chain-dotted lines). Roman numerals indicate the type of slant rules that need to be applied to the site boundaries.*

Third, when the setback lines are determined, and the potential boundaries of the building are outlined, it is time to apply the slant plane restriction rules in conjunction with the height restriction rules (Hasegawa, 2013) to determine possible building shapes and roof angles.

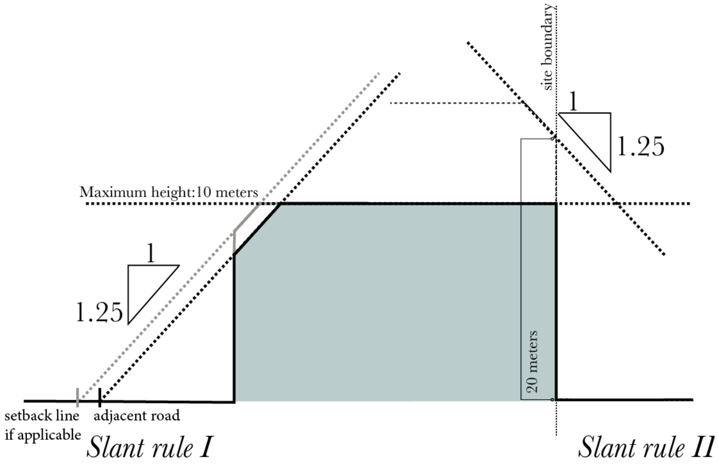


*Figure 12. Application of slant rules I and II*

Slant rules are applied according to three conditions (see Figure 12):

1. Adjacent road,
2. Adjacent site, and
3. North side of the site.

In Figure 11 (Roman numerals), we can see that four sides of the property are affected by the adjacent road slant rule (I) and four by the adjacent site slant rule (II), and an additional two sides that need to comply with the North-side rule (III). The slant rule (I) applied to the side of a road for low-rise residential areas specifies a 1:1.25 ratio angle measured from the opposite side of the road, including the setback line if a setback line was required. While the adjacent site slant rule (II) uses the same ratio, it is measured from the site boundary at a 20-metre height point from the ground (Hasegawa, 2013) (see Figure 12).

The third slant rule – i.e., the North-side rule (III) – applies a 1:0.6 ratio angle for this zoning category, measured from the site boundary at a five-meter height point from the ground (see Figure 12). Fourth, as the codified zoning tag also specifies height restrictions, the buildable area is regulated once more by the maximum height rule, in this example, ten meters (see Figure 12 and 13).

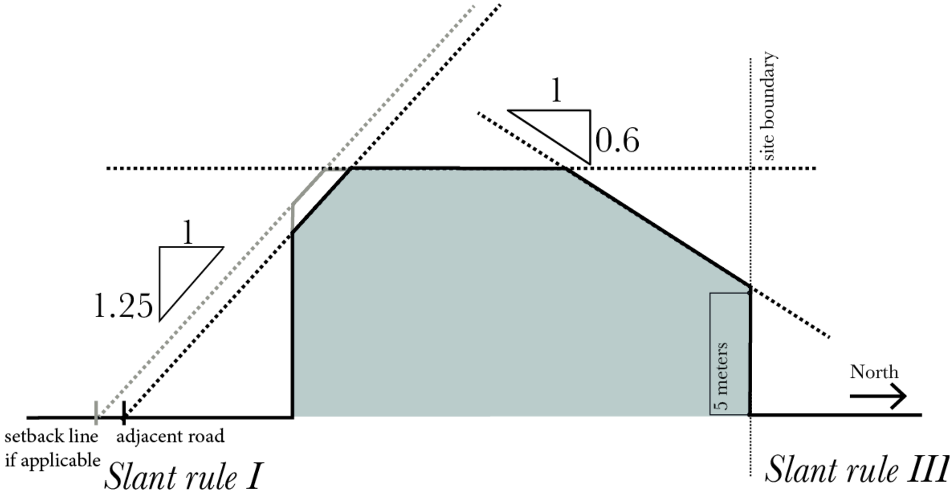


*Figure 13. Application of slant rules I and III*

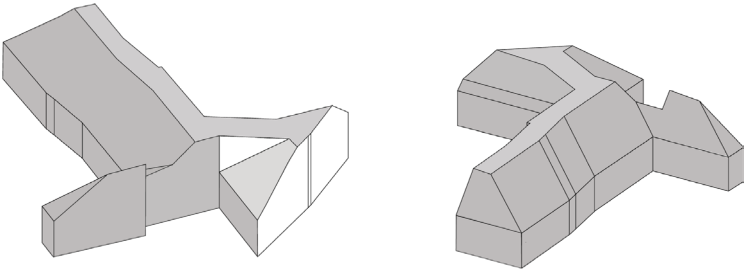


*Figure 14. Volume study of the maximum buildable volume*

Fifth, from the application of the setback rules, slant rules and the maximum height restriction rule, the maximum buildable volume is derived (see Figure 14).

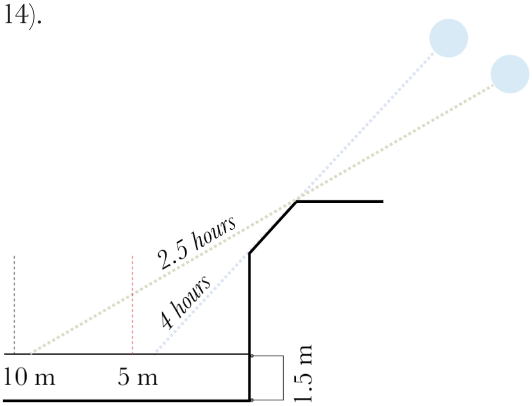


*Figure 15. Shadow restriction rules based on the site specifications. Shadow is measured at the winter solstice between 08:00 and 16:00.*

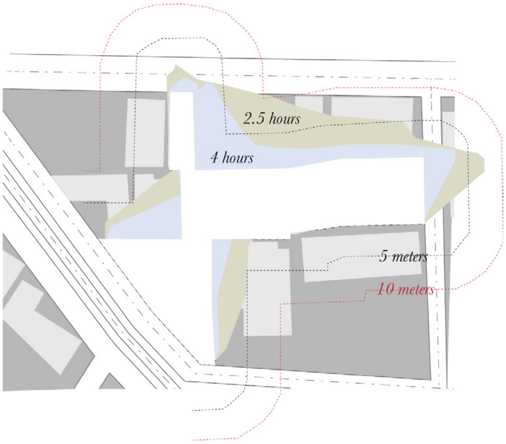
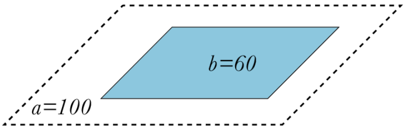


*Figure 16. Shadow analysis of the maximum building volume. Five- and ten-meter maximum shadow boundaries in dotted lines.*

The sixth step after the basic buildable volume has been determined is to comply with the shadow restriction rules, with shadows being measured at full sun height at the winter solstice between 08:00 and 16:00 (Mizukoshi, 1978). These rules will further reduce the buildable volume if the maximum buildable volume casts a longer shadow over the time limit specified in the codified zoning stamp for the site. According to the specifications assigned to the site (see Figure 9), the shadow length of five meters from the site boundary is allowed for four hours of shadow time, while shadow lengths up to ten meters are only allowed for two and a half hours. The zoning tag also specifies that the area affected by the shadow is to be measured at a 1.5-metre height from ground level (see Figure 15). The shadow analysis of the site (see Figure 16) shows the boundaries of the shadows and the maximum durations, using the maximum buildable volume derived from applying the setback, slant and height restriction rules, confirming that the building volume generally falls within the limits of the shadow restriction rules.

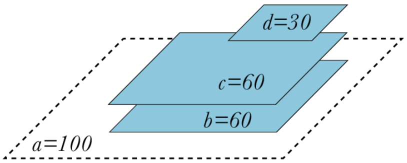
The final step determining the volume and area of the building is less deterministic compared to the previous rules applied to the site. This step involves complying with the maximum BCR and the FAR as specified in the zoning tag. This step brings the creative force to the front to maximize area and accommodate building functions within the allowed building volume by working with the proportions between the floor areas and the number of floors. This phase is more dynamic from the design perspective since, from this step on, the final design can be consolidated, and there is a possibility for a bit of manipulation through design to comply with the rules. Instead of determining exact angles and heights, FAR and BCR only indicate the maximum percentage of areas to the site area (see Figure 17). This control of proportions allows for flexibility, whereby the floor area and the number of floors can be adjusted so that the final design provides an optimized use of the allowed space, corresponding to the architectural concept and the required functions.



*In this example calculating the BCR would be as following, if a = site area, and b= building footprint area.*

*60/100 x 100 =60% (BCR)*

*BCR (%)= Building Footprint Area/Site Area x 100*



*In this example calculating the BCR would be as following, if a = site area, b= First floor area, c= Second floor area and d= third floor area.*

*(60+60+30)/100 x 100 =150% (FAR)*

*FAR (%)= Total Floor Area/Site Area x 100*

*Figure 17. Calculation of BCR and FAR*

Applying this proportion control to the case site rendered the building design seen in Figure 18. This building's footprint and the number of floors were generated by implementing the basic concept of the central core shared space and two private spaces connected through a corridor, and removing volumes for small gardens, thus utilizing the maximum 60% BCR and 150% FAR assigned to the site.

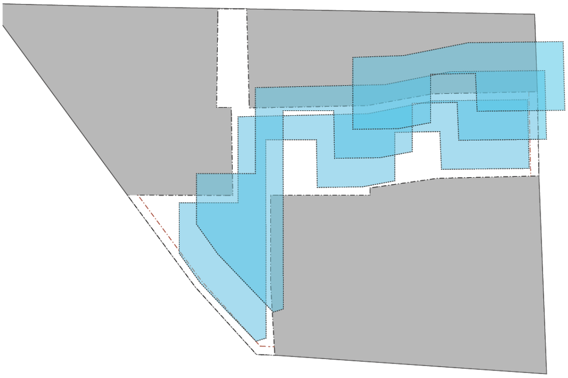


*Figure 18. The building volume after complying with the BCR and FAR specifications for the site. Building footprint and number of floors determined.*

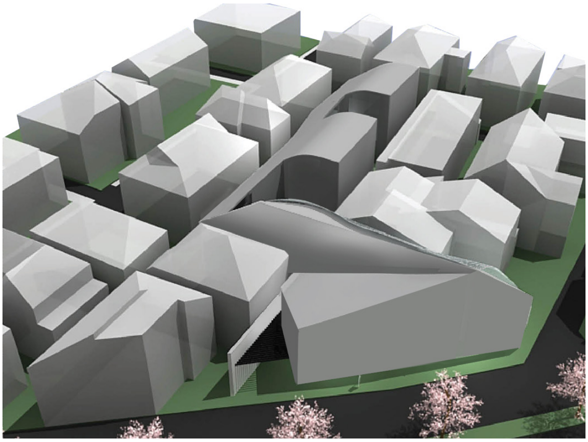


*Figure 19. The rendering of the final building volume on-site*

The preliminary building volume and shape are now determined, after complying with all the rules shaping the roofscapes in Tokyo. Figure 19 shows a rendering of the maximum volume placed on the site.

Aesthetically, this outcome could be attractive for some but slightly uncomfortable for others. There is hence a subjectivity in the evaluation of aesthetic values in urban systems arising from urban codes to control the appearances of, e.g., building materials or building frontages (Marshall, 2011; Rezafar & Turk, 2016), or from cultural and historical preservation codes that are assigned to certain chosen buildings (Rezafar & Turk, 2016). On the one hand, this can lead to problematic disagreements between decision-makers and the public regarding the outcomes (Sternudd, 2007). On the other hand, control through rules that generate specific building shapes on particular sites through regulating zoning assignments that define, e.g., the height, shadow, and proportions of buildings could provide manageability of macro aesthetical patterns without the need for micro design control, for instance of colors, materials, or style. Still, the capacity for adaptation resulting from such control mechanisms would depend on the flexibility in the rule implementation according to the changing urban context and needs (Sorensen et al., 2010).

Sorensen et al. (2010) call attention to the changes in the Building Standard Law of 1987, which changed the building scape of Tokyo and contributed to an urban intensification with the proliferation of taller buildings. The image below shows the slight changes in the slant rule that would generate new forms of buildings in the city (see Figure 20).

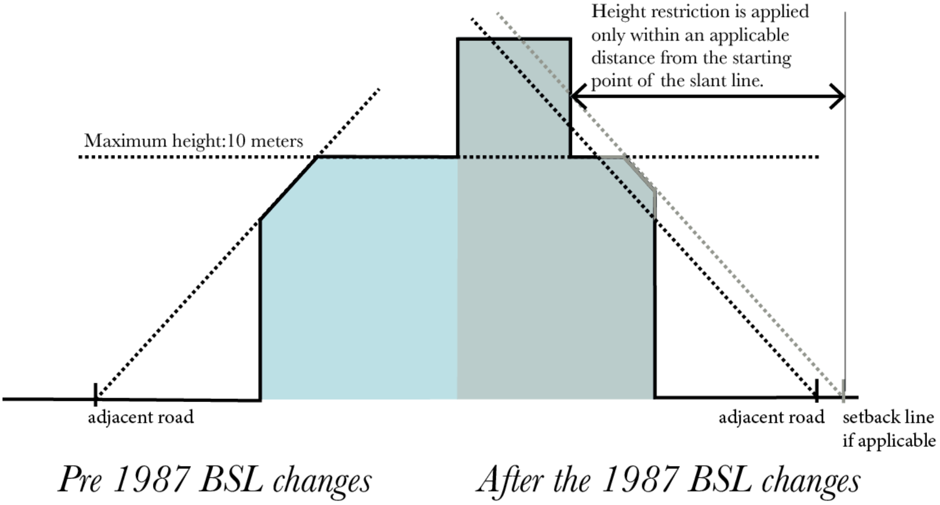


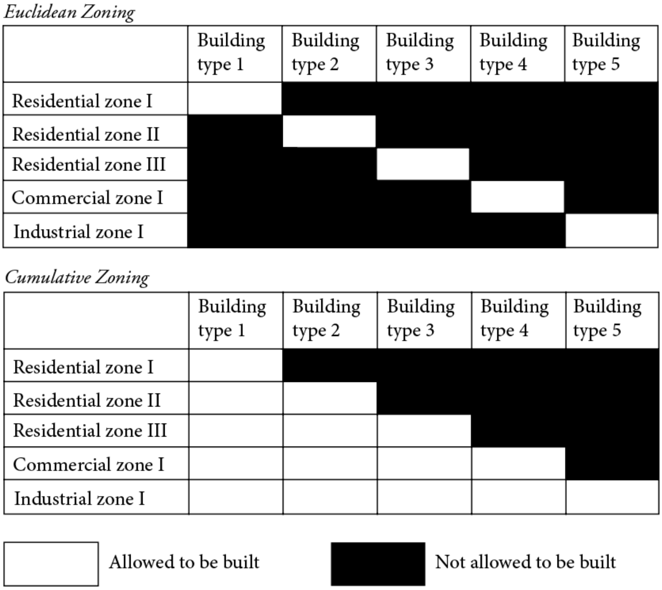
*Figure 20. 1987 Building Standard Law changes regarding slant and height restriction. Modified from the figure from Sorensen et al. (2010, p. 568).*

## 3.5 Euclidean vs. cumulative land-use zoning

Land-use zoning is a core element in the system of rules we applied to determine the building volume and shape in the previous section. However, 'zoning'? The zoning system has been heavily criticized as being a force behind, e.g., racial and socio-economic segregation, urban sprawl; a rigid modernist remnant that destroys mixed, walkable, diversity-oriented urban development (Jacobs, 1961; Hall, 2007). So how do simple rules that abide by a top-down 'zoning' control mechanism still create something as adaptive as the roofscape of Tokyo?

It seems as if the answer lies in the realization that we are confronted with different types of zoning. In the much-criticized modernist Euclidean single-use zoning, the separation of urban functions to reduce the negative impacts of mixed development was the very aim. In comparison, the Japanese zoning system is cumulative and also proscriptive rather than prescriptive.

In this context, cumulative means that each level of zoning categories allows urban functions that are less of a nuisance compared to the previous category. For instance, in a commercial zone, a residential building is permitted (see building types 1-4 in Figure 21/ Bottom), since a residential building is not considered a nuisance to a commercial building. However, a prominent commercial building is not allowed in the residential zone, since the noise or influx of car or pedestrian traffic would be considered a nuisance to residents who dwell in the area.



*Euclidean Zoning*

| | Building type 1 | Building type 2 | Building type 3 | Building type 4 | Building type 5 |
|---|---|---|---|---|---|
| Residential zone I | □ | ■ | ■ | ■ | ■ |
| Residential zone II | ■ | □ | ■ | ■ | ■ |
| Residential zone III | ■ | ■ | □ | ■ | ■ |
| Commercial zone I | ■ | ■ | ■ | □ | ■ |
| Industrial zone I | ■ | ■ | ■ | ■ | □ |

*Cumulative Zoning*

| | Building type 1 | Building type 2 | Building type 3 | Building type 4 | Building type 5 |
|---|---|---|---|---|---|
| Residential zone I | □ | ■ | ■ | ■ | ■ |
| Residential zone II | □ | □ | ■ | ■ | ■ |
| Residential zone III | □ | □ | □ | ■ | ■ |
| Commercial zone I | □ | □ | □ | □ | ■ |
| Industrial zone I | □ | □ | □ | □ | □ |

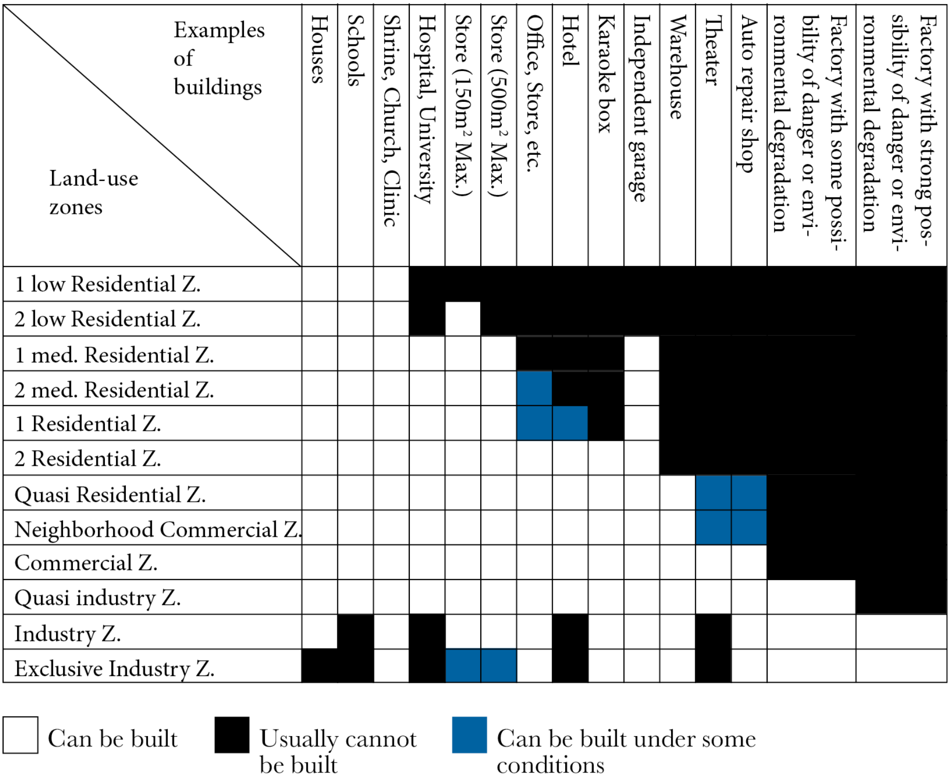
□ Allowed to be built

■ Not allowed to be built

*Figure 21. Schematic illustration of the difference between Euclidean single-use zoning and the cumulative zoning.*

In a prescriptive system, a specific building type or types would be designated for a zone while, in a proscriptive system, all building types are allowed in each zone, excluding only certain specific types of buildings. In this way, a cumulative and proscriptive system allows a broader range of building types in each zone.

On top of the functional diversity created within a neighborhood by the cumulative zoning strategy, the Japanese zoning system also allows a functional mix on the individual building level (Lai & Han, 2012). A house with a small area dedicated to commercial functions (e.g., a 150m$^2$ store) is allowed even in the second-most reclusive residential zone (see Figure 22). Such small houses with corner shops, small restaurants, and repair shops can be seen in most of the residential areas in Tokyo.



| Land-use zones \ Examples of buildings | Houses | Schools | Shrine, Church, Clinic | Hospital, University | Store (150m$^2$ Max.) | Store (500m$^2$ Max.) | Office, Store, etc. | Hotel | Karaoke box | Independent garage | Warehouse | Theater | Auto repair shop | Factory with some possibility of danger or environmental degradation | Factory with strong possibility of danger or environmental degradation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 low Residential Z. | □ | □ | □ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| 2 low Residential Z. | □ | □ | □ | ■ | □ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| 1 med. Residential Z. | □ | □ | □ | □ | □ | □ | ■ | ■ | ■ | □ | ■ | ■ | ■ | ■ | ■ |
| 2 med. Residential Z. | □ | □ | □ | □ | □ | □ | 🟦 | ■ | ■ | □ | ■ | ■ | ■ | ■ | ■ |
| 1 Residential Z. | □ | □ | □ | □ | □ | □ | 🟦 | 🟦 | ■ | □ | ■ | ■ | ■ | ■ | ■ |
| 2 Residential Z. | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | ■ | ■ | ■ | ■ | ■ |
| Quasi Residential Z. | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | 🟦 | 🟦 | ■ | ■ |
| Neighborhood Commercial Z. | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | 🟦 | 🟦 | ■ | ■ |
| Commercial Z. | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | ■ | ■ |
| Quasi industry Z. | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | ■ |
| Industry Z. | □ | ■ | □ | ■ | □ | □ | □ | ■ | □ | □ | □ | ■ | □ | □ | □ |
| Exclusive Industry Z. | ■ | ■ | □ | ■ | 🟦 | 🟦 | □ | ■ | □ | □ | □ | ■ | □ | □ | □ |

□ Can be built ■ Usually cannot be built 🟦 Can be built under some conditions

*Figure 22. Japanese land-use zones and allowed building functions*

As discussed in Sections 1.1.4, 1.1.5, 2.1, and 2.2, these kinds of small-scale neighborhood businesses are acknowledged in the literature as an essential element of the economic resilience of a place, providing necessary complexity with the diversity and proximity of urban functions offering a capacity for adaptive transformation (Quigley, 1998; Glaeser, 2011; Bettencourt, 2013). The strengths of this type of mixed-use zoning can be seen in Tokyo, as its zoning system allows smaller units of domestic workshops and production facilities to be incorporated in the neighborhoods. This integration, in turn, enables the subdivision of manufacturing lines into smaller segments of production processes, whereby jobs can be subcontracted and performed at home-based workshops spread throughout the city, contributing to robust production chains with high specialization and separation of production segments (Echanove & Srivastava, 2013).

Furthermore, as can be seen in the urban history of Tokyo, regeneration efforts in disaster-ridden areas have rematerialized pre-existing old city structures through 'self-reconstruction' – i.e., an accumulation of urban changes and adaptation over time – encouraged by the government as a means for a quick recovery back to normality by mimicking pre-disaster urban layouts and frameworks (Pernice, 2014). In turn, this practice of preserving the complex and fragmented urban plot structure, which had been incrementally developed throughout history, reduced the feasibility of the implementation of modern urban master-planning practices (Pernice, 2014), further reducing the potential for, or risk of, simplification. As the complexity needed for urban resilience arises from 'a complex web of causes and effects, its inter-related parts interwoven through time' (Batty & Marshall, 2012, p. 24), a 'compact city' that has emerged this way would undoubtedly embed enough complexity for continuous adaptation (Scheurer, 2007).

# Chapter 4.

# Methods

## 4.1 Comparative study of Japanese and Swedish planning systems

A comparative study was conducted to understand the differences in the physical outcomes from different planning approaches in relation to compact city urban characteristics, such as density and diversity (Research Question 1).

In this study, the Japanese and Swedish planning systems were chosen for comparison based on the assumption that they represented 'rule-based' and 'design-based' planning approaches, respectively. However, a closer study of the planning contexts of the two countries showed that both planning approaches could be found in urban areas in both Japanese and Swedish planning systems, even though the initially hypothesized approaches were more prevalent in respective cities. In consequence, ten urban areas in both Tokyo and Gothenburg were chosen for analysis, representing:

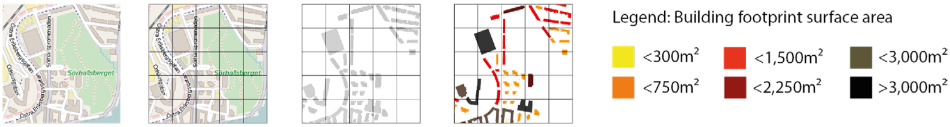
1) emergent compact urban form (Type 1): An inner-city urban structure incrementally developed through multiple actors' interactions,
2) designed dispersed urban form (Type 2): An urban structure designed from the 1960s-1970s with intention to separate functions and provide uniform standards, and
3) designed compact urban form (Type 3): An urban structure where density and diversity are designed by multiple developers during a short period to create a 'compact city.'

Based on the assumption that compact city qualities regarding density and diversity contribute to urban resilience (see Sections 2.2, 2.4), density, diversity of building scales, and distribution of building scales were chosen as proxy indicators for compact city resilience. These three attributes were studied across the three types of urban form, as mentioned above and in the two cities, by analyzing building footprints, i.e., the perimeter of the first floor of buildings (see Appendix 1 for details).

Each study area covered 250,000m$^2$, the size representing the scale of a neighborhood, which could be walked from one end to the other within ten minutes (see Figure 23, step 1). The analysis of the building footprints was performed by dividing each study area into 25 cells measuring 100 x 100 meters each and then analyzing each cell (see Figure 23, step 2). The analysis made this way was aimed to provide results based on the continuous urban fabric and not based on specific project sites.

First, each cell's total building footprint area was calculated (see Figure 23, step 3). Second, all built objects found in each cell were individually classified by size into six categories, ranging from building footprints smaller than 300m$^2$ to larger than 3,000 m$^2$ (see Figure 23, step 4). Finally, the distribution of diverse building scale was calculated by analysis of the number of built objects and their total building footprint area in each of the six categories for each cell (see Figure 24) and the studied neighborhood area as a whole.

The analysis included the total number of buildings in each cell, the total building footprint area, and number of buildings and building footprints for each building scale category.



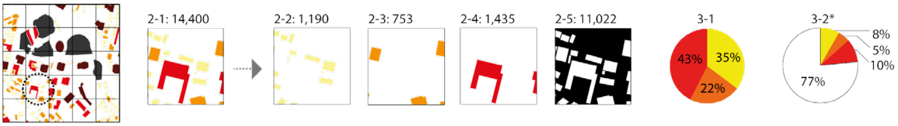
1. Site Area Openstreetmap.org

2. Grid of 25 cells of 100m x 100 m are overlayed on the site area.

3. Building footprints are extracted.

4. Building footprints are color coded by surface area sizes.

*Figure 23. Steps taken for the footprint analysis*



1. Colour coded site area in Roppongi

2. Analysis example of cell #9

2-1. Total number of pixels in one cell
2-2. Number of pixels for objects <300 m$^2$
2-3. Number of pixels for objects <750 m$^2$ and >300m$^2$
2-4. Number of pixels for objects <1,500 m$^2$ and >750m$^2$
2-5. Number of pixels for unbuilt area

3. Visualisation of analysed scale proportions
3-1. Scale proportions of buildings in a cell
3-2. Total scale proportions of the cell*
* The total scale proportions are only analysed for the whole site areas, not individual cells

*Figure 24. Steps of analysis of building footprints of each cell*

# 4.2 Literature review method

A literature review was carried out with a focus on how processes of emergent urban development can be understood from an urban planning theory perspective (Research Question 2). The literature review was initially guided by key search words identified from personal knowledge from architectural practice in Japan, the summarizing of the Urban planning systems in Japan (JICA, 2007), and inspirations from supervisors, including the informal mentorship of Professor Hideki Koizumi[2] at the University of Tokyo. This process led to multiple tracks of literature searches using Chalmers library, as well as Google Scholar. Each article with relevance was then snow-balled both backwards – identifying articles from the reference lists, and forwards – 'articles that have cited the articles found in the search' (Jalali & Wohlin, 2012, p. 29).

This process resulted in a collection of a library of articles with varying degrees of relevance. However, three crucial moments made it possible to streamline and focus the scope for the literature review. First, the empirical studies presented in Appendix 1 (Lim & Kain, 2016) included an initial database search using key terms, such as 'rule-based,' 'design-based' and 'urban planning systems' in combination with 'Japanese' and 'Swedish' in the scholarly literature, and references. In a parallel track, another category of key terms relating to 'compact city' and its 'critiques' and 'benefits' was searched for in scholarly articles and policy guidelines. Furthermore, the combined searches of, e.g., 'rule-based' and 'compact city,' led to concepts, such as 'incremental' and 'diversity,' in turn leading to key terms such as 'self-organization' and 'collective creativity,' which became an important basis for further theory development.

The second critical moment guiding the literature search was the Ph.D. course 'Complex urban systems[3]', held from 2014 to 2015. The abovementioned searches had produced a compilation of seemingly unrelated articles. For instance, an article from Hong and Page (2004) discussing rates of innovation, derived from searches on 'diversity' and 'complexity' and problems found in a

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[2] *https://www.rcast.u-tokyo.ac.jp/en/research/people/staff-koizumi_hideki.html*

[3] *http://idealeague.org/urban-systems-2014-2015/*

study on the Tama New Town by Ducom (2008) seemed to be unrelated apart from some vague relation to compact city benefits and problems. However, with 'CAS' (Complex Adaptive Systems), a keyword brought by the course subject, 'complexity' and 'adaptability' seemed to connect both these studies. This connection enabled reconnecting authors and keywords that, to start with, had seemed to be irrelevant or too far-fetched from the research subject. Recombination of previously searched keywords in conjunction with 'CAS' generated results that became a significant part of the theory development.

The third moment was brought on by the research-through-design approach, described in detail in the next section. During the research-through-design practice, designing tools for 'citizen inclusion,' a literature search was needed to support the design of a 'tool' for 'visualization' and 'urban perception,' based on 'gamification.' These new categories of search terms were then combined with other keywords, such as 'bottom-up,' 'ICT,' 'multiple-stakeholder inclusion,' and 'rule-based,' again linking back to complex adaptive systems and urban planning systems.

With the main keywords listed below, in total, approximately 159 scholarly articles by 145 authors, seven policy guidelines, and four items of reference literature have been reviewed for the chapter on a hybrid approach of urban planning. Of these, 47 were published after 2015, 54 between 2010 and 2014, 23 between 2005 and 2009, and 25 between 2000 and 2004. Fifteen articles were published in the 1990s, two each in the 1980s and the '60s, and one each from the 1950s, and the '70s.

*Moment 1:* urban, architectural, policy, rule-based, design-based, Japanese, Swedish, comparison, process, planning, designing, top-down, bottom-up, development, incremental, zoning, coding, detail-planning, master-planning, compact city, Tokyo, new towns, public housing, density, diversity, self-organization, collective creativity
*Moment 2:* complex adaptive systems, complexity, adaptability, resilience, emergence, emergence, agent-based modeling, application, multiple-stakeholder, inclusion, participation, communicative, collaborative, consensus,

simulation, collective, gamification, agent
*Moment 3:* visualization, immersive, Perception, ICT, Augmented reality, mobile, outdoor, 1:1 scale, tools, urban games, AR tracking, user-interface, projection, collaborative design, on-site

## 4.3 Research-through-design for tool development

A research-through-design method was employed to approach the challenge of developing a tool that can stage urban emergence through citizens collaboratively designing on the neighborhood scale by aggregating people's ideas and views (Research Question 3). Frayling first coined the term 'research through art and design,' and his definition entails 'development work [carried out by] customizing a piece of technology to do something no-one had considered before and communicating the results' (1993, p. 5). Unlike 'research for design,' meaning 'doing research as a part of doing design' (Stappers & Giaccardi, 2017), 'research-through-design' entails the activities of designing to generate knowledge through creating 'possibilities for people and products to engage in interaction that were not possible before' (Stappers & Giaccardi, 2017, section 43.1.4).

The process of research-through-design included two pre-studies investigating aspects of citizen engagement in collaborative urban design and citizens' perception of the built environment and a subsequent main study developing a prototype tool for citizens' collaborative urban designing using outdoor MAR technology, i.e., the Urban CoBuilder.

This chapter is thus divided into three subsections, introducing the methods applied during the various phases of research-through-design. The first two sections describe the two experimental pre-studies of developing tools for citizen engagement, and the third section describes the iterative prototyping process of designing the outdoor MAR tool as the main study, as well as the user tests carried out throughout the process.

### 4.3.1 Pre-study 1: Beyond the poster

In this pre-study, a board game based on the map of the city of Gothenburg was developed to explore outcomes of different planning systems (see Appendix 4 for details). The board had two separate pixelized sites representing ‘rule-based’ and ‘design-based’ urban planning systems, respectively. The players collaboratively designed city areas using ‘mission cards’ that detailed the needs for developments on site. This means that the city was built with the same urban project missions, but applied two different urban system settings according to the game rules. The interactions of the players were observed, and the patterns of development were noted.

The game was designed by exploring the potential of using game pieces to cover a game board through mechanisms emulating design- and rule-based urban planning approaches. Various prototypes of boards and game pieces were designed and tested through a series of workshop sessions (see Figure 25).

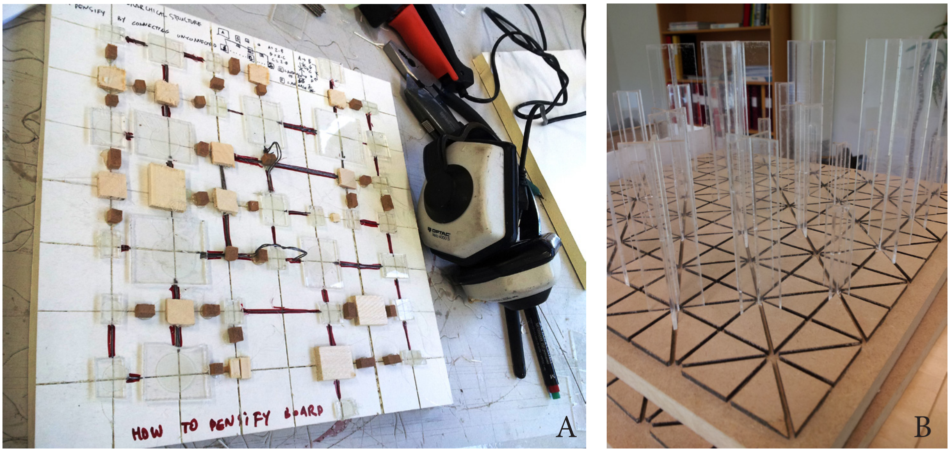

*Figure 25. Initial prototypes developed to represent design-based (A) and rule-based (B) planning systems.*

Incorporating the takeaways from game board prototypes, the map of the city of Gothenburg was analyzed and pixelized to abstractly represent the city

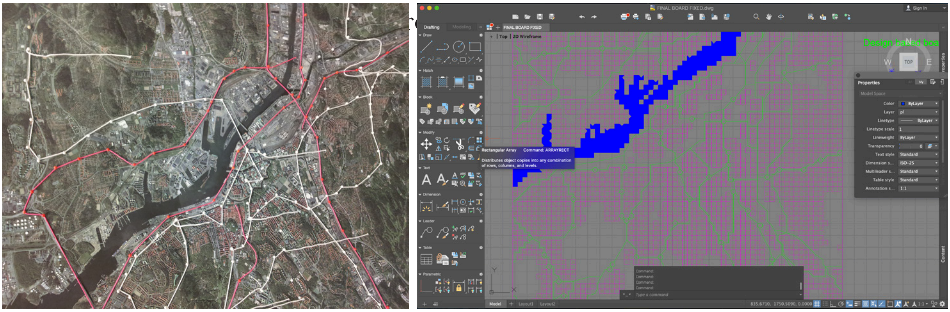

*Figure 26. Research-through-design process for the game board production identifying major roads and traffic nodes for the overlaid grid on the map of Gothenburg*

For the 'design-based' board, game pieces, and game rules were designed by analyzing and abstracting the aspects of design-based urban development and street patterns that are frequently found in Gothenburg (see Figure 26). This entailed making strategies of how to place the game pieces representing the street patterns so that it would be possible to lay pieces next to each other without breaking the continuity of streets, for instance by placing a piece that would fit in any given situations (see Figure 27, Appendix 4).

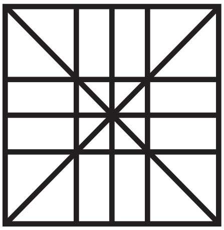

*Figure 27. The design-based game piece indicating street patterns that can be connected to all the other pieces*

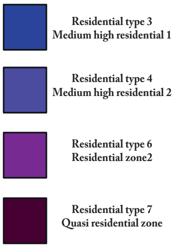

*Figure 28. The rule-based game pieces that can be placed next to each other*

Zoning rules and regulations from Japanese building standard laws (1987) were used for the 'rule-based' board. In this case, game pieces were color-coded, representing the zoning categories. The mechanisms to play out the pieces emulated the zoning regulations where certain zones, i.e., exclusive industry zones, cannot be placed next to certain other zones, i.e., exclusive low-rise residential zones. Specifically, the rules indicated that the game pieces with specific colors were not to be placed next to each other (see Figure 28, Appendix 4).

The production of the physical board, the game pieces, and the set up was made in collaboration with Tabita Nilsson[4], Lecturer in Architectural Theory and Methods at the Architecture and Civil Engineering Department at Chalmers University of Technology, in conjunction with her exhibition project 'Beyond the Poster[5],' during a course, also named 'Beyond the Poster' (see Figure 29).

*Figure 29. Figure (top) shows the production stage of the boards, and bottom figure shows the set up during the exhibition.*

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[4] *https://www.chalmers.se/sv/personal/Sidor/tabita.aspx*

[5] *https://chalmeristbloggen.wordpress.com/2013/04/16/bygg-och-fortata-goteborg-med-pussel-pa-chalmers/*

### 4.3.2 Pre-study 2: Design of the smartphone app Urban CoMapper

The second pre-study involved the design of a smartphone application using geo-location technologies, GIS, and a questionnaire through which citizens are invited to evaluate compact city urban qualities on-site regarding perceived diversity and density (see Appendix 5 for details). This study has three phases of development. The first phase was a concept development phase by the author for a specific urban perception survey smartphone app that uses Geo-location and mapping. This concept was developed linked to the takeaway from the pre-study 1 (Section 4.3.1) by using a grid laid out on a map of the city for evaluation of an urban area at a cell level, eventually composing the larger-scale urban area. This concept was submitted to the Adlerbertska funding organization and received the grant for further development. The second phase, launching the project, involved a collaboration forming with Anna-Maria Orrù[6], former Ph.D. student at the Department of Architecture and Civil Engineering at the Chalmers University of Technology. The collaboration was intended to extend the application of the tool initially conceived as a specific compact city urban perception survey tool to a more generic urban research tool using the same mobile, geo-locating, GIS, and questionnaire functions, i.e., surveying perception of urban food production.

After sharing the research subjects and research design between the collaborating Ph.D. students, the initial concept of the tool developed by the author was introduced and examined through the lens of the collaborator's research theme. Through discussion, the potential use of a mobile mapping survey tool within the two research was identified. Maintaining the basic concept of using geo-locating, GIS, and questionnaire with enabled user information collection, including time and location of data input, two separate questionnaire formats were developed.

After that, during the third phase, feasible technologies for tracking, mapping, and the use of open-source data were determined through discussions with the

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[6] *http://www.annamariaorru.com/*

[7] *Changemaker AB http://changemaker.nu/about*

software engineers[7] engaged for the development of the app. During this design phase, mock-ups of the tool were developed using Balsamiq©[8], illustrating the user interface and user interaction (see Figure 30, see Appendix 5). In conjunction with the mock-up illustrations, a storyboard was made.

Mixed functionality
Mixed functionality refers to how much of the urban space you find yourself in belongs to a certain fuction. For instance, do you think 90 percent of the area you are in is residential buildings? Or do you think 30 percent of the buildings are served as commercial

*Figure 30. Example of mock-up sequence developed for Urban CoMapper using Balsamiq©*

This storyboard listed sequences of user interaction and the contents of the app, e.g., user information input, user location verification, survey contents, uploading the survey to the server, and user data input including texts, videos, and images with location and time stamp, as both user and administrator. Each process and sequence were described divided into themes of action, category of person who is taking the action, aims of action, results of the action, and side notes (see Appendix 5). For example, the storyboard section would list the theme as registration and login, with a user who aims to register an account so that logging in is enabled as a result. Additionally, an entity-relationship diagram[9] was provided for the software engineers with sequences of action taken during the urban perception survey using the app, the categories of surveyed elements, and the metadata structure indicating user ID, user location of data input, and user input data as images, video clips or text.

### 4.3.3 Main study: Urban CoBuilder

The pre-studies identified some critical issues that needed to be dealt with

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[8] *Graphical tool to sketch out user interfaces, for websites and web / desktop / mobile applications https://balsamiq.com/*

[9] *ER diagram shows entities and the relationships between those entities*

in the following steps of design research, such as the importance of urban perception during citizen engagement for urban designing and simulation, the identification of available technologies for on-site-supported visualization, and gaming mechanisms for motivating participants to use the tools. To provide a solid basis for the tool development, a review of both academic and grey literature was carried out, covering the four main tool functionalities: Simulation of built structures and incremental development processes through multi-stakeholder inclusion; Immersivity for the perception of on-site information; On-site AR projection; and Rule-based process simulation through gaming mechanisms. The results from this review were then used to develop a set of specifications to be implemented during the iterative prototyping processes (see Appendix 2 for details).

#### 4.3.3.1 Iterative prototyping of Urban CoBuilder and user tests

To develop the Urban CoBuilder, the subsequent process of research-through-design employed iterative prototyping based on the specifications delineated through the literature review. Software engineers from Atvis AB[10] were engaged in the programming of the app. In the initial phase, mock-ups of the tool were drawn up in collaboration with Stig Anton Nielsen[11], former Ph.D. student from the Department of Architecture at Chalmers University of Technology, and through successive meetings and discussions with the software engineers. Step by step, the mock-ups were modified and simplified with consideration to the limitations of the budget and the time available for the Ph.D. project (see Figure 31).

The specifications previously developed through literature review were re-grouped into four sets of design criteria: Tracking strategies; Design elements; User experience and interaction (UX-I[12]) including gaming mechanisms; and Data retrieval and storage (see Table 1 and Appendix 3 for details). Among available prototyping methods, the ‘explorative prototyping’ method (Bäumer, Bischofberger, Lichter, & Züllighoven, 1996, p. 532) was employed as a way to clarify requirements and solutions. For the prototype assessment, a user test was

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[10] *https://atvis.com/*

[11] *http://www.stigantonnielsen.com/*

[12] *UX-I design in this thesis combines both the design of UI, focused more on the graphical elements and the user experience concerning the components, structure and the logic of such UI.*

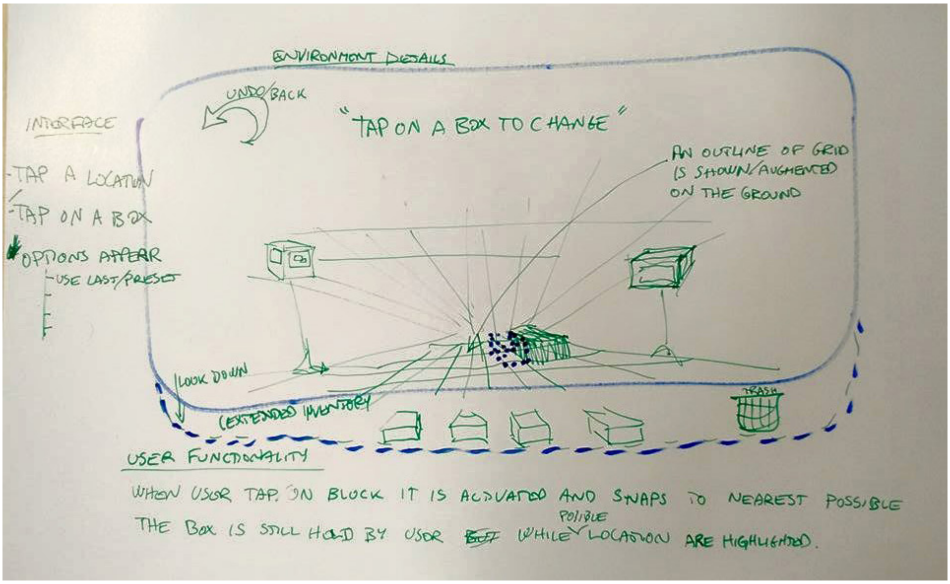
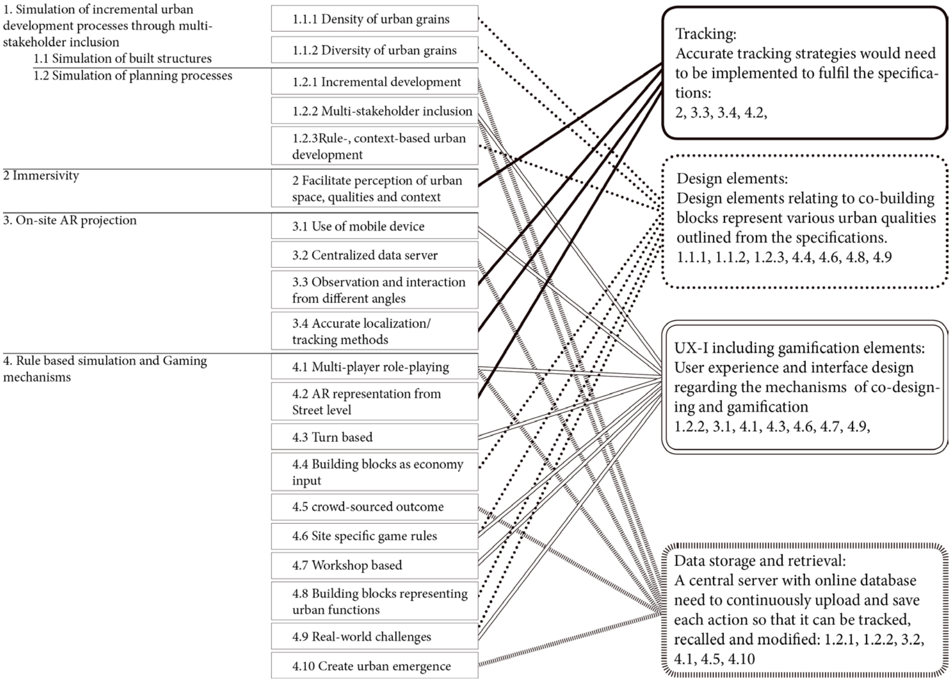


*Figure 31. Initial mock-up of Urban CoBuilder design*



1. Simulation of incremental urban development processes through multi-stakeholder inclusion
    1.1 Simulation of built structures
    1.2 Simulation of planning processes

2 Immersivity

3. On-site AR projection

4. Rule based simulation and Gaming mechanisms

- 1.1.1 Density of urban grains
- 1.1.2 Diversity of urban grains
- 1.2.1 Incremental development
- 1.2.2 Multi-stakeholder inclusion
- 1.2.3Rule-, context-based urban development
- 2 Facilitate perception of urban space, qualities and context
- 3.1 Use of mobile device
- 3.2 Centralized data server
- 3.3 Observation and interaction from different angles
- 3.4 Accurate localization/ tracking methods
- 4.1 Multi-player role-playing
- 4.2 AR representation from Street level
- 4.3 Turn based
- 4.4 Building blocks as economy input
- 4.5 crowd-sourced outcome
- 4.6 Site specific game rules
- 4.7 Workshop based
- 4.8 Building blocks representing urban functions
- 4.9 Real-world challenges
- 4.10 Create urban emergence

Tracking:
Accurate tracking strategies would need to be implemented to fulfil the specifications:
2, 3.3, 3.4, 4.2,

Design elements:
Design elements relating to co-building blocks represent various urban qualities outlined from the specifications.
1.1.1, 1.1.2, 1.2.3, 4.4, 4.6, 4.8, 4.9

UX-I including gamification elements:
User experience and interface design regarding the mechanisms of co-designing and gamification
1.2.2, 3.1, 4.1, 4.3, 4.6, 4.7, 4.9,

Data storage and retrieval:
A central server with online database need to continuously upload and save each action so that it can be tracked, recalled and modified: 1.2.1, 1.2.2, 3.2, 4.1, 4.5, 4.10

*Table 1. The specifications grouped into the design criteria*

performed on each iteration so that the following modifications would include relevant feedback (see Table 3). During the development of eight prototypes of the Urban CoBuilder, in-house user tests assessed the first six prototypes regarding their usability, involving the author, software engineers, and other UI designers from the same software firm, Atvis AB.

The last two prototypes were getting close to being so-called 'pilot systems,' referring to a 'very mature prototype that can be practically applied' (Bäumer et al., 1996, p. 533). Based on the available resources, the objective was to produce the Urban CoBuilder as far as a step before being a final pilot system that can be tested with a broader public, i.e., through publication on the android Appstore for download. These two pilot systems – or rather semi-pilot systems since they were not yet fully functional – were assessed through focus group pilot tests in relation to the developed sets of design criteria. One focus group pilot test was carried out with fellow visualization and urban researchers using the Urban CoBuilder as a 1:1 scale outdoor co-designing tool on an urban planning site in Gothenburg. The second pilot test was made in conjunction with a master student workshop with random citizen passers-by, using a table-top version of the Urban CoBuilder as a smaller-scale modeling and visualization tool with a portable tracking marker.

During the first six prototype user tests, the feedback was collected after each test through discussions between the author and the software engineers, for implementation in the next round of iteration. The first focus group pilot test included testing the app as a complete system from creating the account to saving the design, resulting in ample suggestions for future improvements. During the second focus group pilot test, the student workshop, the citizens were interviewed using a prepared interview sheet relating to the tool's usability and usefulness, and whether they would like to design a neighborhood using the tool and send it to the municipality or design firms. The students made notes of the answers and also wrote down their observations regarding the participants' attitudes.

| Nº | Test conditions | Tested design criteria | | | |
|---|---|---|---|---|---|
| | | **Tracking** | **Design Element** | **UX-I and gaming mechanisms** | **Data retrieval and storage** |
| 1 | Date: 21st March 2016<br>Time: 14.00<br>Sunny<br>Place: Lindholmen, Gothenburg (SE)<br>Participants:<br>2 developers | Photo marker using building facade and 3D data of the site.<br>Photos uploaded to Vuforia for processing. Processed images downloaded to Unity as Image Marker Database. | Use of coloured cubes as building blocks to represent various, not yet specified urban functions. | Laptop and web-camera are used. | |
| 2 | Session 2, 3, and 4 were held on the same day.<br>Date: 8th April 2016<br>Time: 9:00<br>Cloudy<br>Place: Johanneberg, Gothenburg<br>Participants:<br>2 developers and 1 researcher | Use of 3D object as photo markers with 3D data of the site.<br>Use of Vuforia | Definition of urban functions for building blocks.<br>Cube size defined by 3m x 3m x 3m (scale 1:1) | Android smartphone environment is used.<br>Toggling between the camera and 3D view enabled.<br>Implementation of building ground planes for placing 3D objects. Interface for removal and addition of cubes. | Every action of the user is centrally saved and can be accessed at any moment. |
| 3 | | Use of smartphones GPS, compass, gyroscope, without Vuforia.<br>3D geodata for site used. | | | |

|  |  |  |  |  |  |
|---|---|---|---|---|---|
|  |  | 3D scene created in Unity. |  |  |  |
| 4 |  | Using gyroscope to manual alignment environment with 3D data of site. |  |  |  |
| 5 | Date: 15th June 2016<br>Time: 15:00<br>Cloudy<br>Place: Johanneberg, Gothenburg<br>Participants:<br>2 developers and 1 researcher | Use of public display as photo-marker. Selection critieria: rich in details, good contrast, no repetitive patterns, availability.<br>Photo-marker used together with 3D database for the location. | Grid plane of 3m x 3m is added for localization and placement of building blocks. | Location of new building block indicated as semi-transparent box, always placed in the center of the screen.<br>Implementation of economic concept that indicates available money for a design turn and costs for each building block. |  |
| 6 | Date: 3rd July 2016<br>Time: 13:00<br>Cloudy<br>Place: Lindholmen, Gothenburg<br>Participants:<br>2 developers<br>+ 3 external Users | Use of one standing, printed bi-tonal marker 0,9m x 0,9m. | Semi-transparent box locating building block with a dashed line to indicate a not yet built object. | Addition of urban function icon to unfold available categories.<br>Interface for add-on/ removal buttons and up/ down buttons to build on top of or below the selected cube. |  |
| 7 | Date: 11th Oct 2016<br>Time: 13:00<br>Cloudy<br>Place: Public parking lot in Masthugget, Gothenburg<br>Participants: | Use of one printed bitonal frame marker 1,8m x 1,8m (M:A), and two markers 0,9m x 0,9m (M:B/C).<br>Markers | Facade textures added to distinguish urban functions with randomized green areas. | Bird's eye view disabled.<br>Additional economy rules implemented.<br>Stakeholder role-playing enabled. |  |

|  |  |  |  |  |  |
|---|---|---|---|---|---|
|  | 2 developers and 3 urban researchers | mounted on wooden panels for vertical stability. M:A set up against a facade, M:B/C placed on the ground.<br><br>Gyroscope used while user switched between markers. |  |  |  |
| 8 | Date: 22nd Oct 2018<br>Time: 10:00<br>Cloudy<br><br>Place: Hammarkulletorget, Gothenburg<br><br>Participants:<br>1 developer, 1 researcher, 5 master architecture students,<br>and 20 citizens<br><br>Age of citizens: (Male/Female)<br>Under 12: 5/2<br>12-20: 3/7<br>20-30: 0<br>30-40: 2/0<br>40-50: 0<br>50-60: 1/0 | Printed bitonal frame marker of 19 cm x 19 cm mounted on filing folder to add portability for a scaled-down use of the tool.<br><br>Use of scaled-down bi-tonal Printed marker to fit A4. | Facade textures for building blocks were replaced with textures modified from an ongoing housing project. Each cube represents a facade element. | Table-top version. |  |

*Table 3. Conditions of the user tests and the tool functions that were tested.*

# Chapter 5.

## Results

# 5.1 What are the differences in the physical outcomes of different planning approaches in relation to compact city urban characteristics, such as density and diversity?

The results presented below are based on the study presented in Lim and Kain (2016), where more details can be found (see Appendix 1). The comparative study investigated the compact city properties of density and diversity in relation to urban forms as outcomes of different urban planning approaches – i.e., emergent compact urban form (Type 1), designed dispersed urban form (Type 2), and designed compact urban form (Type 3). For this study, three indicators of compact city qualities – density as the building coverage ratio, diversity of built objects' scale, and distribution of the diverse scales of built objects – were chosen and assessed through analysis of building footprints.

The building footprint analysis showed the lowest density in Type 2 areas, then in Type 3 areas, and the highest density in Type 1 areas in both cities. (see Figure 32) In Tokyo, Type 1 and Type 3 areas showed similar density, which was not at all the case in Gothenburg, where density in Type 3 areas was considerably lower. The comparison between the two cities showed that both the highest and the lowest footprint density clusters were found in Gothenburg, while Tokyo had a more even distribution of footprint density across the three types of planning approaches.

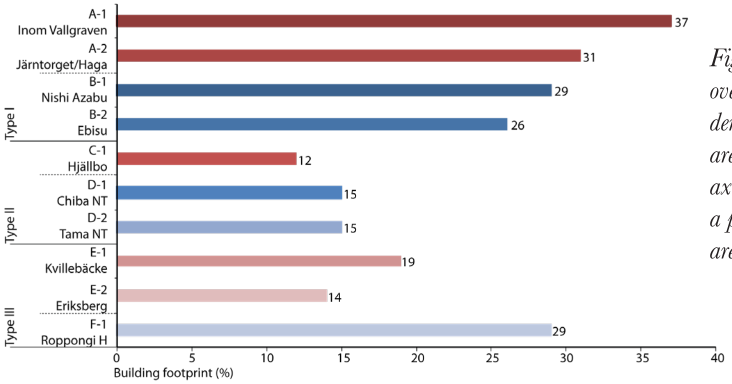


*Figure 32. Graph over building footprint densities in the ten study areas. The horizontal axis shows the density as a percentage of the total area.*

The examination of the distribution of building footprint scales showed a gradual decrease in the proportions of smaller-scale buildings from planning approach Type 1 to Type 3 and then to Type 2, following similar patterns in both cities (see Figure 33). Still, compared to Gothenburg, smaller-scale buildings were found more frequently in Tokyo across all types of urban planning approaches. In contrast, Gothenburg showed a higher rate of larger-scale building in all Type 1 and Type 3 urban areas, and also had more unbuilt areas than Tokyo. However, an analysis of building footprints in Type 3 areas in Gothenburg only studying newly developed intensification projects showed some increase of smaller-scale buildings but not any significant increase of density (see Figure 34).

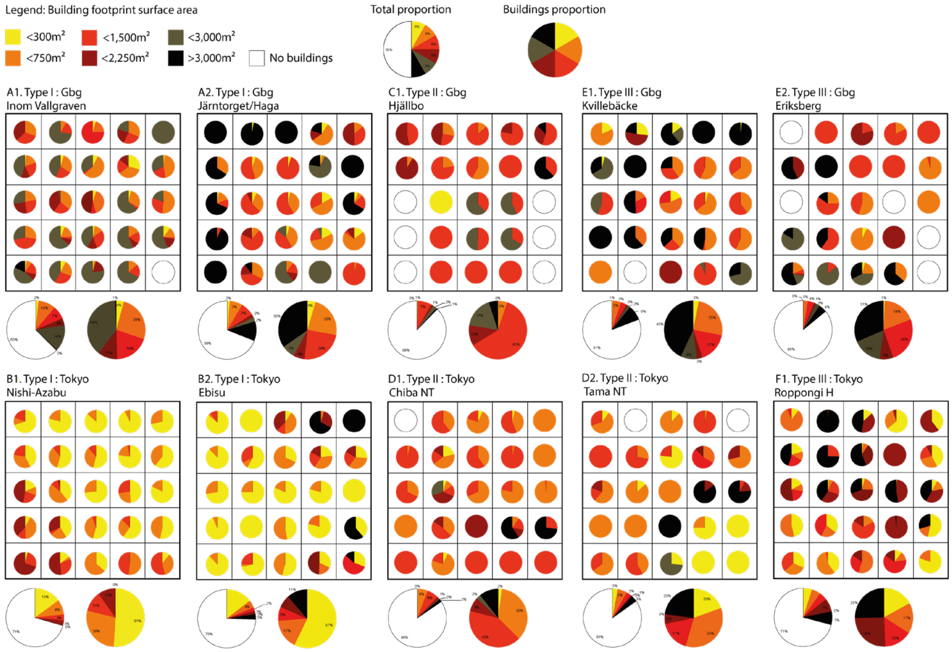


*Figure 33. Diagrams showing the scale distributions of building footprints as well as the total proportions including, unbuilt surfaces for each cell in the ten study areas.*

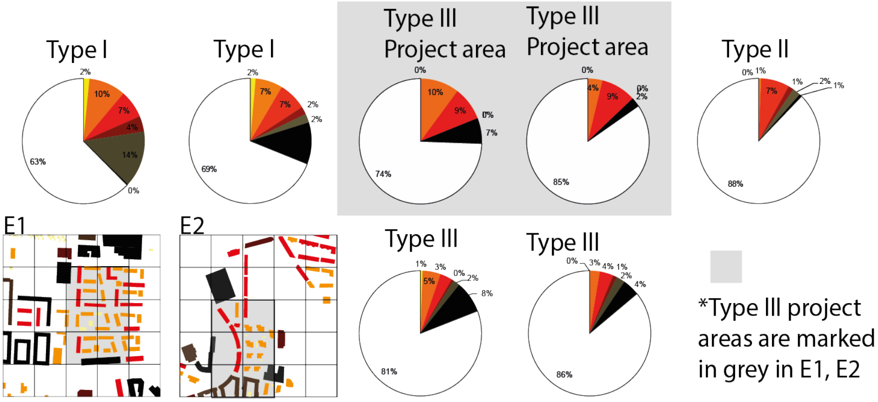


*Figure 34. Proportions of the scale distributions of building footprints of Type 3 areas in Gothenburg re-analyzed, focusing only on newly developed parts of the study area.*

## 5.2 How can processes of emergent urban development be understood from an urban planning research perspective?

This section presents the results of a literature review leading to theory development. It connects the example case from Tokyo to planning theory and, by doing so, develops a proposal for a hybrid theoretical approach to emergent urban development.

### 5.2.1 The 'rule-based' and 'design-based' planning approaches

As we observed in the example of Tokyo from the previous Chapter three, the resilience of the city of Tokyo might, in part, be attributed to the complexity that constitutes the city fabric and originates from a planning approach allowing small-scale, incremental, self-organized adaptation to urban challenges. Mimicking the pre-disaster urban structure, incrementally developed over a long period by a multitude of individuals throughout the city's history, also contributes to the undiminished complexity embedded in this urban patchwork. Bettencourt (2014), recognizing cities as complex social networking systems, claims that increasing the complexity of the city by a continuous division and recombination of social networks and businesses would increase a city's opportunities to harvest environmental and social benefits (Bettencourt & West, 2010). Bettencourt (2014) argues that rather than a few experts trying to plan for such complexity, supplementing preconditions for a diversity of people to network and adapt through simple local rules would be more effective. Such rules would then guide future development with some necessary constraints, such as environmental impacts. As seen in the case of Tokyo, the absence of detailed master planning (Okata & Murayama, 2011) of the city has created fertile ground to breed enough complexity in its emerging urban patterns to accommodate necessary changes, e.g., the sharp increase in population (see Figure 3).

This shortcoming of master planning is corroborated by Marshall (2012), pointing to the difficulties of planning for complexity when full knowledge of the consequences of the planning activity is lacking and unpredictable. He divides urban planning types aiming to replicate the complexity of incrementally developed urban structures into three categories:

> *Planning by design*
>
> Planning by design entails master planning, urban design, or outlines of designs, whereby the final state of the design is preconceived and then realized. Here, a design might include buildings, infrastructure, green areas, an urban block, or an entire district.
>
> *Planning by coding*
>
> Codes are used to indicate generic specifics of building blocks and relationships between these blocks through prescriptive or proscriptive control, by either designating or restricting urban

functions, or building types. Codes are used in zoning and land-use regulations, or design element control, e.g., height control and building materials. These generative codes can steer how urban components can be put together to assemble an aggregated urban form. The main difference between planning by coding and planning by design is the non-site specificity of the former, in comparison to the latter in which specific designs are created for specific sites. Urban codes are often established and implemented by public authorities, but in some cases, it is also possible for diverse actors, including individual developers, to act as code-setters.

*Planning by development control*

Often practiced in conjunction with planning by design, planning by development control gives public authorities the power to accept or reject development plans and designs proposed by private individuals or master planners through 'artificial selection' pursued for the public good, as opposed to the 'natural selection' through the market dynamics that 'optimizes individual utility' (Marshall, 2012, p. 202).

As the term 'code' carries a certain ambiguity in its meaning in urban research, a clear definition needs to be established. According to Marshall (2011), even though the term can imply a design detail for a specific site and project codified for adherence, it should be differentiated from the 'code' used in planning by coding, in which the codes are used as a generative framework which is not site- or project-specific. In the latter sense, the code corresponds more closely with the term 'rule' argued for by Bettencourt (2014), whereby simple generative local rules permit many unspecified choices, allowing individuals to develop their parcels according to their needs. The combined use of some or all of Marshall's three planning types on various urban scales and contexts would certainly generate a certain level of the desired complex outcomes that can be seen in 'unplanned' traditional urban cores (Batty & Marshall, 2012).

This thesis, therefore, uses the concept of 'rule-based planning' instead of 'planning by coding.' As it is rare for urban planning systems to adopt only one type of planning, in this thesis the concept of 'rule-based planning' is composed of mechanisms related to planning by coding, with or without the combination of either or both planning by design and planning by development control.

For instance, designing a public facility would include a main public building as well as public space, which might include placements of a bench and a tree. The public building would need to be placed and designed in accordance with the Japanese Building Standard Law; however, the design of the bench placement and landscaping, including planting a tree, are not guided by rules. The final results would be essentially rule-based planning, incorporating planning by design for the components making up the space.

If the municipality seeks a suitable design through an architectural competition and chooses one of the designs, this would also include 'planning by development control.' In this thesis, this would be categorized as 'rule-based planning,' since it recognizes the core mechanism as 'planning by coding.' With this perspective, design-based planning, on the other hand, is defined as an approach, composed of planning by design as a core mechanism, with or without planning by development control (see Figure 35).

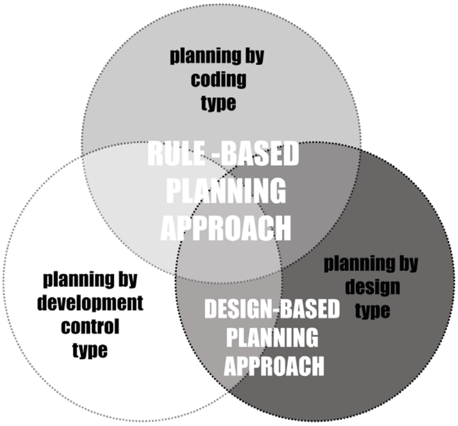


*Figure 35. the rule-based and the design-based planning approaches*

*Figure 36. Picture of Suwa-Nagayama apartment complex in Tama new town (source: Author Terebitou from https://commons.wikimedia.org/wiki/File:Tama_new_town_suwa.jpg)*

#### 5.2.1.1 Designed dispersed urban forms

In comparison to the rule-based planning approach, the design-based approach can be seen in many modernistic top-down plans, most notably in many forms of new towns and massive-scale social housing to accommodate an increasing population. Examples of these planning practices can be found in Miljonprogrammet ('the Million Program') in Sweden from the 1960s into the 1980s and in Tama New Town in the West of Tokyo from the 1960s and 1970s (see Figure 36). The massive, dispersed housing areas designed and constructed under Miljonprogrammet across Sweden epitomize the social segregation issues involved with a predominant concentration of low-income, immigrant populations in those areas (Lilja & Pemer, 2010), with slow integration and lower life quality (Gothenburg City Council, 2014). In Tama New Town, the population is decreasing and aging, and the adaptation to the shrinking population is slower than the demographic changes (Ducom, 2008). Tama New Town represents one of the few top-down design-based plans implemented in the Greater Tokyo region. It consists of blocks of apartments, called Danchi, designed by the Japan Housing Agency in the 1960s to provide housing for a growing population (Nakazawa, 2011), accommodating around 300,000 residents. Individual apartment blocks, so-called Mansyons, were then designed to accommodate small baby boomer families, with sizes ranging between 50 and 60 m$^2$ per dwelling. It is precisely this implementation of a homogeneous design of housing over a large area that is seen to create inflexibility when family patterns change over time (Nakazawa, 2011). According to Nakazawa (2011), the conversion or reconstruction of these apartments also requires a consensus among the many members of the apartment building union, making it rather hard to adapt. The demographic segregation that has resulted from the establishment of Tama New Town is similar to that of Miljonprogrammet areas in Sweden, even though the types of demographic categories that are segregated are quite different regarding age in Tama New Town (Ducom, 2008; Nakazawa, 2011), and socio-economic status and ethnicity in Swedish Miljonprogrammet areas (Lilja & Pemer, 2010).

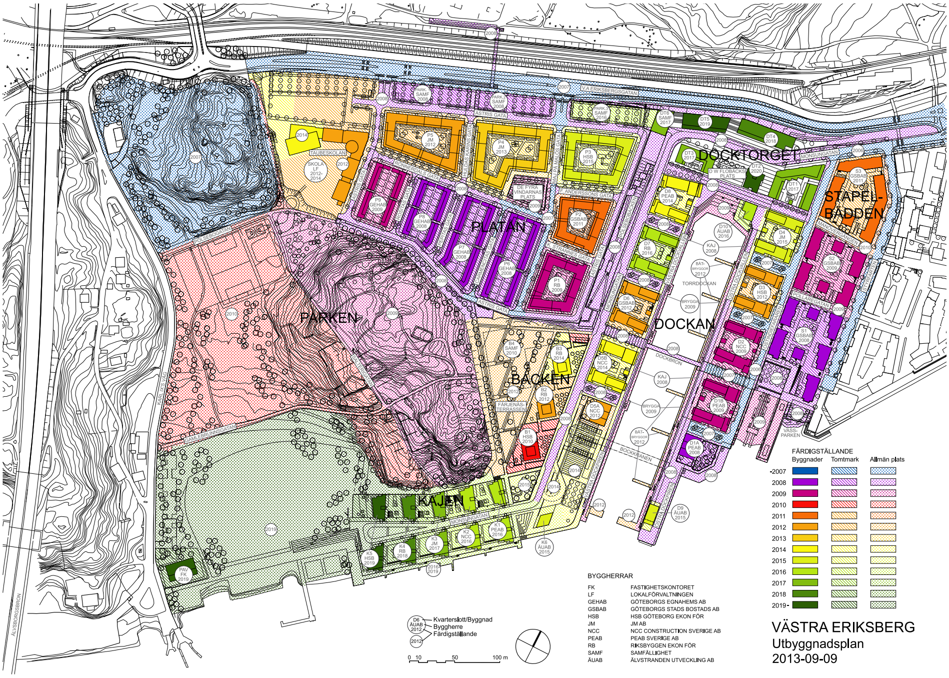


*Figure 37. Master-planning of West Eriksberg (Source: vastraeriksberg.se)*

#### 5.2.1.2 Planned incrementalism + delegated diversity + coordinated complexity = designed compact urban form

To remedy the damages caused by these massive-scale, monolithic urban designs implemented in large segments of cities, recent planning policies embrace the compact city as an ideal solution and advocate for urban planning to be oriented towards diversity and incrementality. The recent urban intensification projects in the city of Gothenburg also follow compact city policy guidelines promoting a diverse and vibrant urban-scape to attract diverse businesses and create walkable street conditions by connecting the city's central area across the Göta Älv river (Rivercity Gothenburg, 2012).

To comply with the policy goals, the city has created a master plan for incremental development by diverse actors. This master plan incorporates various development phases and delegates the design of different segments of the master plan during different times to multiple architectural firms (see Figure 37). This planning approach adopts incrementalism through a 'planned incrementalism' in addition to the diversity created through the 'delegated diversity' in an effort to generate complexity, or rather a 'coordinated complexity'. Still, the actors involved in this process are represented by a handful of expert design firms. In this sense, this approach to the compact city should be regarded as a design-based approach, combining planning by design and planning by development control, the outcome of which aims to mimic the complex urban fabric observed in rule-based, incrementally developed, traditional urban patterns (Scheurer, 2007; Marshall, 2011; Batty & Marshall, 2012). However, in this case of a design-based compact city, mimicking the process of incremental diversity to create complexity through master planning has resulted in issues of segregation similar to those of many modernist, master-planned urban districts with the intention to separate the urban functions, especially the Miljonprogrammet areas in Sweden.

For instance, the one-room apartments in the Kvillebäcken district have a 160% higher rental cost per m$^2$ than the average rental cost for a one-room apartment in Gothenburg (Ivar Kjellberg Fastighets AB, 2015; Statistics Sweden, 2015). This concentration of high-cost apartments, coupled with the removal of existing buildings and urban functions in the whole district, has rendered these areas rather demographically uniform and gentrified (Thörn, 2013), again producing demographically segregated areas within the city of Gothenburg.

Examples of planned ethnic integration exist. In Singapore, ethnic integration is engineered through strict state control of urban space by assigning proportions of ethnic groups represented to each neighborhood (Shatkin, 2014). However, this kind of strict control enabling the design of such integration has also resulted in the streets being designed devoid of possibilities for social interactions, since streets are seen to be too difficult to control by the state (Shatkin, 2014). In Finland, social integration has been encouraged through the assignment of diverse tenure types into new town housing developed in the 1960s and 70s (Vaattovaara, Joutsiniemi, Kortteinen, Stjernberg, & Kemppainen, 2018). This policy has been successful from an international perspective for the integration of diverse demographics. However, due to impactful changes in the socio-economical structures during the 1990s regional growth, this type of large housing development project has more recently suffered from an increase of socio-economic segregation (Vaattovaara et al., 2018; City of Helsinki, 2019). In contrast, a combination of smaller scale real-estate development units, less strict land-use rules that support renewability of aged building stocks, and a well-networked public transportation system has been brought forward as important factors leading to micro patterns of land-use with mixed functions, in turn contributing to less problematic class segregation issues in districts of Tokyo allowing (Fujita & Hill, 2012).

### 5.2.2 Complex adaptive systems: Introduction

The differences in outcomes of the rule-based respective design-based urban planning approach discussed in the previous chapters primarily relate to the properties of complexity that are to support urban resilience (Scheurer, 2007; Marshall, 2011; Batty & Marshall, 2012; Bettencourt, 2013). Within the perspective of such urban resilience, which is related not only to disaster-mitigative aspects but also to a long-term adaptation strategy for social, environmental, and economic challenges (Mehmood, 2016), it becomes especially interesting to see cities as Complex Adaptive Systems (CAS) where simple rules unfold a complex macro urban pattern as a result of individual micro implementations of the rules, as is seen in Tokyo's Building Standard Laws, New York's Zoning Ordinance (Pisano, De Luca, & Shirvani Dastgerdi, 2019), and the height rules in Los Angeles and Paris (Lehnerer, Christiaanse, & Hovestadt, 2009).

CAS refers to systems that are 'composed of populations of adaptive agents whose interactions result in complex non-linear dynamics, the results of which are emergent system phenomena' (Brownlee, 2007, p. 1). Agents in CAS refer to 'semi-autonomous units that seek to maximize their fitness by evolving over time' (Dooley, 1996, p. 2); in other words, 'situated within and a part of an environment that senses that environment and acts on it, over time, in pursuit of its own agenda and so as to effect what it senses in the future' (Franklin & Graesser, 1996, p. 5).

Much like Tokyo's restoration processes after the catastrophes, the system adapts to its surroundings through evolutionary procedures with many distributed, interacting parts, each dictated by its own rules without any central control (Holland, 1992). Moreover, and more importantly, to be able to adapt to new challenges the system continuously shape-shifts and maintains itself without settling into a permanent structure (Lansing, 2003), with the result that nothing in the environment is fixed (Chan, 2001). This is very different from the rigid fixity shown in urban structures where top-down master planning has dominated the outcome. Since the agents consistently act and react according to other agents' actions, any understanding of 'the workings of causation at the level of individual elements' (Lansing, 2003, p. 185) becomes impractical or, in highly complex situations, impossible. Global patterns of behavior, nonetheless, emerge as system phenomena through parts or individual agents continuously adapting to the changing surroundings (Holland, 1992; Brownlee, 2007).

According to Holland (1992), the properties of CAS can be summarized as follows:

1. *Evolution/adaptation*

The system is changed and reorganized through its parts, adapting to the problems posed by their surroundings. Holland (1992) offers the example of a thermostat that turns itself on or off to adapt to changing temperatures to achieve a certain climate condition. In the case of CAS, the system is composed of these individual components (thermostats) adapting individually (turning on or off) to deal with the changing conditions (climate).

2. *Aggregate behavior/emergence*

'Complex adaptive systems also exhibit an aggregate behavior that is not simply derived from the actions of the parts' (Holland, 1992, p. 19). The aggregate behavior emerges from the interactions of the parts. It can be observed in the economic activities of individual parts creating flows of demand and supply in an immune system distinguishing itself from other bodies, in an ecosystem's overall food web or the patterns of the flow of energy and materials.

3. *Anticipation*

An individual part's anticipation changes the existing conditions. For instance, the anticipation of an oil shortage can impact oil prices. Even if the anticipated event does not ultimately occur – i.e., the expected oil crisis does not happen – the surrounding conditions – i.e., oil prices – have already changed – i.e., increased – causing the individual parts – i.e., car owners – to adapt – i.e., selling their cars – to the new condition – i.e., increased oil prices.

*4. Individual parts continuously revise the rules for interaction*

Each part perpetually finds itself in novel surroundings, given the changing behavior of the other parts. As seen with the thermostat that turns itself on or off, this action can impact other components of the surroundings, for instance, a humidifier that changes its behavior and rules to adapt to the new condition posed by the thermostat's actions.

*Figure 38. Murmuration seen in Rome (Source: Author)*

The above characteristics of a CAS system can be seen in natural systems, for example, in a murmuration of starlings (see Figure 38). Constantly evolving starling murmuration is created by the simple rules of each bird, avoiding the most and least dense areas of the flock, always maintaining a certain distance from the neighboring birds (Pearce, Miller, Rowlands, & Turner, 2014). The flock is kept cohesive, not by the central command of a leader bird but by each adapting individual bird continually moving to maintain a specific flock density. Hypothetically, as the flock's cohesiveness makes it harder for predators to spot individual birds, even as they avoid making the densest possible flock formation, this allows as many birds as possible to maintain a line of sight for approaching potential predators (Pearce et al., 2014).

As murmurations are maintained by continuously changing forms and directions of birds without crashing into each other, the systems denoted in CAS are also recognized by their resilience. The system continually evolves through self-organizing behavior to adapt in the face of challenges of the surrounding environment through constant dynamic interactions between the agents (Holland, 1992), providing its resiliency. Knowledge concerning the strengths and characteristics of CAS is indispensable for devising methods for formulating responses to challenges, especially considering the unpredictability of the increasingly complex urban future. As Holland points out, CAS is not about reaching the most optimal endpoint or conclusion; instead, it is always a way of becoming (Holland, 1992).

Compared to the design-based planning approach, which aims to define potential challenge scenarios and devise plans and designs as solutions to these forecasted challenges, contemplating urban systems as CAS allows us to devise novel methods for facilitating the adaptation of individual urban components, such as built objects, citizens, infrastructure, and urban functions, based on simple rules. In other words, ideally, establishing simple rules denoting what individual agents should abide by when adapting to changing urban conditions would encourage the emergence of desired urban patterns. This is opposed to defining exact edges and corners of urban design to produce an optimal urban form as a response to predicted future challenges. Emerging patterns adapting to surroundings can be seen in the roofscape of Tokyo, where globally implemented slant rules and shadow rules orchestrate a particular roofscape composed of each roof piece adapted to a specific site within the urban boundary. The emerging roof shape of a new building is unpredictable; however, new roofs will reflect a fragment of a macro-scale pattern, at the same time as they change this pattern.

Urban systems are complex, with all their moving parts diverging, mutating, combining and interacting at every cross-section (Bettencourt, 2013), making it hard to reduce them to a number of simpler subsystems. Even a smaller portion of a subsystem interlocking to constitute what is an urban system could be seen as a CAS in itself.

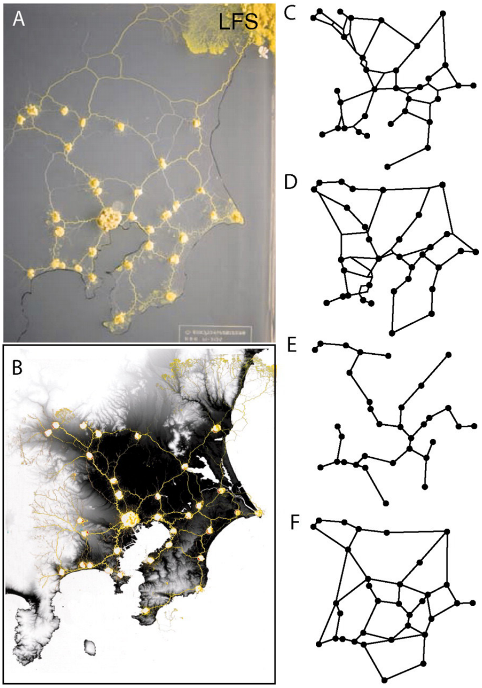


*Figure 39. Comparison of the Physarum networks with the Tokyo rail network. (Source: Tero et al., 2010)*

### *Slime mold network and Tokyo's railway system*

A striking example of the emergent and adaptive behavior of CAS can be observed in a lab experiment created with slime mold to simulate and replicate the emergent pattern of Tokyo's railway system. In this experiment, a group of researchers placed nutritive sources in a Petri dish replicating the geography of populous areas in Tokyo and introduced the slime mold Physarum polycephalum to it (Tero et al., 2010). The slime mold soon created networks between the sources of nutrition, creating cost-efficient and resilient foraging channels, based on the simple guiding rule of finding the shortest connection possible between the food sources (Tero et al., 2010). To replicate the geographical obstacles, the scientists added varying intensities of illumination, which slim mold is averse to, allowing the mold to dynamically adapt through the reiteration of local rules, based on these challenges (see Figure 39).

Interestingly enough, Tokyo's railway system is also an example of a self-organized, non-centrally planned system emerging through incremental local adaptation. The development of Tokyo's railway system was, to a great extent, responsible for the expansion of urban Tokyo from the end of the 19th century. The system was developed by private railway companies purchasing property surrounding the railway stations, where they would develop housing and commercial properties to fund additional segments of the railway (Okata

& Murayama, 2011). Even though the network system developed by the slime mold connecting the food sources in a Petri dish and the railway network system created by extending the network's length through developing the nodes manifest a type of reverse process, resilience tests performed on both networks showed similar strengths in fault tolerance as well as cost- and transport efficiency (Tero et al., 2010). Regardless of the direction of development, the two systems share common qualities that the extension follows simple rules: for the slime mold to create the shortest way possible to the next food source, and for the railway network to create a new node within the means of the gains from previous node investments. In other words, both systems are built upon growth adapting to surrounding conditions and the newly created present context, by following simple rules for growth, which is a core mechanism of a CAS system.

#### 5.2.2.1 Why Complex Adaptive Systems?: Resilience and emergence

> *There once were two watchmakers, named Hora and Tempus, who manufactured very fine watches. Both of them were highly regarded, and the phones in their workshops rang frequently - new customers were constantly calling them. However, Hora prospered, while Tempus became poorer and poorer and finally lost his shop. What was the reason? The watches the men made consisted of about 1,000 parts each. Tempus had so constructed his that if he had one partly assembled and had to put it down to answer the phone say - it immediately fell to pieces and had to be reassembled from the elements. The better the customers liked his watches, the more they phoned him, the more difficult it became for him to find enough uninterrupted time to finish a watch. The watches that Hora made were no less complex than those of Tempus. But he had designed them so that he could put together subassemblies of about ten elements each. Ten of these subassemblies, again, could be put together into a larger subassembly; and a system of ten of the latter subassemblies constituted the whole watch. Hence, when Hora had to put down a partly assembled watch in order to answer the phone, he lost only a small part of his work, and he assembled his watches in only a fraction of the man-hours it took Tempus. (Simon, 1962, p. 470)*

Resilience is a concept fostered by increasing awareness that the idea of sustainability alone might be too limiting for dealing with the unpredictable challenges we now face concerning climate change, resource depletion, and financial and geopolitical instability (Ahern, 2011; Benson & Craig, 2014).

CAS is especially appealing at present because of its qualities that are associated with resilience, particularly in light of the possible failure to contain climate change. We could, albeit cautiously, state that sustainability policies, including the much-publicized 2015 Paris Agreement, to contain the detriments to the environment at a sustainable level have already failed (Howes et al., 2017). New policies, confronted with the ever-increasing unpredictability of future conditions, both long-term and short-term, would benefit from acknowledging the improbability of being able even to grasp what we are to sustain. Benson and Craig point out that 'sustainability assumes that there are desirable states of being for SES[13]s that humans can maintain (within a certain range of variability) indefinitely' (2014, p. 779). Complexities of interlocking systems, such as economic conditions, the attitudes and beliefs of the public, environmental factors, technological failures, legal factors, competency levels, and political causes (Howes et al., 2017) contribute to the failure of sustainability policies, rendering it even more futile to come to a consensus on them and delineate what we can sustain (Benson & Craig, 2014). With these kinds of uncertainties, Ahern (2011) argues that we need to redirect our focus to creating 'safe to fail' systems, rather than keeping our attention on designing ones that are 'fail-safe.'

Summarizing Ahern's article (2011), a 'safe to fail' system in urban resilience context would retain:

> *Multi-functionality*
> Given the increasingly limited spaces within compact city settings, multi-functionality can be achieved by combining functions, stacking, or time-shifting. Ahern argues that multi-functionality enables spatial and economic efficiency and that it can support response diversity in the functions provided. Ahern's examples of these include the Green Streets program in Portland, Oregon; urban stormwater

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[13] *Social-ecological system*

wetlands at Potsdamer Platz, Berlin; wildlife highway crossings in Banff National Park, Alberta; and floodplain parks in Buffalo Bayou, Houston Texas (p. 4).

*Redundancy and modularization*

Providing multiple components with the same, similar, or backup functions will spread risks across time, geographical areas, and multiple systems. This prevents system collapse when a centrally distributed function, service, or infrastructure fails to respond to a specific disturbance, with backup functions and services provided by a distributed or decentralized system. A resilient system needs to prepare for system failure; it is a system that is 'safe-to-fail.' The examples of such as system include site-based or sub-watershed based sewerage and stormwater systems of the Green Alley program in Chicago, Illinois; and the Augustenborg Housing Project retrofitting in Malmö, Sweden (Ahern, 2011, p. 5).

*(Bio- and social) diversity*

This refers to the diversity of species within functional groups that respond differently to disturbance and stress. He argues using an example of response diversity applied to urban biophysical systems with low-impact development practices such as permeable pavement and urban tree canopy, each of which reduces the amount of storm drainage infrastructure during heavy rainfall, thus enhancing the overall resilience capacity of the system. Likewise, Ahern claims that a higher level of economic and social diversity will provide more complex response diversity in order to adapt to change and socio-economic disturbances. As an example, he argues this type of socio-economic diversity in a city can 'support social services and cultural programs that keep it economically vibrant, equitable, and attractive

> place for people to live and work, despite economic and social disturbances' (Ahern, 2011, p. 6).
>
> *Multi-scale networks and connectivity*
> Connectivity is a critical parameter of a function's performance, and a lack of connectivity is often a primary cause of that function's failure. Complex networks build resilience capacity through redundant circuitry that maintains functional connectivity even after network disturbance. Functions that operate on multiple scales need multi-scale connectivity. This is especially important in multi-scale connectivity with built urban form and the surrounding blue-green networks for biodiversity, hydrological processes, climatic modification, and other enhanced urban qualities. The Staten Island Bluebelt supporting urban drainage, wildlife habitat and recreation in the city of New York is one example of such connectivity (Ahern, 2011, p. 7)
>
> *Adaptive planning and design*
> For adaptive planning and design, experts and planners assess how a policy or project will influence particular landscape processes or functions and implemented planning policies or design become 'experiments' from which experts, professionals, and decision-makers may gain new knowledge through monitoring and analysis. Ahern's examples for this type of planning are the restoration of Emscher Landscape Park in Germany and the Street edge alternatives (SEA) project in Seattle, Washington (p. 8).

While the concept of resilience is promoted and widely used in urban design and planning, policies, and social-ecological system (SES) contexts, similar to that of sustainability, the concept can be vague and divergent enough to be marginalized as a rhetorical device that falls short of being practical and operational (Brand

& Jax, 2007; Benson & Craig, 2014). This ambiguity of the term persists in the urban field, perhaps weakening the concept due to the lack of clear definition and ensuing overlaps with the term 'urban sustainability' (Zhang & Li, 2018). To overcome these fuzzy obstacles, Meerow et al. (2016, p. 39) suggest the following definition of urban resilience:

> 'Urban resilience refers to the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change and to transform systems that limit current or future adaptive capacity quickly.' (Meerow et al., 2016, p. 39)

The phrase 'return to desired functions' in this definition would reflect Gunderson and Holling's (2002) argument that resilient systems would not only bounce back to their pre-shock state but would also extend beyond the state which showed previous vulnerability to the shock, through self-modification and adaptation. In this case, adaptability and transformability are two critical qualities in resilience thinking (Folke et al., 2010). According to Folke et al. (2010), adaptability and transformability can be defined as follows:

> 'The capacity of actors in a system to influence resilience, while transformability as following: the capacity to transform the stability landscape itself in order to become a different kind of system, to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable.' (Folke et al., 2010, p. 3)

In other words, Folke et al. (2010) explain that the 'adaptability is the capacity of an SES to adjust its responses to changing external drivers and internal processes and thereby allow for development within the current stability domain, along with the current trajectory. Transformability is the capacity to create new stability domains for development, a new stability landscape, and cross thresholds into a new development trajectory' (pp. 4-5). With this definition, bouncing back to surpass the previous state of vulnerability (Gunderson & Holling, 2010) would necessitate both adaptability and transformability.

From an urban economics perspective, a resilient place would have the following characteristics to potentiate adaptability and transformability qualities (Bristow, 2010, p. 156):

1. 'Diversity (as opposed to uniformity) in the number of "species" of business, institutions, sources of energy, food, and means of making a living.'

2. Modularity or capacity to re-organize in the event of shock without substantial reliance on transport through networking and information sharing.

3. Emphasis on small-scale, localized activities, and businesses in the local context that are locally adapted.

4. Mutual access to local assets, capacities, resources, and localized production, trading and exchange, 'strong in reciprocity, co-operation, sharing and collaboration.'

In Tokyo, as a resilient compact city (see Chapter 3), the restoration of the city after the shocks required both adaptability and transformability. Comparable to the properties of Bristow's (2010) resilient place – i.e., diversity, the self-organized capacity to re-organize, and the ability for small-scale adaptation – mixed-use neighborhoods expedited Tokyo's adaptability, with smaller-scale urban components that were able to incrementally re-establish through self-organization and adaptation (Tsukamoto & Almazán, 2006; Hein, 2010; Okata & Murayama, 2011).

### *On emergence*

As simple rules can generate complex urban patterns by individual agents' adaptation, the 'novelty generated by finite means puts us at the threshold of the phenomenon called emergence' (Holland, 2002, p. 28), thus defining CAS results as 'emergent system phenomena' (Brownlee, 2007, p. 1).

Even though the terms 'emergence' and 'emergent properties' are vital characteristics in defining CAS, their exact meanings are still vague. The resilient rule-based Tokyo version X emerged after the restoration, but how is this different from the emergence of a design-based modernist bedroom town, such as Tama New Town (see Section 5.2.1.1)? Does one have emergent properties and not the other? Alternatively, do they both have emergent properties that drive forth the adaptability found in CAS? The following sections will attempt to clarify the term 'emergence' by summarizing Holland's (2002) criteria for emergence, by applying these to the cases of rule-based and design-based planning approaches, and then examining the attempts by De Wolf and Hovoet (2005) at defining the term within the context of CAS.

### *Holland's four criteria for emergence*

Holland (2002, p. 28) has listed four criteria for emergence. Below, these criteria are listed and then applied to the rule-based and design-based planning approaches.

1. *'A repeating pattern in a system that exhibits perpetual novelty.'*

   Relating to this criterion, the rules in the rule-based planning approach would be regarded as the repeating pattern, which creates perpetual novelty, as we could study in the roofscape of Tokyo or the slime mold networks. These repetitions of the simple rules in these two cases create novel contexts, one with a new roof changing the macro roofscape of the city, and the other with a new link between nodes creating, again, a novel macro network of slime molds. In contrast, in the design-based approach, the site and project specificity of the approach makes it hard to exactly repeat and replicate the same pattern in another site or project. Moreover, the repetition of a specific design would not necessarily exhibit perpetual novelty. The main point here would be that a few simple rules that are applied in a diversity of conditions are capable of generating multiple and unpredictable outcomes. In contrast, design solutions that are applied to specific conditions generate specific (and predictable) solutions.

*2. 'Exhibit a hierarchical organization wherein selected combinations of building blocks at one level become building blocks at a higher level of organization.'*

This criterion relates to resilience, whereby a group of independent subsystems forms a higher-level subsystem that would, in turn, be part of an even higher-level system. An adaptation occurring independently in a smaller part of a subsystem in a complex network of systems would respond more quickly to challenges than if the whole system needed to change each time an event took place (Simon, 1991). As seen in the fable of the watchmakers (Simon, 1962) in the introduction to this chapter, the watchmaker who divided his work task into smaller independent subsystems would withstand challenges of broken focus better than the one whose watchmaking was a single complete system, whereby the success of the task depends on completing the whole process from beginning to end. Applying this to the rule-based planning approach, some similarities can be found. We can look into the changes of the Japanese Building Standard Law of 1987 (see Section 3.4), which were enforced to yield higher volumes of buildings within each site boundary in the city to accommodate an increasing population. The simple change of a slant rule (see Section 3.4) within the complex urban system could be representative of a mechanism for a subsystem to individually adapt quickly to changes or to modify the macro system pattern according to the changes in urban conditions or new demands (Sorensen et al., 2010). In a design-based planning approach, using Tama New Town as an example, it would entail either demolishing a part of the built environment or finding a new design solution. In this case, the problem lies in the built environment, which has already been designed as a complete system, providing a solution to problems that existed at the time of design. The design designated a perfect $m^2$ area of the dwelling, e.g., 50-60 $m^2$, for a perfect number of apartments, e.g., for a predicted population of about 300,000, for perfect demographics, e.g., baby boomer families who were to live in the area, not leaving much room for additional changes or future adaptation.

*3. 'The overall form and persistence of an emergent regularity depend upon both bottom-up and top-down effects.'*

Similar to the second criterion, this criterion explains how the exertion of influence that goes in both top-down and bottom- up directions can maintain the system at a constant 'emergent regularity' (Holland, 2002, p. 28). Holland (2002) describes the working of the stock market to explain this exchange of influence between bottom-up and top-down effects. In his example, the overall market indicator is generated by the average actions of individual actors through a bottom-up effect, while, in turn, the changes of an indicator exert a top-down influence on the actions of the individual investors. Top-down, in this sense, lacks the notion of normativity or hierarchy, rather it entails the microstate that has emerged. Similarly, the example of changes to the Japanese Building Standard Law of 1987 can also be applied in this category, whereby the state of urban conditions that emerge through bottom-up individual adaptations within existing rules, e.g., an increase in population, eventually influences and changes the top-down rules, e.g., more allowed buildable areas. This cycle of influence between bottom-up and top-down adaptation continues to generate an emerging macrostate that is novel. In the design-based system, when a top-down design is modified in a specific area to accommodate bottom-up changes, e.g., aging population or loss of industry, this influence is explicitly contained to the area where the design has been changed, contrary to the possibilities of global application as seen in a rule change.

*4. 'The whole emergent regularity is more than the sum of its parts.'*

The last criterion contrasts the reductionist approach, which entails adding carefully studied building blocks with the expectation that each quantifiable behavior of these blocks would add up to constitute the behavior of the whole (Holland, 2002). In the design-based planning approach, the design mechanisms inevitably involve a reduction of the complexity by drawing out selected core urban functions and expected future projections to respond to contemporary challenges, and this would provide a rather static response to ever-changing urban conditions (Batty, 2009).

### *Defining emergence in relation to Complex Adaptive Systems*

More concretely, within the framework of CAS, De Wolf & Hovoet (2005, p. 3) suggest the following definition of emergence:

> 'A system exhibits emergence when there are coherent emergents at the macro-level that dynamically arise from the interactions between the parts at the micro-level. Such emergents are novel w.r.t. the individual parts of the system.'

De Wolf and Hovoet assert that in highly complex systems, coherent global behavior at the macro level can only arise from autonomous interactions of micro-level individuals, which would indicate self- organization, as imposing a structure a priori would not be feasible due to the tantamount complexity. In other words, the 'spontaneous order' that arises from a vast agglomeration of individuals interacting individually in non-linear dynamics (Chialvo, 2010) would be the emergence retaining the adaptive qualities of CAS. As observed in the comparisons of the rule-based and design-based planning approaches above, based on the Holland's (2002) criteria of emergence, urban patterns incrementally developed through micro individual adaptation and modifications over time would show emergent qualities; designed urban segments with specific reductionist functional divisions would not (Lim & Kain, 2016).

Even though De Wolf and Hovoet's concept of emergence does not explicitly refer to an urban research framework, the definition strongly resonates with CAS qualities found in the workings of cities.

Referring to the rule-based and design-based planning approaches described in the previous chapter, the imposition of a structure a priori to micro-level agents' interactions for self-organized emergence would explain why the reductionist approach of modernist design-based planning fails to embrace the complexity needed for the adaptability and transformability of cities for resilience. For a compact city to exhibit resilient qualities, it ought to emerge through diverse interacting micro individuals' continuous incremental self-organization and adaptation. In other words, planning 'for' a compact city, seeking to deal with complexity by 'trying to take into account almost unlimited kinds of quantifiable aspects' (Mayer, 2009, p. 833), would not be feasible (Batty, 209).

## 5.2.3 Communicative rationality and agent-based models

### 5.2.3.1 Actors and agency

Modernist urban planning practices, such as many public housing projects, especially the Miljonprogrammet in Sweden, have resulted in several detrimental consequences, among which social segregation, exclusion, stigmatization, and unrest stand out as significant issues (Lilja & Pemer, 2010; Parker & Madureira, 2016). As a consequence, planning theory has shifted its focus from top-down, reductionist, master planning to a more diverse landscape of theories that better embody the complexities embedded in cities (Allmendinger, 2002; Batty, 2011; Batty & Marshall, 2012; Portugali, 2012). Even though planning practitioners are slower than the planning theorists in accepting the drawbacks of top-down planning approaches (Portugali, 2012), planning theories that are evolving around notions of complexity and adaptivity have moved beyond top-down reductionist approaches which place 'experts' at the top of an authoritative pyramid of planning and design (Innes & Booher, 2010).

Currently, planning theories that embrace complexity and bottom-up, inclusive planning seem to separate into two main research fields (Crawford, 2016; Imottesjo & Kain, 2018). The first of these engage with participative and collaborative planning (Healey, 1992, 2002, 2007; Innes & Booher, 1999, 2010), originating from theories of collaborative/communicative planning (Fischer & Forester, 1993; Healey, 1996; Innes, 1996). The second field involves rule-based urban planning (Alexander et al., 1977; Batty & Marshall, 2012; Marshall, 2012; Moroni, 2015) and agent-based modeling (ABM) (Crooks et al., 2008; Santé, García, Miranda, & Crecente, 2009, 2010; Batty, 2009, 2011; Kennedy, 2012) derived from complexity science (Rittel & Webber, 1973; Simon, 1991; Holland, 1992;

2002; Kauffman, 1995; Lansing, 2003), the study of processes of emergence (De Wolf & Hovoet, 2005; Chialvo, 2010) and game theory (Mayer, 2009; Portugali, 2012). In complex situations, serious games are argued to simulate interactivity in complex multiple-stakeholder situations (Mayer, 2009) and promote subjective interpretations of such situations (Sawyer & Rejeski, 2002).

Both collaborative/communicative planning and rule-based planning executed through ABM involve strengths and weaknesses. The collaborative/communicative approach typically promotes bottom-up participation of diverse stakeholders through continuous consensus-building discourses and activities for iterative policy changes (Healey, 1992, 2002, 2007; Innes & Booher, 1999, 2010, 2015). However, some of the planning theories relating to bottom-up democratic procedures instead embrace inherent conflicts, such as agnostic planning (Mouffe, 2000, 2013; McAuliffe & Rogers, 2018) aiming to turn "hostility into agnostic and consequently replacing enmity by disagreement or aggression by competition" (Davoudpour & Karimzadeh, 2018, p. 56) and approaches based on argumentation (Lapintie, 2002).

Innes and Booher (2003) summarize three key features concerning dealing with CAS based on collaborative/communicative planning: first, the heterogeneity of stakeholders with diverse knowledge and motivations; second, the interaction between the participants, sharing knowledge as well as building trust; and finally, the selection of the most effective solutions for urban development issues through evaluation. According to Innes and Booher (1999), by incorporating these key principles, consensus-building through collaborative/communicative practices delivers not only high-quality agreements and tangible products in the form of agreements, plans, or policies but also intangible products, such as newly formed trust. These qualities are understood to be necessary to better deal with complex social and political fragmentation through 'helping communities and organizations move to higher levels of performance and creativity in a constantly changing world' (Innes & Booher, 1999, p. 416). With this type of inclusion and recognition of multiplicities and diversities, the collaborative/communicative planning approach in spatial strategies is argued to generate 'distributive justice, environmental well-being and economic vitality' (Healey, 2007, p. 268).

Still, the potential of this approach to fully embrace the CAS principles (Imottesjo & Kain, 2018), and its capacity to achieve adaptability (Batty & Marshall, 2012), is questionable. There are challenges linked to the power dynamics within such consensus-building processes, for example between facilitators and stakeholders and between a previously created consensus in a group of stakeholders and diverging opinions of more recently involved stakeholders (Smith & McDonough, 2001; Allmendinger & Tewdwr-Jones, 2002; Allmendinger & Haughton, 2012). In addition, this type of participation method embeds a range of issues (Kahila-Tani, Kytta, & Geertman, 2019), including relatively limited representation of the demographics (Halvorsen, 2001; Irvin & Stansbury, 2004) and a reluctance of institutions to accept and follow through the decisions made (Smith & McDonough, 2001; Irvin & Stansbury, 2004). Finally, consensus-based outcomes also risk being irrational or populistic (Swyngedouw, 2010; Mouffe, 2013).

On the other hand, ABM, based on complexity theory, where simple rules enacted by micro-agents over time are seen to generate emerging macro patterns (Smith & Conrey, 2007; Siegfried, 2014; Mittal, Diallo & Tolk, 2018; Sabzian et al., 2019), has applications in regional and urban sciences (Bithell et al., 2008; Crooks et al., 2008; Santé et al., 2009, 2010; Batty, 2009, 2011; Heppenstall et al., 2016; Levy, Martens, & van der Heijden, 2016). The simulations of urban policy models using ABM are based on 'a behavioral unit, such as a person, household, business, landholder, or farmer (the "agent")' (Clarke, 2014, p. 1218). ABM attempts, through a combination of 'game theory, complex systems theory, evolution programming, and stochastic modeling…. to simulate the actions and interactions of multiple agents, in an attempt to emulate the overall system behavior and to predict the patterns of complex phenomena' (Clarke, 2014, p. 1226). ABM has been used in policy analysis relating to transportation (Auld, Hope, Ley, Sokolov, Xu, & Zhang, 2016), agriculture (Happe, 2004), as well as riot intervention through crows behavior simulations (Torrens & McDaniel, 2013), by exploring 'systems of multiple interacting agents which are spatially situated and evolve over time' (Sabzian et al., 2019, p.3).

Agent-based models are developed through the simulation of decisions and interactions of agents in a simulated urban context, based on the rules assigned to these individual agents by the programmer (Crooks et al., 2008). In this way, CAS with autonomous agents can be simulated (Portugali, 2012) in environments containing other autonomous agents and resources (Batty, 2009). The simulation of agents' interactions is based on different types of rules (Crooks et al., 2008; Clarke, 2014; Millington & Wainwright, 2017), and the decisions and interactions of the agents evolve through learning and adapting in reaction to information collected from their immediate environment (Smith & Conrey, 2007).

Even though such a simulative approach can approximate processes that would take place in a segment of the real world, a computer representation of real human motivations for taking different types of actions can be questioned (Bithell et al., 2008; Kennedy, 2012; Tan & Portugali, 2012). Another criticism includes the difficulties involved with validating outputs of such models, due to different results generated from the same model when it is run multiple times, and the inherent unpredictable characteristics of adapting agents (Levy et al., 2016). Finally, the high level of abstraction (Batty, 2005; Mayer, 2009; Heppenstall et al., 2016) and in some cases the balance between the model's realism and simplicity (Santé et al., 2010), as well as difficulties in calibrating heterogeneous individual characteristics in finer-scale models (Heppenstall et al., 2016), are seen as other weaknesses.

As have been described above, collaborative/communicative planning and ABM have their strengths and weaknesses. Nevertheless, on their terms, both approaches incorporate the principles of CAS in the urban context, especially regarding processes of incremental and bottom-up self-organization – at least in theory. However, what differentiates the two seems to depend on how they approach the aspects of 'actor' and 'agency.' Following communicative rationality, it is human actors who supposedly create a consensus for actions, and it is this consensus that is seen to lead to agency ultimately. In ABM, in contrast, it is the computer-simulated agents who individually have the agency to create a composite/collective urban outcome through an automated chain of actions engineered by a number of set rules. Both the collaborative/communicative planning approach (Allmendinger & Haughton, 2012) and agent-based simulation (Mayer, 2009) are exposed to problems of reduction of complex urban issues, and bias, with practical applicability of such approach also an issue (Fainstein, 2000; Clarke, 2014). While both approaches are somehow incomplete in their representation of the whole spectrum of urban CAS, combining the two into a complementary approach that may lead to increased adaptability and urban resilience seems both fruitful and necessary (Imottesjo & Kain, 2018).

In the following chapters, these two urban research approaches are compared in aspects of understanding the intelligence of a collective, the perception and cognition of a place, and the visualization and representation of a place.

#### 5.2.3.2 Superminds: The roles of people and collaboration

> *Cities have the capability of providing something for everybody, only because, and only when, they are created by everybody. (Jacobs, 1961, p. 238)*
>
> *No single individual today, for instance, knows how to make something as simple as a modern pencil, much less a jet airplane or an iPhone or an athletic shoe. All these human activities require many different specialized kinds of knowledge. (Malone, 2018, p. 218)*
>
> *More is different. (Anderson, 1972, p. 393)*

In his book Superminds, Malone (2018, p. 25) defines such superminds as ‘a group of individuals acting together in ways that seem intelligent.’ Further, he defines ‘collective intelligence’ as ‘the result of groups of individuals acting together in ways that seem intelligent,’ which he considers produces better knowledge output than individualized efforts. Similarly, using the ‘wisdom of crowd’ as an argument, Surowiecki (2004) argues that solving ill-defined problems would benefit from decentralized support that generates numerous and diverse solutions – i.e., with decision-making agency given to groups of people with diverse backgrounds.

‘Collective intelligence’ and ‘wisdom of crowd’ are slightly different in their processes of being intelligent. Collective intelligence is shown through a collaboration of diverse minds to solve a problem. In the book Superminds, a collaborative online project is offered as an example of collective intelligence. In this collaborative project, 39 random interested individuals, with diverse backgrounds ranging from a high school math teacher to an internationally acknowledged mathematician, join together to collaborate online to solve a mathematical theorem, leaving a total of 1,500 comments throughout the project (Malone, 2018). In contrast, 'wisdom of crowd' occurs when the average value is derived from aggregated individual answers by a high number of individuals whose answers are not influenced by other individuals (Surowiecki, 2004). For instance, if one averages the guesses of a mixed crowd predicting the weight of an ox, it would show to be more accurate than a guess by any individual expert, as shown in early experiments conducted by the English scientist Sir Francis Galton (Surowiecki, 2004).

Along the same lines, Atlee & Zubizarreta (2003, p. xi), distinguishes 'collective intelligence' from 'collected intelligence.' While he defines collected intelligence as 'a mere sum of all our individual smarts' (2003, p. xi), he sees collective intelligence as a more integrated action to coalesce the diversity of minds to arrive at a 'creative consensus' (2003, p. xi). He argues that such collective intelligence allows for an understanding of a bigger picture than is possible for an individual alone to apprehend. According to Sanoff, in such processes, the collective outcome is supposedly pursued through deliberative governance, including a diversity of representative citizens 'in a search for mutually acceptable solutions' (Sanoff, 2011, p. 13). The argument that 'if certain conditions are met for inclusion in and conduct of dialogue, consensual conclusions will be, in an important sense rational' (Innes & Booher, 1999, p. 413) further underlines this understanding of 'collective intelligence' in collaborative/communicative practices. However, this denotation of collective intelligence based on consensus would not respond to either Malone (2018)'s Supermind, nor Surowiecki (2004)'s Wisdom of crowd. Using the example of Wikipedia in Supermind (2018), the consensus is temporarily achieved that the content of an article is current and correct until two or more people object its content. This sense, the consensus is made by 'huge group to form an ever-shifting constellation of many parallel small groups, each of which works temporarily on a specific article or other topic' (p. 140), which Malone suspects would not work in 'large face-to-face group' (p. 140). On the other hand, Surowiecki's Wisdom of crowd (2004), explicitly denounces the search for consensus as encouraging 'tepid, lowest-common-denominator solutions which offend no one' (p. 203). Instead, best collective decisions are seen as a result of 'disagreement and contest (p. 162) through 'diversity and independence (p. 162) of opinions.

ABM can also potentially simulate social consensus based on insights from social sciences on the mechanisms of consensus-building (Mittal et al., 2018). Such simulation of consensus-building would assign rules, and modus operandi to individual agents, such as that one individual on average only builds and maintains a certain number of social contacts, and that the duration of these contacts on average is for a specific period. Under such rules, an agent would gradually incorporate information from the other agents into a semantic memory schema, eventually leading the agent to align with the other agents and contribute to a change in consensus (Mittal et al., 2018).

An example of such complex ABM for simulation of emergent behavior can be seen in Lane's (2018) attempt to develop 'empirically based – and psychologically valid- model' (p. 331) of interaction between the individual's memory systems and social stability of a group. This modeling study of dynamic emergence of social identity and group consensus combines theories from social-sciences relating to, e.g., information transfer mechanisms between individuals in social setting; social network links and its individual's ability to transfer information; episodic memories that serves as central aspect of individual's identity; utilization of shared beliefs to align with a group; semantic memories that are socially shared. Using these theories, Lane develops a model assuming types of group alignment, contextual social identity changes based on multiple types of group alignment, and retransmission of information and learning based on empirical studies. In this particular simulation, Lane uses data from the Singaporean church group regarding the number of interactions through communal gatherings, events, and peer to peer interactions.

With variable derived from social science, Lane's model sets values for the number of connections of agents through a social network, shared beliefs and motivations, updates of individual's beliefs and motivations, and how interactions with peers and the group leaders either increase or decrease such values through set intervals. Lane (2018) argues that ABMs facilitate the test of dynamic mechanisms of such psychological models.

However, the irreducibility and unpredictability of changes over time in the relationship between the social schema (i.e., the consensus) and an individual's alignment means that the social schema/consensus of the group should be regarded as 'an "emergent" property of collectives of individuals' (Mittal et al., 2018, p. 325), which is slightly different from the notion of collective intelligence exhibited in processes of creative consensus (Atlee & Zubizarreta, 2003). The consensus in ABM is generated by individuals changing alignment with specific ideas and opinions through social interactions (Mittal et al., 2018). In this way, this type of consensus would reflect more of a global consensus-scape that continuously emerges. Atlee & Zubizarreta (2003, p. xi) explains this as if we would 'arrive at' creative consensus through deliberation by carefully selected representatives who would take into account the multitude of visions of diverse stakeholders. This type of deliberative participation has indeed been criticized as just being an extension of representative democracy (Wilson & Swyngedouw, 2014) but has also been seen to strengthening the existing representative democratic regime (Parvin, 2018).

Even though this type of simulated consensus lacks the collective intelligence seen in collaborative/communicative practices, the macro patterns emerging through collections of intelligent actions by 'heterogeneous, autonomous and pro-active actors where individual variability cannot be neglected' (Siegfried, 2014, p. 19) should not be reduced to a mere collected intelligence (Atlee & Zubizarreta, 2003).

Setting these slight differences aside, both concepts of superminds – i.e., collective intelligence and collected intelligence – build on the idea that the more differences there are, the better; or, as Anderson formulated it in the title of his article on quantum mechanics on the emergence of particle behavior from micro to macro scale, 'more is different' (1972, p. 1). A word of caution, though: even if the diversity of individuals is essential for drawing out the optimal 'wisdom of crowd,' the social influence developing from such collective processes may both affect and be integrated into the individual's answer, compromising its outcome (Lorenz, Rauhut, Schweitzer, & Helbing, 2011). Still, as research on CAS shows how resilient systems should be seen as a collective emergence based on individual agents who adapt and change according to endogenous and exogenous changes (Holland, 1992), both concepts of 'superminds' seem relevant for further investigation.

The supermind phenomenon can be easily identified in the current age of hyperconnectivity (Quan-Haase & Wellman, 2005), with its numerous bottom-up platforms with the potential for self-organization. Wikipedia is an example of 'collective intelligence,' with dynamic, open contributions from heterogeneous actors collaborating to create, modify, and maintain an information database incorporating collective intelligence as a core mechanism (Livingstone, 2016). Numerous online platforms utilizing user voting and reviewing systems are examples of 'collected intelligence.' Such examples include, e.g., Amazon or the Internet Movie Database (IMDB), where heterogeneous ratings and reviews form a collection of opinions on the quality of services or products (Otterbacher, Hemphill, & Dekker, 2011), which then successively change the landscape of market preferences and product developments.

Aiming to offset the outdated but still prevalent planning practices based on the 'heroism' of the modernist expert, urban policies increasingly reflect the need to endow the public with a legitimate voice and encourage public inclusion during decision-making processes (UNECE, 1998; EP, 2003; European Commission, 2011; UN-Habitat, 2012) – i.e., to crowdsource the 'superminds' of people. In this context, the United Nations recognizes the capacity of ICT to create 'inclusive platforms' for the public in 'decision-making' and enhance civic engagement for 'co-provision' and 'co-production' (2016, p. 7). Such policies take civic participation further, beyond practices of informing and opinion surveying into more pro-active participation, e.g., PPGIS (Kahila-Tani et al., 2019), in this way improving the quality of urban decision- making (Kingston, 2002; Hanzl, 2007; Twitchen & Adams, 2012). Even though serious limitations remain, such as an unwillingness of policymakers to share power with citizens and the inherently top-down provision of ICT dialogue platforms (Boonstra & Boelens, 2011; Santos & Tonelli, 2014), global and local policies are pointing in a direction that would include more diversity in solution-seeking and decision-making.

Furthermore, Surowiecki (2014) emphasizes the importance of 'agency' in situations of collective intelligence and action, maintaining that the decision-making power should be given to the group of people who take part in decision- making processes; that the involved group should not be used purely in an advisory role since this would miss out on the possibilities for collective wisdom. In this regard, improving the strengths of civic empowerment during public participation that makes use of ICT becomes a critical issue (Aladalah, Cheung, & Lee, 2015). Unlike more traditional civic engagement through participatory processes designed by policymakers (Boonstra & Boelens, 2011; Santos et al., 2014), the use of ICT, for example through social media (such as Facebook, Twitter, Instagram) (Kleinhans, Van Ham, Evans-Cowley, 2015) and in public participation GIS (PPGIS) (Kahila-Tani et al., 2019) has resulted in self-organized and self-mobilizing civic engagement platforms. While conventional public participatory methods requiring the physical presence of participants can be seen to harbor a narrow spectrum of public participant demographics (Halvorsen, 2001; Irvin & Stansbury, 2004), the use of social media and PPGIS may reach deeper corners of the public (Garau, 2013; Kleinhans et al., 2015; Kahila-Tani et al., 2019). One of the advantages of the use of the connectivity and interactivity of Web 2.0 (O'Reilly, 2005) as a platform for civic empowerment lies in the generation of content that is both top-down and bottom-up (Twitchen & Adams, 2012). Such facilitation of content generation by citizens and citizen groups provides two-way communication and information channels between policymakers and the public (Twitchen & Adams, 2012), to the benefit of citizen inclusion, e.g., self- organized civic movements and organizations (Kleinhans et al., 2015).

#### 5.2.3.3 Perception and cognition of environmental factors: how we perceive a place or how we think of a place

Of course, like all things, there are limitations in relying on a handful of technologies to solve problems that have many facets, ridden with complexity. Especially regarding urban problems, the embodied urban context can often be crucial in decision-making (Orrù, 2018). The sensorial urban context and the direct experience of environmental factors are lacking when public surveys or information sharing and gathering are conducted online, e.g., based on geographic information system (GIS) data alone (Kahila-Tani, Broberg, Kyttä & Tyger, 2016), if the survey is not carried on-site with the use of mobile technologies. In the context of decision-making relating to urban places, enriched spatial information based on the experience of the place is crucial, in order to not end up relying solely on the information relating to built environment provided online by urban professionals and represented through various types of interpretations, visualizations, and diagrams (Monmonier, 1991; Wergles & Muhar, 2009). To maximize the benefit of 'collective intelligence' or 'wisdom of crowd,' the individuals making the decisions should be provided with adequate information to make judgments accordingly (Atlee & Zubizarreta, 2003). In this regard, conventional methods of public participation which require people to meet physically head-to-head (Roghanizad & Bohns, 2017) in workshops, seminars, on-site urban surveys, have certain advantages over urban engagement conducted through online participation that excludes the physical urban context of here and now (Gordon & Manosevitch, 2011). Being able to experience the built environment matters if participants are to assess or evaluate current conditions and an alleged outcome of a future project (Lehnerer et al., 2009; Wergles & Muhar, 2009).

The experiencing of place involves both perception and cognition. Perception usually concerns the immediate apprehension of spatial and environmental information through our sensory input, while cognition refers to the way this information, once received, is stored and organized in the brain (Stern & Krakover, 2010). Since cognition is also developmental (Wapner & Werner, 1957), a change of the individual's cognitive structure influences his/her perceptual selectivity, thus leading to a reconstruction of the perceived condition through selected fields of attention (Stern & Krakover, 2010). An evaluation of the post-constructed 'perception' of urban qualities experienced in the past would involve assessing the person's cognition of these qualities, not his/her perception of them. Also, the way a story is retold can further affect the cognition of an event fraught with selective and biased memories (Marsh, Tversky, & Hutson, 2005).

There are a number of well-known off-site methods aimed at investigating citizen perception of urban spatial qualities, such as perception survey tools using photos (Schroeder & Anderson, 1984; Salesses, Schechtner, & Hidalgo, 2013; Quercia, O'Hare, & Cramer, 2014), PPGIS (Kahila-Tani et al., 2016), or plain text-based questionnaires (Fornara, Bonaiuto, & Bonnes, 2010). However, assessing citizen perception of urban qualities only through online communication channels, based on formulated survey questions and background stories, could be limiting. As Schroeder and Anderson (1984) note, only using features visible in photographs for a survey to assess the sense of the safety of a place had limitations compared to the participants being in this place during the survey. Such limitation of 'not being exposed to the place' while conducting a survey can be counteracted with the help of ICT, for example, mobile technologies including GPS navigation tools and web-browsing, which allow participants to be in the place physically while conducting online surveys. For instance, Maptionnaire, an online map-based crowdsourcing platform, can be deployed on smartphones on-site through the Internet (Maptionnaire, 2019). According to the Swedish report Svenskarna och internet 2018 (iis, 2018), nine out of ten surveyed persons used their smartphone to connect to the Internet in Sweden in 2018. The wide availability of smartphones implies possibilities for new survey methods, advancing from the mail-type questionnaire survey of the 1940s to the telephone-based questionnaire of the 1970s, and the various Internet- type surveys from the 1990s and onwards (Couper, 2011). Combining ICT and smart devices such as smartphones and smartwatches with GIS mapping, geolocation functions, questionnaires, and image rating 'on the go' would increase the quality of citizen urban perception surveys by providing urban contextual input of here and now (Wilson, Tewdwr-Jones, & Comber, 2019).

#### 5.2.3.4 Being in the place vs. visual representation

For a visual representation to present a place located far away from the place of a seminar or workshop, photo images, maps, 2D image renderings, or 3D physical scale models are typically used. This is unfortunate since problems linked to 'being presented a place' instead of 'being in the place' are prevalent in the setting up of public participation activities. Such problems include discrepancies between experts' and non-experts' interpretations of the visual representations of a place (Bates-Brkljac, 2009), the exclusion of non-visual urban qualities in the representation of the built environment (Pizarro, 2009; Pallasmaa, 2012), and increased rates of misinterpretation of what is visually represented compared to on-site assessments of a place (Wergles & Muhar, 2009). In recent years, however, the methods of representation have expanded to include a wide range of 3D computer simulations of the built environment, interactive digital maps, and mixed reality (MR) technologies (Al-Kodmany, 2002; Hanzl, 2007; Gordon & Manosevitch, 2011) in conjunction with the use of GIS and ICT through the Internet (Al-Kodmany, 2002; Kahila-Tani et al., 2019; Lamoureux & Fast, 2019; Brown & Eckold, 2020). The development of these kinds of interactive technologies has increased the capacity of two-way communication between non-experts and experts and has enhanced the level of audience engagement by addressing the lack of tools for visualizing representations for non-experts (Wergles & Muhar, 2009; Kallus, 2016).

Enhanced interactivity of visual representation models might yield deeper levels of engagement on the part of non-experts, and motivate learning, even though the complexity of such models could make them more challenging to implement (Fonseca, Martí, Redondo, Navarro, & Sánchez, 2014). Still, to maximize such benefits in urban participatory discourses, incorporation of the 'here and now' of the urban context is needed. Lehnerer et al. (2009) point to the irreplaceability of personal experience of, and interaction with, a 1:1 scale object in real urban space compared to a simulation of such an object situated in a simulated space. This view is shared by others, pointing out the importance of 'auditory, olfactory, haptic and kinetic experiences' (Wergles & Muhar, 2009, p. 177) in the urban context, and the necessity of bringing in 'immersivity, interactivity and multi-sensoriality' (Piga & Morello, 2015, p. 4) in visual representations of urban conditions and environments.

In ABM, the problem of representation and perception has another dimension. Quoting Smith & Conrey (2007, p. 89), agents in ABM have the following characteristics:

| | |
|---|---|
| *Discrete* | *An agent is a self-contained individual with identifiable boundaries.* |
| *Situated* | *An agent exists in and interacts with an environment that generally includes other agents and may include other (nonagent) resources, dangers, and so forth.* |
| *Embodied* | *An agent may be embodied (robotic) or a purely software-simulated entity; the latter is more common.* |
| *Active* | *An agent not only is affected by the environment but also is assumed to have a behavioral repertoire that it can use proactively.* |
| *Limited information* | *An agent is usually assumed not to be omniscient but to be able to gather information only from its own local environment—for example, agents can see only their neighboring agents (not all agents) and only their behaviors (not their internal states, goals, etc.).* |
| *Autonomous goal* | *An agent has its own internal goals and is self-directed in choosing behaviors to pursue those goals, rather than being simply a pawn under the command of some centralized authority.* |
| *Bounded rationality* | *Agents ordinarily are assumed to gather information and generate behaviors by the* |

| | |
|---|---|
| | *use of relatively simple rules, rather than being capable of extensive computations such as maximizing expected utility.* |
| *Adaptation* | *Some models assume that agents use fixed, prespecified rules to generate their behavior; others use agents that can learn or adapt, changing their rules based on experience.* |

Here, the programmer situates agents in an environment (Singh & Gupta, 2009) where they can act and adapt autonomously to meet their objectives (Siegfried, 2014). This means that the agents act depending on ‘what happens at the present moment’ (Nwana, 1996, p. 27) in the environment, including what other agents do and how their actions continuously change the environment. This situatedness of the agents provides them with direct contact with the ‘perceived’ environment within which they are operating. In this sense, the agents perceive the environment explicitly (Siegfried, Lehmann, Khayari, & Kiesling, 2009). The perception is registered through a certain number of sensors that the agents are equipped with, and either exogenous or endogenous events can trigger these sensors. The activated sensors trigger effectors, which enable the agents to interact with the perceived environment by acting upon or changing the state of being accordingly (Siegfried, 2014). The number of sensors that are modeled into the agent-based simulation depends on which emergent phenomena are to be simulated (Siegfried, 2014). This reduction and approximation that are inherent in ABM into a pre-determined number of sensors and effectors with which the agents operate are still limited to representing the human perception and motivation for actions taking place through the complex interaction between cognitive memory and sensory input (Helbing, 2012).

Even though the mechanisms involved in perceiving the environment of the agents of ABM lack the full complexity of the human capacity to perceive, the situatedness of the agents in the simulated environment could still be seen as a strength. In a more traditional setting for participation in planning and architecture, a comparable type of ‘situatedness’ of civic actors can be found in compulsory installations of 1:1 scale structural mock-ups of future building objects. For example, the mock-up structure, called ‘Baugespann,’ delineates the building’s dimensions and openings, such as doors and windows, for non-expert citizens to interact with before assessing the yet unbuilt environment (Lehnerer et al., 2009) (see Figure 40). Such on-site 1:1 spatial mock-ups enable citizens to be equipped with an enriched urban perception in the space of here and now, and support active and direct participation in shaping their urban future (Lawrence, 1993; Lehnerer et al., 2009). The law stipulates such mock-up installations in Switzerland in order to supply adequate information on planned building projects to citizens for voting for or against such changes to the project site.

*Figure 40. Baugespann. Example from Schönbühlring in Lucerne, Switzerland. (Author: 2011pnm, Source: https://commons. wikimedia.org/wiki/File:Sch%C3%B6nb%C3%BChlring_in_Luzern.jpg)*

In the development and availability of new technologies, such as mixed reality, especially outdoor mobile augmented reality (MAR) tools provide new possibilities to replace or complement traditional 1:1 scale mock-ups, and have been identified as potential candidates to facilitate the visualization of yet unbuilt projects into an urban context for public participation (Hanzl, 2007; Ashraf Khan & Dong, 2011; Sørensen, 2013; Gordon & Manosevitch, 2011; Billger et al., 2017), supplying contextual urban information, such as ‘auditory, olfactory, haptic and kinetic experiences’ (Wergles & Muhar, 2009, p. 177; see also Imottesjo & Kain, 2018).

#### 5.2.3.5 A proposal for a new hybrid approach in urban planning regarding actors, agency, perception, visualization, and superminds

Summarizing the chapter, the author proposes a complementary approach for bridging the communicative rationality and computer-simulated ABM, seeking an integration of the qualities of the two approaches to best incorporate the complexities of bottom-up self-organization through individual adaptation for resilient urban systems (Carpenter, Walker, Anderies, & Abel, 2001; Ahern, 2011, See Table 2).

This hybrid approach suggests, firstly, that the individual human stakeholders should remain as main representative actors, rather than being replaced by simulated agents with their reduced capacity for senses and motivations and with their limited action schemes (Bithell et al., 2008; Kennedy, 2012; Tan & Portugali, 2012). This is to reflect better the complexity of human perceptions and motivations for actions, even if they may sometimes seem irrational. However, the agency, the power to act upon the motivation, should remain not primarily in the hands of the collective consensus but in the hands of the individual actors. This would potentially reduce the issues of power in forming and maintaining consensus (Allmendinger & Tewdwr-Jones, 2002; Allmendinger & Haughton, 2012), and make room for diverse decisions to be made based on individual motivations and adaptational capabilities (Siegfried, 2014). Particular attention also needs to be paid to the issue of power regarding the representation of the built environment, based on which individual actors have motivations for adaptation and the power of accessibility to communication and visualization tools. In the formulation of the roadmap, the author suggests approximation of the situatedness of the agents in ABM in the environment by introducing on-site, 1:1 scale visualization methods for the future built environment. Including the existing urban context, e.g., noise level, air quality, and weather conditions, would allow for the individuals to assess the future environment, so that the decisions made based on this assessment would reflect real urban conditions rather than a manipulated visualization of the environment (Downes & Lange, 2015, See Figure 41).

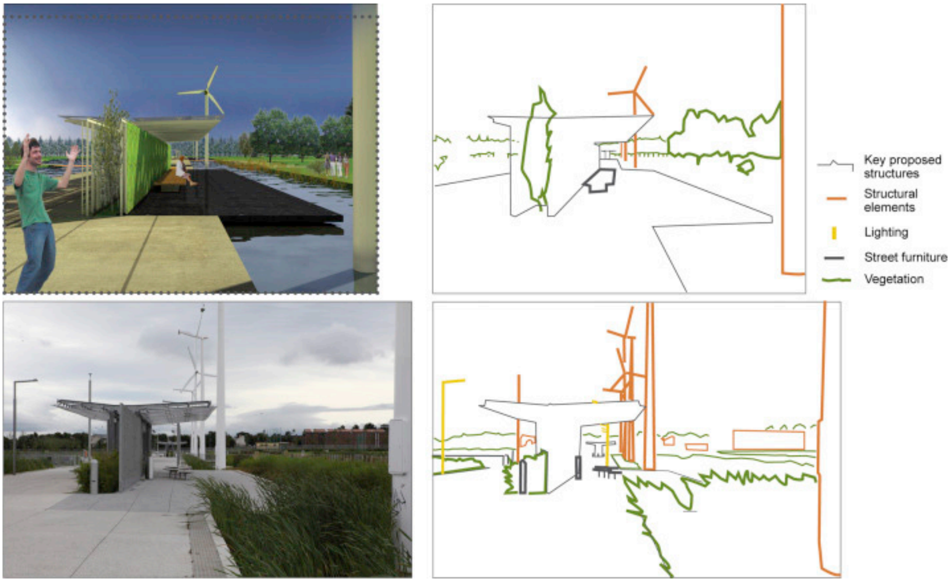

*Figure 41. Illustrations show an analysis of discrepancies between visual representation and reality. (Source: Downes & Lange, 2015)*

While the diverse intelligence and creativity of individual actors are reflected in consensus-building and collective action (Atlee & Zubizarreta, 2003; Sanoff, 2011), bringing these diverse minds together to form one action plan for all seems to limit the true potential of such diversity (Surowiecki, 2004; Lorenz et al., 2011). The author suggests instead to incorporate the 'collected intelligence' or 'wisdom of crowd.' which is a kaleidoscopic aggregation of diverse minds in addition to the collective intelligence. Finally, reflecting the element of 'diversity' from elements of complex adaptive systems' resilience perspective (Ahern, 2011), the author proposes a system that would nurture a continuous emergence of individual adaptation beyond collective action plans, i.e., consensus, as these might reduce the potential diversity and redundancy of the outcomes.

*Table 2. A proposal for a hybrid approach*

| | ***Communicative Rationality***<br>Participative and collaborative planning<br>(Healey, 1992, 2002, 2007; Innes & Booher, 1999, 2010) | ***Proposed hybrid roadmap*** | ***Computer Simulated Modelling***<br>Agent-based urban simulations<br>(Crooks et al., 2008; Sant et al., 2009,2010; Batty, 2009, 2011) |
|---|---|---|---|
| ***Strengths*** | Bottom-up stakeholder participation through consensus building<br>Encourages decentralized bottom-up local actions | | Simulates potential outcomes of certain rules as emergent urban forms and processes |
| ***Weaknesses*** | Overseeing production of space<br>(Yiftachel & Huxley, 2000)<br>Overlooking issues of power<br>(Flyvbjerg & Richardson, 2002; Hillier & Gunder, 2003)<br>Distortion of outcome through politicizing, creating desired consensus, maintaining the consensus<br>(Allemendinger & Haughton, 2012; Allmendinger & Tewdwr-Jones, 2002)<br>The usual participants demographics<br>(Halvorsen. K.E, 2001; Irvin & Stansbury, 2004)<br>Adaptability??<br>(Batty & Marshall, 2012) | ***Combines*** | Challenges for a simulated agent to represent human behaviour in ABM<br>(Bithell, Brasington, & Richards, 2008; Kennedy, 2011; Tan & Portugali, 2012)<br>The motivations of human behaviour based on previous experiences, sensory inputs, emotions, and cultural values need better representation<br>(Kennedy, 2012)<br>ABM might miss on tackling the real-world issues<br>(Levy, Martens, van der Heijden, 2016) |
| ***Actor/Agency*** | **Human stakeholders**/Consensus | **Human stakeholders/Individual agents** | Computer simulated agents/**Individual agents** |
| ***Perception*** | **Through human sensory input**: auditory, olfactory, haptic and kinetic experiences" (Wergles & Muhar, 2009, p. 177) | **Human sensory input** | Determined by the architecture of agent's sensor data (Siegfried, 2014) |
| ***Visualisation*** | Representation or **on-site** | **On-site, situated, implicit perception** | **Situated** in the environment (V. K. Singh & A. K. Gupta, 2009), **implicit perception** (Helbing, 2012) |
| ***Superminds*** | **Collective intelligence** through coalesce of diversity of minds leading to creative consensus (Atlee, 2003) | **Collective intelligence and wisdom of crowd** | Superminds through **wisdom of crowd** type showing aggregation of diverse responses proximates optimal output is potentiated (Helbing, 2012) |
| ***Outcome*** | Collective action plan | **Emergence through individual adaptation** | **Emergence created by collection of individual adaptation** |

## 5.3 What (mobile) augmented reality tools can be developed to stage urban emergence by supporting citizens to visualize and collaboratively design on the neighborhood scale, and then aggregate people's ideas and views?

This section presents three outcomes acquired from three research-through-design processes exploring the development of tools supporting emergence through the aggregation of citizens' ideas and views based on collaborative designing. First, the results from two pre-studies are presented with descriptions of the tools, assessments, and takeaways for incorporation into the subsequent research activities. After that, the third main study introduces the mobile augmented reality (MAR) tool Urban CoBuilder. This section describes the specifications developed through a literature review, combined with the takeaways from the pre-studies, followed by assessments of prototypes through user tests, with the last two prototypes in the form of pilot systems. A more detailed description of these studies and the MAR tool are found in the appendices.

### 5.3.1 Pre-study 1: Beyond the poster

The board game was developed to explore mechanisms and outcomes of a 'rule-based' planning system versus a 'design-based' planning system, with a particular focus on adaptabilities and incremental changes with regard to densification. See Appendix 4 for more detailed information. The game consisted of two boards with a pixelated map of Gothenburg, one representing a 'rule-based' planning approach and the other a 'design-based' approach. Each pixel represented 100 x 100 meters of the urban context. (see Figure 42).

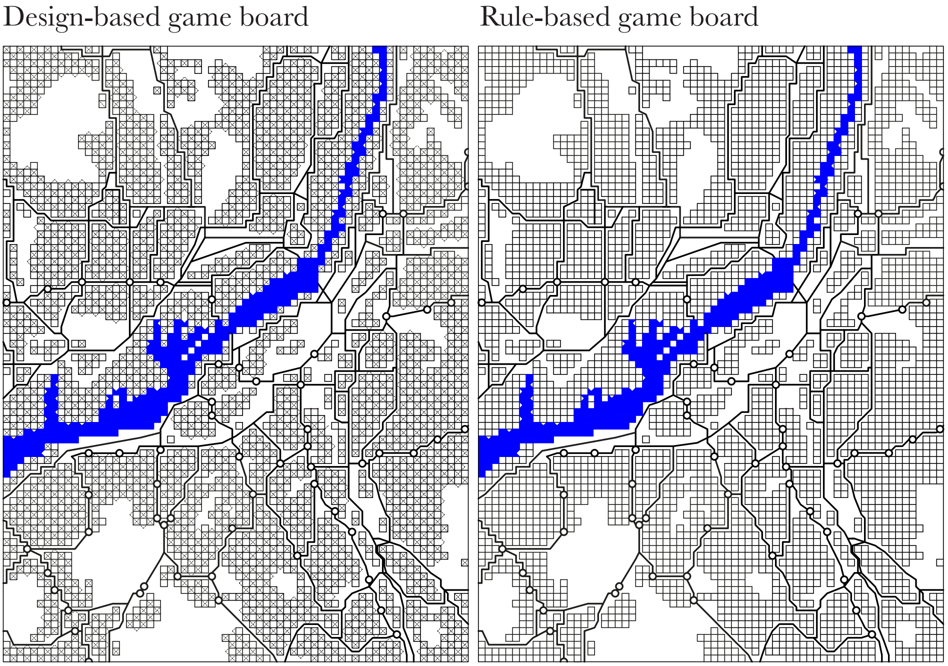

*Figure 42. The Design-based and the Rule-based boards and the grid layout*

Play pieces for the 'rule-based' board were color-coded in ten levels representing various levels of urban intensification, indicating different zoning categories that allowed varying degrees of building footprint ratio on-site and building heights. The play pieces representing the zoning categories were to be placed according to color schemes. The pieces for the 'design-based' boards were designed with ten different patterns representing street layout. The pieces for the design-based system's board should be placed so that the street patterns should be continuous as the adjacent pieces are placed.

Mission cards that were stacked in front of each board explained the urban development tasks that needed to be fulfilled, and which play pieces could be used for the task on each board (see Appendix 4) for example, 'create a commercial trail, a boulevard, or an avenue using three blocks in a straight (orthogonal or diagonal) line.' A player was to take as many mission cards as he/she wanted from the stack, on condition that the player did not change the order of the stacked cards when playing the game.

The board game was exhibited at the main hall of the Architecture Department at the Chalmers University of Technology during the period April 15-26, 2013, and students passing the exhibition area were encouraged to play the game regardless of their field of study. Initially, the research concept was presented verbally, and throughout the period, posters explaining the research concept stood beside the board game.

The board game was perceived relatively simple to play, and the students were curious about the concept of urban planning represented in it. This project and the feedback sessions delivered valuable lessons concerning the importance of participants' motivation to engage in a game setting. As the game was seen as an ongoing simulation and emergence of urban patterns, the goal was not explicit to the participants as they were only considered a small part of the whole series of actions. When there is no apparent winner or a loser, or an explicit goal, with seemingly abstract achievements, the participants were not as motivated to continue playing after the initial phase of curiosity. Regarding the perception of what has been played out on the board in relation to the real built environment, the game pieces that symbolically represented urban patterns when placed on the boards were hard to read as an outcome of urban planning with specific urban qualities. The street patterns or the representation of urban districts were too abstract and did not help in trying to 'design' a 'livable' or 'desired' urban environment on the board.

As a result, the need to implement strategies, such as winning or achieving specific goals through collaboration or individually or gathering points through gamification, became apparent during the sessions, as did the importance of visualization of the resulting urban designs for a better perception of the built environment.

### 5.3.2 Pre-study 2: The Urban CoMapper

In this pre-study, a tool – the Urban CoMapper – was developed to survey citizens' perceptions of urban areas. The tool used smartphone and geolocation technology with GPS navigation, open-source data, in addition to open-source libraries with permissive licenses to conduct a real-time, on-site citizen urban perception survey. This section describes the tool and the takeaway from this design research. More elaborate information can be found in Appendix 5.

The Urban CoMapper was designed to survey citizens' perceptions of urban qualities relating to the compact city, i.e., regarding their perception of the density and diversity of areas where they find themselves at the moment. Based on the smart phone's geolocation functions coupled with an overlaid grid of 100 x 100 meters over the study areas on the map used for the app, the app notified participants to take the survey when they moved across the grid border lines.

After rating the level of perceived density and diversity, the participants were asked to rate the level of perceived positivity or negativity relating to the perceived density and diversity. For instance, if the participant perceived an area to be dense, and the relating perception was a feeling of liveliness, then the rating on the positive-negative scale would indicate positive perception. If the high density was associated with a perception of crowdedness, then the positive-negative scale would lean towards a negative perception of the density (see Appendix 5). The resulting data would show what type of density or diversity qualities were associated with positive feelings such as vibrant, walkable or fun, and negative feelings such as noisy, too busy, or crowded.

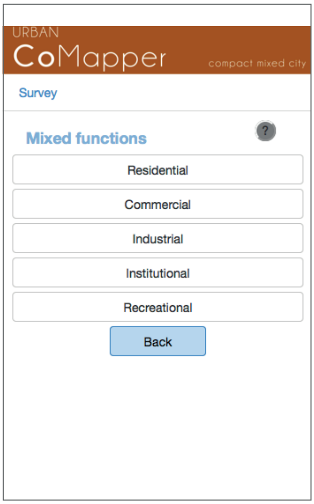

*Figure 43. Choosing a perceived zoning category*

Subsequently, the participants were asked to assess what kind of zoning category the area should belong to by choosing between five broad zoning categories: residential, commercial, industrial, institutional, and recreational (see Figure 43). When a zoning category had been selected, a sub-category of the chosen zoning, e.g., neighborhood commercial, street commercial, and central commercial for a commercial zone, was selected. This part of the study explored a way to assign a zoning category where there has not been any precedent example of zoning, such as in the city of Gothenburg.

A beta version of the Urban CoMapper was produced and could be downloaded via a web link (as of 11th April 2016, hosted at http://216.66.81.48:8080/urbaniaWebApp/density). The app was tested in a workshop with a small user group in Gothenburg to examine its functionality and usability, especially regarding the limitations of the urban quality perception survey protocols so that modifications could be made.

The explanation of how to use the tool was perceived rather simple, but the sequences of the survey process and the survey criteria regarding the zoning of the area were somewhat complicated for the non-expert participants. Especially the detailed sub-categories under the broad zoning categories seemed problematic and added to the complication. The user interface for mapping the perception of density and diversity and the perception of negativity or positivity by selecting along a scale of 1 to 5 seemed to be graphically simple enough for participants to use intuitively.

The delayed response of the smartphones' GPS was problematic, though not so great a concern that it could not be solved on-site. Another concern was the distance between the cells, which seemed somewhat too short to provide different perceptions of the site. Furthermore, the tool should be modified to shorten the survey processes. The participants' categorization of perceived zoning was too complicated and irrelevant, given their misunderstanding of the terminology used. Also, it seemed irrelevant to assess perceived zoning each 100 meters. The study sites also need to be scaled down considerably. The problem of distinguishing the view 'from' the surveyed point and the view 'of ' the surveyed point seen from another location needs to be resolved.

The takeaway from this pre-study was knowledge of various tracking methods that needed to be further investigated for accuracy. The GPS, which is often used for user location tracking, was lagging or inaccurate in short-distance tracking. Also, the importance of managing the time and budget was highlighted in reference to prioritizing tool specifications that were the most relevant for the studies, so that limitations can be managed for more focused development.

## 5.3.3 Main study: The Urban CoBuilder – a mobile augmented reality tool

This section compiles results from developing and pilot-testing a mobile augmented reality tool, where more detailed information can be found in Appendix 2, 3 and 6. It first describes the specifications and design criteria developed for the designing of the tool. Then the section describes the implementation of the design criteria during six iterative prototyping sessions. The following section accounts for the assessments and takeaways from these six prototypes and describes the two resulting semi-pilot systems of the Urban CoBuilder: a 1:1 scale outdoor mobile augmented reality (MAR) version, and a scalable table-top version augmented reality (AR) tool. Subsequently, an assessment of these two semi-pilot systems is provided.

### 5.3.3.1 Specifications and design criteria

The takeaways from the two pre-studies covered gamification, citizen perception of the built environment, the use of geolocation technology and location tracking, and also project management relating to budgeting and prioritizing. Based on these takeaways, reviews of both academic and grey literature were carried out, resulting in a set of specifications for the development of an outdoor MAR tool. The main categories of the specifications were as follows (Imottesjo & Kain, 2018):

1. The tool will simulate built structures and incremental development processes through multi-stakeholder inclusion;
2. The tool will provide immersivity in urban conditions of here and now so that the citizens'

perception of on-site context is not skewed;

3. The tool will have the capacity for on-site AR projection; and
4. The tool will simulate a rule-based process through gaming mechanisms.

Furthermore, twenty sub-categories were developed to specify the detailed requirements needed to fulfill the abovementioned four main categories.

*Specification 1.1 is related to how the built structures should be simulated with regards to urban compactness*

1. Urban compactness as density and diversity of urban grains (buildings, lots)
2. Urban compactness as diversity and proximity of urban functions and actors

*Specification 1.2 lists the requirements for the simulation of planning processes*

1. Incremental development processes
2. Multi-stakeholder inclusion
3. Rule-based and context-based urban development processes

*Specification 2 identifies the conditions of immersivity for on-site perception*

1. Facilitate perception of urban space, qualities and context, such as urban noise, pedestrian flows, climatic information

*Specification 3 details the technical specifications for the on-site AR projection*

1. Use mobile devices (smartphones/tablets) as the collaborative interface, with a simple and intuitive user interface for both visualization and design input
2. Use a centralized server and cloud-computing to continuously upload and update design changes done by the multiple stakeholders, to support collaborative design fully
3. Facilitate observation and interaction from different angles (front, back, sides, around corners, etc.) and distances in relation to the real environment for full immersion
4. Use fiducial markers, rather than GPS or building contour tracking, for accurate localization of AR objects. The virtual objects must be perceived in

correct locations and scale, without glitches and lags, when users move around

*Specification 4 was developed to simulate rule-based urban development processes by including a gaming mechanism in the tool*

1. Multi-player role-playing mechanism
2. AR representation from street level
3. Turn-based mechanism
4. Building blocks as economy input, e.g., prices on building blocks
5. Crowd-sourced outcome
6. Site-specific game rules
7. Workshop-based
8. Building blocks representing relevant urban functions for the site
9. Real-world challenges, e.g., ongoing projects, planning rules
10. Create urban emergence

These specifications were then grouped into four design criteria guiding the practical tool implementation: tracking, design elements, UX-I and gaming mechanisms, and data storage and retrieval (see Table 1 in Chapter 4).

#### 5.3.3.2 The first six prototypes: Implementation and assessment of design criteria

As a result of the research-through-design process, the iterative prototyping produced eight prototypes of the Urban CoBuilder based on implementing the design criteria. Of these, the first six were tentative but gradually refined prototypes, and the last two were more developed prototypes, i.e., semi-pilot systems.

The assessment of the first six prototypes regarding the tracking methods indicated insufficient recognizability when using existing built information, such as façades of buildings, as reliable markers in an urban neigborhood scale outdoors. The use of GPS for tracking was too inaccurate for the players to perceive the location of the placed objects in the built environmentnt. Bitonal frame markers were the most reliable and accurate to be usable for the MAR tool, even though the size of the marker mattered for designing in the distance.

When it comes to design elements, the prototype tests highlighted the importance of perception of the scale of the virtual blocks when placed in the environment. The use of color-coded building blocks was not sufficient and was too abstract for users to understand the built environment.

For UX-I and gaming mechanisms, the prototypes tested various interfaces for the users to add and remove building blocks as well as intuitively select a building block that the user wanted to build with. The display of the remaining budget and building blocks was also tested. It became clear that the main issue that still needed to be dealt with included methods to locate and place the virtual objects on the screen in a more intuitive manner. Furthermore, the use of the grid plane could illustrate the perspective of scale to the ground level. However, when the building block was not on the ground, the location of a hovering block was impossible to perceive. However, this issue was neglected, with the motivation that it is not necessary to be able to simulate a hovering building block, since this would be physically impossible in real-world situations. The addition of stakeholder roles, and projects that belong to these roles with linked different economic rules, was also tested (see Table 4). Here, it was concluded that the many functions and choices that could be made using the tool rendered the screen instead filled with buttons and that the interface needed to be simplified and streamlined through the design of a better user process leading to the selection and changes of different functions.

| Assignment | Stakeholder Roles | Goals | Economy/money units available for assignment | Available building block types | Number of building blocks available | Price of a building block |
|---|---|---|---|---|---|---|
| 1 | Municipality | Improve green area | 1000 | Green | 50 | 20 |
| | | | | Public facilities | 10 | 50 |
| 2 | Private Developer | – | 2000 | Commercial | 30 | 60 |
| | | | | Offices | 50 | 40 |
| | | | | Housing | 100 | 20 |

|  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|
| 3 | Private Developer | – | 2000 | Commercial | 30 | 60 |
|  |  |  |  | Offices | 50 | 40 |
|  |  |  |  | Housing | 100 | 20 |
| 4 | Municipality | Increase Housing | 1000 | Green | 50 | 20 |
|  |  |  |  | Public facilities | 10 | 50 |
|  |  |  |  | Housing | 50 | 20 |
| 5 | Small-time developer | – | 210 | Housing | 7 | 30 |
|  |  |  |  | Commercial | 3 | 70 |
| 6 | Small-time developer | – | 300 | Housing | 10 | 30 |
|  |  |  |  | Commercial | 4 | 70 |
| 7 | Small-time developer/ Coop | – | 300 | Housing | 10 | 30 |
|  |  |  |  | Commercial | 4 | 70 |
| 8 | Small-time developer/ Coop | – | 300 | Housing | 10 | 30 |
|  |  |  |  | Commercial | 4 | 70 |
| 9 | Private Developer | – | 2000 | Commercial | 30 | 60 |
|  |  |  |  | Offices | 50 | 40 |
|  |  |  |  | Housing | 100 | 20 |
| 10 | Municipality | Public facilities | 2000 | Green | 50 | 20 |
|  |  |  |  | Public facilities | 40 | 50 |
| 11 | Private Developer | – | 2000 | Commercial | 30 | 60 |
|  |  |  |  | Offices | 50 | 40 |
|  |  |  |  | Housing | 100 | 20 |
| 12 | Municipality | Increase Housing | 1000 | Green | 50 | 20 |
|  |  |  |  | Public facilities | 10 | 50 |
|  |  |  |  | Housing | 50 | 20 |
| 13 | Municipality | Public facilities | 2000 | Green | 50 | 20 |
|  |  |  |  | Public facilities | 40 | 50 |
| 14 | Small-time developer | – | 210 | Housing | 7 | 30 |
|  |  |  |  | Commercial | 3 | 70 |
| 15 | Small-time developer/ Coop |  | 210 | Housing | 30 | 30 |
|  |  |  |  | Commercial | 14 | 70 |

*Table 4. Assignments of stakeholder role at each turn*

### 5.3.3.3 The Urban CoBuilder 1:1 scale

This section describes the implemented design criteria for, and the assessment of, the first semi-pilot system: The Urban CoBuilder 1:1 scale MAR tool (see Table

3 in Chapter 4). The second semi-pilot system, the Urban CoBuilder table-top version AR app, is described and assessed in the subsequent section.

For tracking, multiple printed bitonal markers were used in conjunction with a location averaging mechanism, developed through this project, using the gyroscope function of the smartphone. This mechanism enabled the tool to position the location of the user whenever more than one marker was visible on the smartphone's screen. Through tracking movements supported by the gyroscope function of the phone, the tool could estimate the user location and the position of the camera of the phone when the phone screen lost the sight of any markers, for instance, while looking up to build upwards.

Different types of building blocks were provided with different façade textures to represent the diversity of urban functions, i.e., offices, residential usage, commercial usage, and green spaces (see Figure 44). To provide a basis for the simulation of AR these design elements in the real environment and to aid the player's perception of scale, an AR grid of three by three meters was overlaid on the site floor. Three by three-meter building blocks could then be placed on this grid (by way of selecting positions indicated by wireframe cubes) and also on top of each other (see Figure 45).

*Figure 44. Building functions; office, residential, commercial, and green functions*

When it came to the UX-I, the possibility to toggle between street view and bird's eye view was removed to guide the users to explore the virtual object by physically moving around the object and creating a design based on the immediate perception of the object from the street view.

*Figure 45. Street level view*

In addition, gaming mechanisms were improved with a system employing a basic form of urban economy to simulate a simple rule, which enabled a player to build according to her/his economic means, depending on the stakeholder role, e.g., a municipal official with public goals linked to housing or services, a private large-scale developer, or a private small-scale developer/cooperative (see Table 4). The player got assigned a certain amount of purchasing power and a certain number of playable building blocks representing various urban functions. The price of building blocks varied depending on the role played by the player and the goal of the project; for instance, it was lower to build residential units as a municipal authority with an aim to increase apartments. These basic economic rules would allow the users to prioritize which urban functions should be built within their economic means.

The pilot user testing of the 1:1 scale Urban CoBuilder tool showed the following feedback, including concerns and potential for improvements. The users did not assess the design criterion concerning the data storage and retrieval since it was implemented as the behind the scene base mechanism for saving and uploading the user actions, ex., adding a block, and not as something user could evaluate the functionality of.

***Tracking:***
Even though the size of the markers was too bulky to be portable, the multiple markers placed on-site, combined with location averaging mechanisms using the gyroscope function of the smartphone, worked sufficiently to stabilize the placed objects locations while the camera leaves the markers.

The integrity of the structure on which the markers were mounted, especially when the marker was placed vertically, was essential. The size of the marker made it easy to become bent during the building sessions, due to its own weight and to weather conditions, such as wind, and this rendered the augmented space to become skewed. Portable smaller standing markers mounted on tripods with three or four faces might make the tracking more stable.

***Design elements:***
The detailed façade textures on building blocks were assessed as positive, aiding the comprehension of the scale of the augmented building blocks within the built environment. Suggestions were made to include a more extensive choice of façade textures and urban functions, including streets and paths. Even though the scale of the building blocks was received positively, the three by three-meter blocks were too small when working on an urban scale, requiring too many blocks to build a neighborhood scale environment.

***UX-I and gaming mechanisms:***
In general, the process of starting the app, registering oneself, choosing projects, and understanding the stakeholder roles and the aim of the project was perceived as easy to take in and operate. Also, the mechanisms to place a building block, and remove or change the building block types were all perceived reasonably straightforward.

However, more complexity would be required to include relevant planning rules and economic rules reflecting the real urban planning issues of the test sites. Suggestions were made to add user-generated complexity relating to issues concerning design elements and enabling communication between the players for negotiations and cooperations relating to rules and economy.

Designing a built environment in an urban scale without the possibility for a bird's-eye view was perceived as unfavorable. The users had desires to view the project from the bird's-eye view to have a comprehensive picture of what was being built.

### 5.3.3.4. The Urban CoBuilder table-top version

The Urban CoBuilder, 1:1 scale version, was also modified so that users could test collaborative designing in table-top setting (see Table 3 in Methods chapter). Regarding tracking, the main modification was the size of the tracking markers for portability, where this version used just one printed bitonal frame marker of 19 x 19 cm.

For the design elements, changes in the building block types and the façade textures of the building blocks were also made, so that the tool would reflect relevant design components for the planning of the study site (see Figure 46). In this case, instead of just including a building's urban functions as building blocks, façade elements, such as windows, doors, and balconies were developed. These block textures were acquired through analysis of a current building project in the test area, i.e., the BoKlok, IKEA's approach to residential housing.

The pilot user testing of the Urban CoBuilder table-top version showed that the portability of the tracking markers made it simple to use them during the workshop session, where students were to interview passer-by citizens. Also, scaled-down markers enabled building from top-down (bird's-eye view) delivered more stable tracking due to smartphones screen remaining in moderately static position, letting the marker to be visible throughout the design sessions.

*Figure 46. Façade elements extracted from BoKlok project*

For the design elements, the building blocks with façade texture indicating a building element (e.g., door, stairs, windows) were perceived as easy to understand and to build with. It was also found that it was quite useful to build scaled AR models on tables or maps indoors, which could then easily be taken outside for projection on site. However, the smaller scale and bird's-eye view designing highlighted some issues relating to the scale of the three by three-meter building blocks. Players tended to place the building blocks quicker and to cover large volumes of built areas, and often the smartphone would freeze, unable to handle such a data load.

Regarding the UX-I and gaming mechanisms, the table-top Urban CoBuilder tool was seen as facilitating dialogue with residents passing by for the interviewers on-site, thus turning the AR tool into a MAR tool. However, while the younger generation of interviewed citizens (see Table 5) found the app intuitive and easy to use, it was not comfortable enough for older residents.

|  | AGE | Gender M | Gender F | Reasons for refusal |
|---|---|---|---|---|
| Participated | Under 12 | 5 | 2 |  |
|  | 12-20 | 3 | 7 |  |
|  | 30-40 | 2 |  |  |
|  | 50-60 | 1 |  |  |
| Refused | Mixed | 6 |  | Busy |
|  | 30s-40s | 6 |  | Language/suspicious |
|  | 50s-60s | 5 |  | Technical discomfort |

*Table 5. List of participants and reasons for refusal to use the tool*
** The age of the participants were approximated by students. Passerby groups of mixed age, e.g., school children with parents, were categorized as Mixed in the refused section.*

# Chapter 6.

# Discussion

This thesis aimed to contribute to research on processes of incremental bottom-up urban planning and design through citizen inclusion in support of urban resilience based on compact city qualities. The following sections discuss to what extent the objectives of the Ph.D. project (see Chapter 2) have been responded to during the research process and link the results to the state of the art.

## 6.1 Urban planning approaches and compact city qualities

> *In other words, imaginative geographies of distant objects and events tend to be represented by their perceived primary or central attributes, while peripheral or incidental features are deleted. Because of this process, construals of very distant worlds tend to be more coherent, more schematic, simpler, and less ambiguous than the more concrete mental construals of more proximate worlds. (Simandan, 2016, p. 251)*

The first objective of the thesis was to understand the relationship between different urban planning approaches and the processes and the outcomes of those from the perspective of qualities of compact city urban form. This objective intended to understand the relationship between compact city structures exhibiting qualities, such as diversity of agents in proximity (Quigley, 1998; Bettencourt & West, 2010; Glaeser, 2011; Bettencourt, 2013) and urban planning processes (Newman, 2006; Brand & Jax, 2007). Here, the comparative study found some differences between the types of urban planning, especially regarding the diversity shown as the number of buildings, the proportion of smaller buildings, and the distribution of diverse building scales throughout the study areas (Lim & Kain, 2016). The analysis showed that the density measured as the building footprints in designed compact city areas resembled that of an emergent compact city. However, the analysis of diversity in such areas, expressed as building scales and distribution patterns, resembled that of dispersed urban forms. Even when the building scale analysis was made focusing on the selected intensification project areas, the number of small-scale buildings was still limited (Lim & Kain, 2016). This result seems to indicate that even if density might be designed, urban diversity might be depending on evolving incremental urban processes, possibly through fragmentation of urban projects over time (Lai & Han, 2012). One argument for decreased diversity in income level based demographics could be speculated by the analysis of higher rental cost for an apartment in the study areas representing the designed compact city urban form in Gothenburg (Kvillebäcken and Eriksberg, see Kjellberg, 2013) and Tokyo (Roppongi Hills, see Moriliving, 2015), compared to the average cost in the respective cities (Statistics Sweden, 2015; REINS, 2015).

Such analysis of urban form diversity based on building footprints alone is inevitably limited, e.g., non-inclusion of building volumes, or intensity of land-use. However, even with the remaining limitation, the rate of the diversity of building scale, even though two dimensional, and the distribution through the study area are indicated in the study. If we consider that urban complexity seems to be created both by interaction between agents in proximity (Glaeser, 2011; Bettencourt, 2013) and by the diversity of its constituting elements (Quigley, 1998 ; Carlino et al., 2007; Bettencourt, 2013), the designed compact city urban form represented in this study appears to lack in qualities that would contribute to the aspired complexity, adaptability and, thus, resilience (Holland, 1992; Scheurer, 2007; Bristow, 2010; Ahern, 2011; Glaeser, 2011; Marshall, 2011; Batty & Marshall, 2012; Bettencourt, 2013; Offenhuber & Ratti, 2014) that is required to deal with changing conditions.

## 6.2 Urban emergence and planning theory

The second objective of the Ph.D. project was to understand how the complexity that renders urban resilience is maintained through urban emergence and how this process can be facilitated from the perspective of urban planning theory.

Here, a number of potential rationales can be found in the literature. First, as Batty (2009) explains, designing a city based on the aim to seek equilibrium in an urban system would create a city that is inevitably unrealistic and static.

In complex systems, such as urban systems, breaking a system down into its components and adding them back together to either increase capacity or delineate control parameters will never produce the intended effects. The resulting whole will always be greater than the sum of its parts (Simon, 1962, from Batty 2009), making it close to impossible to single out one component of a system and modify and re-insert it and expect that the change produced within the system will respond linearly to the modification made. The findings of the Ph.D. project seem to support this argument (Lim & Kain, 2016). In the case of a designed compact urban form, replicating compact city typologies found in an emergent urban form by proportionally assigning rates of diversity and density still appears to result in a reduced rate of complexity, thus can be seen as less supportive of the emergent dynamics of Complex Adaptive Systems (CAS) which are seen to be in conjunction with urban resilience properties (Mehmood, 2016).

Second, an explanation for the mechanisms of emergence process can be found in Holland's four criteria relating to the emergence in complex systems (see Section 5.2.2.1), and especially Point 3: 'the overall form and persistence of an emergent regularity depend upon both bottom-up and top-down effects' (Holland, 2002, p. 28). In this context, the top-down influence would not necessarily imply normativity (See Chapter 5). Instead, it would be the emerged macro-state created by the individual actions of stakeholders, which, in turn, would exert influence regarding the individual adaptation of stakeholders downwards, similar to that of workings of the stock market used as an example by Holland (2002). In contrast, in the designed compact urban form, where top-down master plan is implemented, such as in Kvillebacke, or Eriksberg (see Chapter 5), the activities that arise or emerge might have less potential to quickly respond to changes and influence in an upwards direction to change the designed urban structure. Such a lack of reciprocal exertion of influence is considered as a factor for diminished the effectiveness of any CAS to deliver urban adaptability, thus limiting the capacity for urban resilience during sudden changes (Holland, 2002).

Here, the proposed hybrid theoretical approach to emergent urban planning (see Section 5.2.3.5) may complement existing approaches dealing with this complex interaction between the top-down and bottom-up influence by merging participatory methods based on consensus and ABM. While stakeholder consensus might represent bottom-up influence, in practice, an asserted consented ideal could in itself be seen as a top-down mechanism with a notion of normativity, limiting the individual stakeholder's alternative actions (Mouffe, 2000; 2013). Furthermore, while ABM might be closer to a simulation of CAS, the exclusion of the complexities of human social nature into the modeling limits its potential (O'Sullivan & Haklay, 2000). However, the proposed tool, while has the potential for citizen inclusion in the design of smaller-scale neighborhood areas, it is unclear, if this could be an alternative to and replace expert-driven top-down design involving more extensive areas of intervention (O'Sullivan & Hakley, 2000; Ioannis, 2014). Even though the suggested simulation of the policies on urban rules using the tool also might enhance citizen involvement through heightened engagement and interest in urban issues, similar to the issue of ABM (Clarke, 2014), the type of result that is generated through the use of the tool would make it hard to be implemented in the policy.

In this regard, the scale for an individual – as a non-expert citizen –to function as a micro-agent, to intervene would be interesting to speculate. How big should the immediate surrounding environment for an individual be considered that by interacting with and adapting within influence the emerging macro urban pattern? Research shows how we thrive psychologically and engage more in a complex environment, in environments where perceptual richness is an embedded environmental quality (Jacobs, 1961; Merlino, 2011; Marshall, 2012; Eom & Cho, 2015). If so, walking along the street filled with smaller units of buildings (Lim & Kain, 2016) would increase the diversity and complexity, thus potentially provide perceptual richness and engagement in contrast to walking the same distance through a mono-functional Miljonprogrammet area characterized by a quasi-copy-pasted repetitious modernist architectural landscape. The awareness of how and at what scale bottom-up emergence should be staged seems to be valuable for creating the complex environment that can foster urban resilience, and it also highlights the importance of urban design produced at street level on a smaller scale – i.e., the neighborhood. An example of diversification through policy implementation could be Helsinki housing development projects with an integrated policy of spatial and social mixing (Vaattovaara et al., 2018). Initially, this project used the scale of an urban block as a unit of tenure type to be mixed with other blocks of designated tenure types. Later the revision of the policy introduced blocks of identical building types but mixing diverse tenure types within each block for a finer level of integration. In both cases, the size of such projects seems to matter, either as large single tenure type urban blocks or single architectural types in large areas in contributing to the decline of portions of city areas. When the newly affluent population left to the suburbs of the city, leaving these public housing areas behind during the 90s, the fragmented housing development project areas were occupied with the new immigrating population, segregated and underprivileged (Dhalmann & Vilkama, 2009, Vaattovaara et al., 2018; City of Helsinki, 2019). In this case, rather than the efforts to control to diversify through policy implementation and design, the extensiveness of the scale of such development projects which cover whole neighborhood blocks seems to contribute to the issue (Lim & Kain, 2016).

Conversely, rule-based urban planning approaches with cumulative and proscriptive rules (see Section 3.5) within which individual agents have the room to play out self-organized bottom-up adaptation seem to approximate the condition of the CAS (Marshall, 2011; 2012; Bettencourt, 2014), especially regarding understanding of self-similarity across scales (Bettencourt et al., 2008) 'from blocks to neighborhood to cities' (Ramaswami et al., 2016, p. 940). Self-similarity in, or fractal mixed-use patterns is seen to be the result of mixed-use zoning, which allows fragmentation of development projects over time (Lai & Han, 2012).

Nevertheless, in such rule-based urban systems, the question remains concerning who can change the rules when urban conditions change. Surely, urban rules should change, for example, if the population density increases two-fold, but who assesses these changed conditions and changes the rules in a rule-based planning system? Historically, we can find several examples of who takes up the task of designing or setting rules and regulations. Uniquely top-down policymakers, such as King Henry IV of France, personally ordered the assignment of building codes regarding building lines and height limits to embellish the urban fabric of Paris and take control over the growing urban texture (Krofp, 2011).

Alternatively, it has been done in collaboration with the local landowners, such as seen in Kyoto's community-based urban codes until World War II (Baba, 2011) or by scholars and experts, as seen during the wartime reconstruction era in the mid-1940s in Japan (Akimoto, 2012). A more recent example is the form-based codes developed by scholars and planners linked to New Urbanism (Center for Applied Transect Studies, 2019). Here, the proposed hybrid approach to urban planning is based on a combination of individual bottom-up adaptation, with potential for adaptation through deliberation and top-down rule-setting, also through deliberation and adaptation. This approach attempts to complement contemporary, participative notions of urban democracy, where it is argued that one problem lies in difficulties in finding 'theoretical solutions able to release the deliberative model (and its applications) from a "micro" (localized and local) scale, linking it up more (though not univocally) to a "macro" (generalized and global) dimension' (Tebaldi & Calaresu, 2015 p. 12).

Yet another issue associated with ambitions for urban democracy is that the emphasis on collaborative rationality in public participation, often relying on consensus achieved through dialogues and discussions, tends to overlook the risk of popularism and suppression of pluralistic alternatives (Mouffe, 2000, 2013; Swyngedouw, 2010; McAuliffe & Rogers, 2019). The emphasis on consensus is based on the assumption that, in general, the public will likely be willing to represent and express their desires and wishes. However, when we look at the disparity of behavioral choices made on moral issues – such as selfish versus selfless – depending on the social context and whether or not one is being observed (Bateson, Callow, Holmes, Redmond Roche, & Nettle, 2013; Frimer, Schaefer, & Oakes, 2014), revealing in public what individuals actually want may be challenging. Big data research has shown a significant gap between surveyed, self-reported behavioral patterns, and what big data reveal about actual behavioral patterns (Stephens- Davidowitz, 2014). Even more baffling is that individual beliefs that result in supporting a particular political agenda are not only incongruent with, but downright contradictory to the individual actions taken, e.g., regarding environmental issues (Hall, Lewis, & Ellsworth, 2018). Fortunately, research suggests that regardless of how individuals behave, the decisions made collectively show strengths concerning creativity and intelligence in problem solving, given that the collective mind consists of a diversity of people (Hong & Page, 2004), a high number of people (Krause, James, Faria, Ruxton, & Krause, 2011), and with the collective decision-making taking place within a facilitating social context which supports dialogue between people (Woolley, Chabris, Pentland, Hashmi, & Malone, 2010). Based on such findings, the integration of collective intelligence and wisdom of the crowd suggested by the proposed hybrid approach to urban planning seems to provide a workable approach to circumvent the selfish versus selfless paradox. Ideally, in the hybrid rule-based system suggested in this thesis, individual actions reflecting an adaptation motivated by self-interest would be contained within the frame of urban rules that would reflect the global or common interest. Still, the question of ideal relation between the top-down and bottom-up approach, and if consensus should be the basis for the top-down implementation of policy rules, even for simulative purposes, remain a question.

Currently, ABM simulates urban emergence based on simple sets of rules that are played out by computational 'agents' in specific scenarios through interaction and adaptation. However, such simulation strategies could factor in human participants that change and bend these rules through social interaction, adding creative tracks of adaptive emergence in response to wicked problems (Rittel & Weber, 1973; Neuman, 2005; Mayer, 2009). By combining the strength of collective human factors from deliberative models of participation with ABM, this Ph.D. project highlights the potential for developing a rule-based co-designing functionality by providing a platform for continuous dialogues, collaborations and negotiations through the use of ICT as next step (Imottesjo & Kain, 2018). Such a co-decision-making platform, in addition to the co-designing functionality, would intend to play out the potential for the rules that were initially implemented top-down by the game managers to be adapted and evolved incrementally bottom-up, based on the changing virtual urban context that evolves through the game simulation and the participants' input. Still, without public policy supporting and guiding such a bottom-up evolution of urban rules as elements of adaptation maintained by micro-agents, the resulting qualities might be insufficient or counterproductive. In this sense, the role of public governance, which can provide and create a framework and structure within which such a bottom-up evolution can flourish (Colander & Kupers, 2014), becomes essential.

## 6.3 A tool developed with aim to stage urban emergence

The third objective of this Ph.D. project was to understand how an AR and MAR tool can be devised, which would potentially trigger processes of urban emergence based on non-expert input.

First, the Ph.D. project developed specifications for a tool that may support rule-based collaborative neighborhood design in a way so that this collaborative design would simulate emergent urban development (Imottesjo & Kain, 2018) and the potential of the use of AR as a visualization method was examined (Imottesjo & Kain, 2018; Imottesjo et al., submitted). By examining the use of AR, the project responded to some of the difficulties concerning communicating and relaying architectural and urban design solutions to non-expert laymen (Bates-Brkljac, 2009; Pizarro, 2009; Pallasmaa, 2012). Moreover, the combination of mobile and AR technologies, i.e., MAR technologies, were examined as a complement to traditional modes of communication, bringing in the auditory, olfactory, haptic, and kinetic urban contextual information (Wergles & Muhar, 2009) that is typically missing in visual representations of the built environment (Gordon & Manosevitch, 2011).

Second, with the development of ICT and Internet accessibility among the general public, crowdsourcing (Morschheuser, Hamari, Koivisto, & Maedche, 2017) has been embraced as a method for collecting and applying collective intelligence (Otterbacher et al., 2011; Livingstone, 2016). The investigation into the tool specifications pointed towards gamified crowdsourcing as a potential mechanism for such crowd-creating of emergent content through what Morschheuser et al. label as 'heterogeneous contributions' (2017, p. 27). This position also agrees with arguments that mixing games and simulation supports stakeholder participation in dealing with complex problems (Sawyer & Rejeski, 2002; Mayer, 2009; Portugali, 2012; Tan & Portugali, 2012). According to Mayer (2009), gaming can bring together ‘technical-physical-economic complexity’ (p. 846) and ‘real players with stakes, tacit knowledge, emotions, intuitions’ (p. 846), unlike just relying on digital ‘agents’ in computer simulations. This would help us to explore the power of the crowd (Palacin-Silva et al., 2017) through deepened engagement across diverse demographics (Ben-Attar & Campbell, 2015; Faliu, Siarheyeva, Lou, & Merienne, 2018), efficiently representing the ‘dynamic behaviors of complex systems’ (Mayer, 2009, p. 848). Using the strengths of simulation through ABM that combines complexity science, game theories, evolutionary programming, and stochastic modeling (Clarke, 2014), and responding to the criticism concerning the simplistic view of ABM regarding social systems (O’Sullivan & Hakley, 2000), the suggested tool intends to promote human-stakeholder based simulation, but including deliberation between the stakeholders on-site.

Third, apart from methodological concerns, to profit from this collective wisdom, attention needs to be paid to the aspects of ‘agency.’ Surowiecki (2014) argues that ‘agency’ should be given to citizens who are (or should be) involved in the process of decision-making. Numerous participatory citizen workshops lack actual policy implementation of the results, due to a ‘lack of authority’ (Irvin & Stansbury, 2004, p. 59), ultimately leading to citizen dissatisfaction (Smith & McDonough, 2001; Irvin & Stansbury, 2004). To make citizen participation relevant for policy implementation, local authorities need to ‘identify and legitimize a real-world use’ for participatory platforms (Wilson et al., 2019, p. 291) and more responsive decision-making is necessary (Smith & McDonough, 2001). Working with the ICT tool the Quick Urban Analysis Kit, Mueller, Lu, Chirkin, Klein, & Schmitt (2018) suggest juxtaposing bottom-up and top-down collaborative design efforts, where experts or urban planners delineate the design tasks that could be performed by citizens online, and with a voting system that would allow a multitude of citizens to vote for their design of choice. In this way, it is suggested, experts would receive more relevant citizen input with higher potential to be implemented in practice (Mueller et al., 2018). The assignments of urban rules in the Urban CoBuilder, coupled with tasks designated to the stakeholder roles (Imottesjo & Kain, 2018), would allow such a tool to implement relevant top-down needs for planning projects, e.g., by delineating height restrictions, types of urban functions, and buildable areas with certain urban functions.

Still, the Urban CoBuilder, as a semi-pilot system, still lacks the complexity with which urban planning policies can be extensively tested and simulated. To receive relevant feedback that could be reflected in policy-shaping, the tool needs to extend its accessibility, increase the independency from the software developers, and offer better motivation for the users to continue the dialogues through the tool.

Fourth, through transdisciplinary collaboration, in this case, between the author and software engineers, diverse sets of knowledge were poured into producing a tool that was relevant to current urban challenges and technically innovative, but still usable. As reinventing the wheel is not always the best solution, modifying an existing tool to respond to specific urban challenges would have had certain benefits. However, existing tools did not bring together MAR with crowdsourced co-design based on a gaming mechanisms, outdoor tracking that is sufficiently precise for co-designing in an urban neighborhood context, and a UX-I, which enables the concept of co-designing (Imottesjo et al., submitted).

As the tool development had limited funding, the need for designing a tool from scratch had to be based on a rather rapid sequence of iterative prototyping (Dow, Heddlestone, & Klemmer, 2009; Christie et al., 2012; Camburn et al., 2017). Due to the limitations in time and budget, priorities had to be made regarding how the defined game specifications should be implemented so that a basic but quite complete prototype could be developed to verify all the concepts listed in the specifications. For instance, the concept of 'gamification' was tested through implementing a type of turn-based, role-playing UX-I whereby each participant was affiliated with a stakeholder role, having specific urban development goals and individually assigned budgets (Imottesjo & Kain, 2018). A similar approach was applied to developing the interface for building block placements and the AR location tracking. The weakness of this type of low-budget project is the difficulty of estimating the cost of software development (Sukhoo, Barnard, Eloff, & Van der Poll, 2004; Chirra & Reza, 2019). The cost of each prototype was hard to foresee due to the uncertainty of which part of the implementation would need further research and investigation, in the end, leaving the project somewhat unfinished and under-developed. Another challenge associated with a software development projects is the difficulty of adding a new developer to an existing project (Sukhoo et al., 2004). Especially combined with the low-budget issues, when a set of developers were not able to continue with the project, the difficulties lay in delegating a new development team, and as a result, restarting the project from the ground, unable to use the programming developed by the previous engineer.

Fifth, initially, the author intended to develop a tool that could crowdsource citizens' incremental urban designs to simulate an emergent urban form, e.g., to test specific planning rules, such as zoning regulations. To fully enable this type of simulation would require the tool to be used over a longer time and by far greater number of citizens with various backgrounds than was done during this phase of the research. At this stage of development, the current version of the Urban CoBuilder is not capable of simulations of such magnitude. However, the implemented mechanisms concerning data storage and retrieval, where every action by users is uploaded to a central server enabling later data retrieval of each design moment, confirmed the potential of co-creation by multiple participants and the collection of crowdsourced data (Imottesjo & Kain, 2018). This shows the possibility of simulating bottom-up urban emergence with citizens as 'agents,' reflecting individual adaptations and decision-making according to a changing environment and the actions of other 'agents.' Still, to better integrate ABM characteristics (Crooks et al., 2008; Clarke, 2014) and collaborative/communicative planning (Healey, 1992, 2007; Innes & Booher, 1999, 2010), an integration of a chat or forum function into the tool for the participants to cooperate and negotiate seems necessary. Even though, developing a consensus between the participants might not need to be the primary objective of such platform (Mouffe, 2000, 2013; McAuliffe & Rogers, 2018), neglecting the deliberative qualities inherent in social systems when it comes to decision making would be limiting (O'Sullivan & Hakley, 2000; Davoudpour & Karimzadeh, 2018).

Finally, the test of the table-top version of the Urban CoBuilder (see Section 5.3.3.4) showed it to be an efficient participant attractor for interviews and discussions in a neighborhood, especially involving the youth (<15 years). This confirms research on the use of digital tools and the role of age dependence in learning how to use such tools (Underwood, 2007; Friemel, 2016). Engaging youth in public discourse and policy-making processes has been an essential agenda in global policies (UNDESA, 2013; OECD, 2018), to recognize youth as a significant human resource for development and as 'critical agents for social change' (UNDESA, 2013, p. 1). Still, the reluctance of some older participants to even try out the tool, with the pre-conceived idea that it was challenging to learn, was a hard barrier to break, which substantiated the existence of an age-based digital divide (Friemel, 2016). Also, as may be the case with both collaborative/communicative approaches to planning (Allmendinger & Haughton, 2012) and agent-based simulations (Mayer, 2009), game-based multi-stakeholder simulations, such as the Urban CoBuilder, may also be susceptible to reduction, bias and misuse, and to being co-opted by those in a position to define the rules of engagement or by those who are the most literate in the use of ICTs (Imottesjo & Kain, 2018).

While the Urban CoBuilder has shown some future potential, both as a table-top application for citizen communication and a 1:1 scale outdoor co-creation tool, radical improvements are needed to fulfill the function of creating emergent urban form through crowdsourced simulation. Regarding the need for better tracking methods, a recent approach to localizing and tracking (SLAM[14], Huo et al., 2018) uses simultaneous localization and mapping, enabling multiple devices to register together for instant collective spatial localizing. This research shows promising results regarding possibilities for spontaneous collaborative AR actions with multiple users (Huo et al., 2018), with the claim that this would facilitate multi-user collaboration in outdoor urban planning. With further development (see Ventura, Arth, Reitmayr, & Schmalstieg, 2014), this type of approach could be efficient for collaborative AR actions in an urban context. However, the requirements for using additional devices other than smartphones would limit the use of this as a crowdsourcing tool, since crowdsourcing requires extensive accessibility of the tool for spontaneous actions.

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[14] *SLAM problem 'asks if it is possible for a mobile robot to be placed at an unknown location in an unknown environment and for the robot to incrementally build a consistent map of this environment while simultaneously determining its location within this map' (Durrant-Whyte & Bailey, 2006, p. 1).*

# Chapter 7.

# Conclusion

## 7.1 Being able to crowdsource through gamified simulation: Limitations of outdoor MAR

The Urban CoBuilder was designed to crowd-create through gamification involving individualized tasks, as well as to have the potential to form 'cooperatives' between participants for collaborative urban planning (Imottesjo & Kain, 2018). However, to generate enough data to provide insight into such complex matters, such as simulation of a rule-based urban design by multiple participants, would perhaps demand a different strategy than the use of on-site, 1:1 scale outdoor MAR. The initial ambition was to have printed fiducial frame markers incorporated into various on-site urban project information placards placed by the city so that the citizen passer-by would spontaneously engage and play the game. This was intended to provide design data from a multitude of participants with varying knowledge levels and interests in urban planning. However, the prototype tests, user tests, and a workshop using the tool revealed several limitations and difficulties. The main challenges for spontaneous engagement, apart from the technical issues concerning tracking methods and gamification aspects, are related to the time required for citizens to learn to use the tool. 5 out of 6 persons of the age group between 50 to 60, approached for interview refused due to an aversion to using digital tools (Imottesjo et al., Submitted).

These two limiting factors make the tool more suitable for use in a workshop setting, where participants have time to learn to use the tool through a hands-on demonstration. Moreover, this would possibly engage older participants in a more accommodating environment than a spontaneous setting in which they are forced to make a quick decision on whether or not to test the tool. As older generations' use of smartphones and the Internet increases (iis, 2018), and digital tools using AR technology become less of a novelty, these limitations might hopefully be reduced in the near future for most age groups. This would enable the spontaneous engagement of varying groups of citizens and not only the younger generations. However, at this stage, workshop settings are recommended

for engaged co-creation, as the perceived difficulty of using the tool disengages some of the public in an on-site setting. Still, in workshop settings, the challenges may remain regarding uniform participant demographics, as well as top-down agenda-setting, as discussed in Section
3.3.1 and Section 3.3.2.

## 7.2 Implementation of the citizen urban design in practice

The Urban CoBuilder tool could potentially be modified so that practitioners could set design criteria and design rules relating to specific urban design issues that need citizen input. In conjunction with a voter mechanism, this would facilitate that the best design proposal could be chosen through citizen rating. Even though this would take the tool farther from a crowd-created simulation of rule-based urban design evolution, it could enable its ongoing use for a diversity of issues specific to urban challenges defined by planners and designers. In- situ technologies, such as geolocation mechanisms (Wilson et al., 2019) allowing citizens to be notified when approaching an area where a design task can be performed, could also increase the potential for the tool to be used over the long term as a citizen dialogue tool in various types of urban areas where tracking markers could be placed. This type of use would entail specific enquiries regarding planning objectives, so participating would be much simplified than currently existing version of Urban CoBuilder. An example of such inquiry that would be enhanced by pervasive on-site participation would be an on-site AR projection of alternatives of flood barriers that are feasible for the Göta river (Sweco, 2014) in Gothenburg, so that participants would only need to make a simple preference choice, between a or b. However, this would not fulfill the specifications of the tool as a citizen collaborative urban design and simulation tool. The strategies for collecting crowdsourced big data might benefit from looking into other urban AR-based pervasive urban gaming projects (Sánchez-Francisco, Díaz, Fabiano,

& Aedo, 2019) such as Pokémon GO[15], and Ingress[16] (Söbke, Baalsrud, & Stefan, 2017).

## 7.3 Limitations of the project

The project had a limited number of participants for the user tests of the tool. Especially relating to the test of crowd-creating through gamification, the limited number made it hard to assess the potential of such a concept at this point. Even though user tests involving internal researchers from the Department of Architecture provided valuable feedback regarding issues of citizen inclusion using such digital tools and what types of tool specifications could be developed further, the number of contributors limited the potential for testing the urban simulation based on rules. However, testing and evaluation of the basic concept of the tool for use as a collaborative on-site urban designing using a 1:1 scale outdoor MAR, of its rule- and turn-based gamification potential, of suitable tracking methods and the UX-I could be carried out during this project. The prototype test, including randomly interviewed citizens during a student workshop session, also provided valuable insight into the limitation of such a tool, clearly indicating the age-dependent digital divide.

## 7.4 Potential future research

The issues and limitations of an outdoor MAR tool for citizen co-design include the above-mentioned age-dependent digital divide, the implementability of citizen co-created urban designs in practice, and the limitation of exclusive use

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[15] *In May 2018, there were 147 million monthly active users world-wide (https://www.businessofapps.com/data/pokemon-go-statistics/#1)*

[16] *Updated information in 2018 reports 20 million downloads, 200 countries with players, 2,000 real-world events related to the game, and 1.2 billion geolocated portals (https://videogamesstats.com/ingress-stats-facts/)*

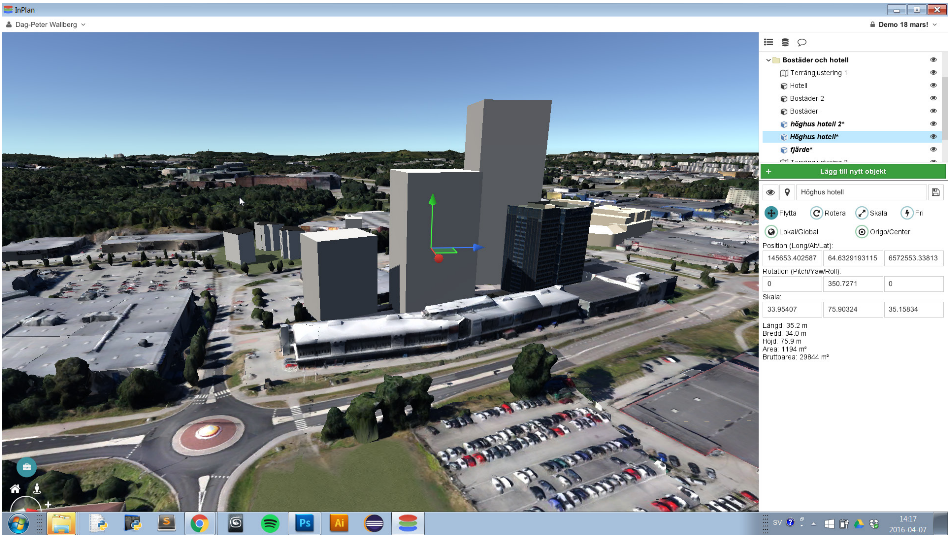
of outdoor MAR as a method for citizen co-creation.

More practically, the Urban CoBuilder needs significant improvements if it is to be used as an outdoor 1:1 scale citizen co-designing tool using gamified crowd simulation. Better outdoor tracking methods, a UX-I to enable user inputs for design modules, and the appropriate use of urban rules need to be further investigated for the tool to be functional as a co-designing tool. Furthermore, there is a need of an improvement of the game mechanics, the implementation of chat and voting functions for collaboration, and simultaneous visualization of other participants' modification of designs for the tool to function for crowdsourced simulation. However, primary challenge of how this type of simulations could be implemented in practice, how best to garner relevant data through such simulations, and what type of policies best benefit from such simulative analysis need further research. This could entail future research investigating the potential of integrating other mediums. By integrating VR, web-based design modification, and physical 3D scaled models with the MAR tool, the group of citizens who are wary of using an outdoor MAR tool as the primary participation method would have a higher chance of being included.

The integration of various other mediums would also entail the inclusion of a diverse range of design methods into the tool, such as top-down bird's- eye view designing with 3D environmental data of the site, as a complement to the Urban CoBuilder's bottom-up module-by-module designing (see Figure 47, 48, 49). In a way, combining these could create a synergy between the planners and the stakeholders. Planners could generally outline the area of concern and illustrate crude volumes of built objects in areas where the buildings could be built, and the stakeholders could then fill up the buildable space using the modular approach with diverse design elements from the street level, in this way combining top-down and bottom-up design methods. This method could extract more relevant citizen design data for the planners to implement in practice.

Another area of interest, in addition to the integration of media and design mechanisms would be whether simultaneous remote collaboration could or should be facilitated. The central server data storage and retrieval used in the

Figure 47. Urban CoBuilder tabletop version shows a modular block by block designing mechanism



Höghus hotell

Position (Long/Alt/Lat): 145653.402587 64.6329193115 6572553.33813

Rotation (Pitch/Yaw/Roll): 0 350.7271 0

Skala: 33.95407 75.90324 35.15834

Längd: 35.2 m
Bredd: 34.0 m
Höjd: 75.9 m
Area: 1194 m²
Bruttoarea: 29844 m²

Figure 48. InPlan shows bird's eye-view volumetric designing mechanism.

Urban CoBuilder showed a potential for simultaneous collaborative design, even though more improvements need to be made. Integration of media could lead to multiple stakeholders in various locations simultaneously designing an urban area of concern through a VR application or a web page. The burden of bringing in stakeholders to the same location for discussions, workshops, and seminars relating to urban planning and design could be lowered with a form of simultaneous remote collaboration, saving both time and money. Similar to Google Drive, this kind of simultaneous editing, modifying and saving, as well as the capacity to view historical changes in urban design collaborations, might improve communication between the stakeholders in the long run.

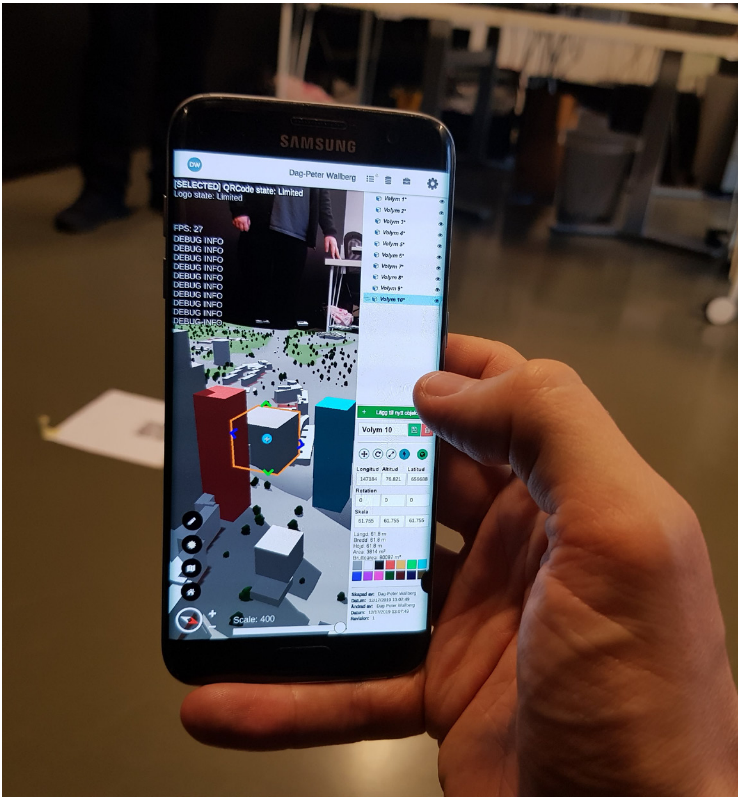


*Figure 49. Test deployment of Inplan in Urban CoBuilder as MAR tool*

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