Digital Methods of Organic Growth Simulation

Tjark Gall | tjark.gall@urban-framework.com

Urban Framework / M.Sc. Student Architecture, TU Brunswick / M.Sc. Student Urban Management and Development, IHS, Erasmus University

1 Abstract

Today's cities and metropolitan areas face new and rising challenges while the process of planning becomes more complex. The amount of data, the geographical size, the challenges of sustainability, rising social and spatial inequality and even faster urbanizing and transforming urban realms, ask for new ways of thinking the planning processes. Master plans are not suiting today's needs anymore due to the necessary time to prepare and implement them. Instead, adaptive and extended urban growth frameworks must be developed, which foster sustainable, inclusive development.

But on what base and how can this be created, without neglecting the local contexts and the memory and identity of the planning environment?

We at Urban Framework work on innovative conceptual theories to cope with the previously mentioned situation. The work in the last years included indicator-based sustainability assessment, an urban growth framework, simulation tools in larger scales and recently started to combine these and try them in a smaller environment in one of the self-planned settlement in Lilongwe's peri-urban area. The input from the governmental and traditional authorities is combined with the experiences of several community workshops and creates another base for the development of the growth-simulation tool.

This research will give a thorough overview of existing concepts, combine them with our own work and tries to define solutions under the consideration of the theoretical question, how far a computer can plan, where the limits are, and how the incorporation of innovative methods could look like, always in the exemplary application in Malawi's local context.

***KEYWORDS:* Computational, Urban modelling, Organic, Growth**

2 Introduction

Cities are growing larger and faster than ever before, mostly in sub-Saharan Africa. From about 1 billion people in Africa today, more than 4 billion are expected by the end of the century. At the same time, the percentage of people living in cities increases further. People are migrating from the rural to the urban areas, from one country to another, or increasing through the natural process in the city. Most of this growth occurs in unplanned or self-planned settlements in the outer peri-urban areas or previously unused areas in the inner city. This scale and pressing issue of accommodating everyone stresses most urban planners in our cities. Additionally, rising complexity, resilience, climate change, and big data, to just name a few, make it even more challenging to plan and make informed decisions and plan accordingly. A master plan seems to be not sufficient anymore; instead, an adaptive and responsive method is needed. In this paper, a digital approach is presented, which tries to cope with the rising challenges. However, it is not about replacing the traditional planning practices; it is more about how both methods can be combined, how planning can change and mostly in the regional context adapt in a flexible, resilient, and sustainable way.

Furthermore, in the case of sub-Saharan Africa, there is an additional need to decrease the influence of outdated western concepts, the American dream or the garden city as the ideal, or the neo-/post-colonial impact in general. A new method is urgently needed. A method, which works in the given circumstances, works with the information and resources which are available and breaks free from transferred concepts and theories, which were developed far away in a different spatial, temporal, and societal context!

How can a newly proposed, computational-oriented planning approach manage this, while reducing the necessary human and financial resources? How does it help to include more stakeholders and the public in the planning process? How can scenario-based simulations assist in creating better cities and plans? What are the dangers of this methodology and how could it be misused?

These issues, combined with more specific challenges, hindering the needed progress, of, for example, not understanding the full functionality of advanced digital computer usage, even more in the case of, e.g., artificial intelligence, shall be discussed on the next pages. The paper attempts to give an overview of what is there, what works already, and what needs to be studied more and finally what questions remain unanswered? What is the general direction in which the planning practice develops?

2.1 Research questions

Building on the underlying theory and the dichotomy between analog and digital planning, neo-colonial theories and concepts developed in the global south, as well as between top-down master plans and bottom-up approaches, two main research questions evolve:

1) Why and how can digital planning function better than analog master plans, and why is the latter outdated?

2) How far can a computer plan? Where are its advantages and disadvantages and where its limitations? Which precautions are necessary to make it work to produce 'better' cities?

3 Theoretical background

Before starting with the conceptual framework and our approaches to apply them, a short introduction in some of the theory is necessary. This overview will be mainly divided into two parts: Once the comparison of the planned versus the unplanned, and which approach has which advantages and disadvantages. Therefore, Bettencourt's, Barthelemy's and Alexander's perspectives and theories will be discussed. Afterwards, some criticism of master plans and top-down planning follows, supported by an early approach of Beeker in the 1960s in Burkina Faso's capital Ouagadougou to plan the African city on a smaller scale with the input of the residents, and to create a structure in which the city can develop efficiently. The second section goes one step further and provides some background information about the integration of digital methods in urban planning, including Hillier's concept of 'Space is the machine' and Sevtsuk's approach in 'De-Coding the City', as well as a critical statement of simulations in the urban development sphere.

Christopher Alexander takes on a pioneering role with the publication of his paper 'A city is not a tree' (Alexander 1966) which acknowledgment and common understanding followed much later. He distinguished between the natural and the artificial city, where the former is the natural and more or less spontaneously grown city while the latter is created by planners over shorter timespans and is constituted mostly of concrete and glass. He states for example that:

> "*It is more and more widely recognised today that there is some essential ingredient missing from artificial cities. When compared with ancient cities that have acquired the patina of life, our modern attempts to create cities artificially are, from a human point of point of view, entirely unsuccessful*" *(Alexander 1966).*

Today, this statement is more actual than it was ever before. People want to live in the old and more organic areas of cities, travel to ancient cities and disguise new realities of living between skyscrapers, multilane streets, and fully artificial environments. The same can be found in African cities, even if at least in sub-Saharan Africa, the difference is not so much between the old and the new but the self-planned settlements and the planned garden city-inspired suburbia (in the center of the cities). Of course, aspects like security or access to basic services play another important role, but a human-focused life, rich in interactions, does not happen in between fences, walls, and highly secured gated communities.

Bettencourt continuous this argumentation in 'The kind of problem a city is', referring to Jane Jacobs's famous statements and calls its handling a "challenge [… of] the creation of new and better re-conceptualizations of cities as complex adaptive systems" (Bettencourt 2013). His paper discusses various aspects and proofs of complexity in the city, however for the purpose of this paper, one of his main statements should be sufficient:

> "*In terms of urban design, this conceptualization of cities emphasizes the importance of generative models, where local structures remain to be developed by agents possessing particular goals and information, but must also be constrained by the function of the city as a whole, as an open-ended 'social reactor'…" (Bettencourt 2013)*

The paper 'Self-organization versus top-down planning in the evolution of a city' (Barthelemy et al. 2013) studies the evolution of road networks in Paris over 200 years beginning with the Haussmann-plan and gives the concept of natural versus artificial an even more scientific character. The paper shows interestingly, how a mainly organically grown city transforms over time if top-down interventions change their structure from the inside. The 'organicity' remains partly and adapts to the new circumstances while the larger scale structures increase the efficiency and seem to be necessary for certain levels (Barthelemy et al. 2013). Therefore, the question remains, how artificial and the natural city come together. It seems clear that only one brings along too many challenges, and their efficient combination could be the solution. But how?

In 'Model Town: Using Urban Simulation in New Town Planning' from the International New Town Institute, this challenge is extended by the call for digital intervention to plan better cities. While mainly presenting different analog and digital projects of organically simulating new town layouts, the books starts with a criticism of master planning due to its failure to cope with today's challenges in the same way as top-down master plans, like the garden city movement or transit-orientated new towns do to steer urban growth towards a more decentralized character. Instead, they call for planners and designer to "move beyond the current (often simplified) analyses and design exercises" and become "more communicative and facilitators of inclusive processes in which all relevant stakeholders are involved." Furthermore, they ask to "gain more insight into potential social complexity in the planning and design process [… by using] academic insights on these matters in the form of simulation models" (Stolk and Broemmelstroet 2009). This closes the loop of moving from natural to artificial cities, towards combining them, and finally utilizing modern possibilities to simulate their development.

Another process, which was innovative at its time and somehow still is today, is the Beeker Method, applied in Ouagadougou in Burkina Faso in the 1960s, as an analog way of opening the participatory dimension (Folkers and Perzyna 2017). In that case, Beeker consulted the communities and developed with them several options to restructure existing settlements and create a grid which allows the integration of infrastructure over time as well as better ways of future densification and growth. Surprisingly, the community voted for the most rigid fabric which was then realized in several neighborhoods. In the beginning, it created a strange picture of huts and tents surrounded by fences in a perfect square grid. However, over time the facades moved towards the borders and densification as well as advanced plot divisions took over and formed a nowadays functional and adequately serviced neighborhood (Folkers and Perzyna 2017). This project shows the long-term benefits of a primary growth framework which, in the inside, evolves naturally but does not limit the city's future development but instead allows a gradual transition from rural and traditional towards more modern urban characteristics.

In the less space and planning related field, complexity seems to connect most approaches. This complexity can be manifold: It can be the urban fabric itself, the social interactions, economic developments up to larger scale regional interactions. Today, this complexity also extends into the information-based dimension. With Big Data and the Internet of Things as commonly announced concepts, the amount of data in the urban scale multiplies constantly and presents the planners with new challenges and opportunities. Hillier analyzed and experimented with this development in his book 'Space is the machine' (2007) and describes cities, amongst others, as movement economies, while introducing different models of digital analysis and interpretation of space. Many interesting approaches and methods can be found in his book. However, one of his most interesting conclusions is that:

> "*…our interventions in the city can only be based on our understanding of the city. Where this understanding is deficient, the effects can be destructive, and this will be more the case to the degree that this false understanding is held in place by a value system.*" *(Hillier 2007)*

He emphasizes the importance to understand the city before we can plan it properly and deal efficiently with its challenges. Sevtsuk further expands this understanding in his writings in 'De-Coding the City: Networks of the Built Environment' with a continuation of the space syntax idea and includes the third dimension and more advanced models in the network analysis (Sevtsuk 2013). Most of these approaches focus on the (transport and movement) networks, but also give a thorough insight into interrelations and show the broad span of possibilities of a field, which is still in a very early stage.

But what dangers or difficulties does this range of digital tools and the simulation market bring with it? Vince (200?) questions the whole idea of simulation in his commentary 'The Death and Life of Simulated Cities'. Two of his main arguments are once the problem that simulations fail to represent the dynamic and complex realities which can be found in the city and secondly often have too strong implications of modernist visions imposing how the city should be (Vince 200?). While his doubts are understandable and at the moment partly right, it should not stop us from working with these new tools. The integration of advanced complex and organic models including increasingly more layers of urban metadata on the one hand and new and more democratic participatory models on the other hand. The combination of both could tackle these challenges step by step and eliminate these doubts– requiring the willingness of urban planners and designers to try and examine the new methods and therefore opportunities. The access to these technologies and more data gets easier, requiring less technical knowledge, and will continue to do so, which will hopefully foster the inclusion of the concepts and methods which are discussed next.

3.1 Simulation of organic/natural urban morphology and growth

This chapter begins with a short overview of the mathematical and theoretical concepts of simulating, re-creating, and analyzing the organic and natural processes in our cities. It starts with older concepts like fractals, continues with diffusion-limited aggregation and Cellular Automata, which gained track in the past ten years and finish with the most promising, but simultaneously most challenging to apply concepts of complexity and chaos. Complexity is already used in many fields of urban development in all scales, at least in the theoretical field, while the chaos theory is indeed closely related to complexity, it brings new and promising opportunities; mostly in the organic simulation.

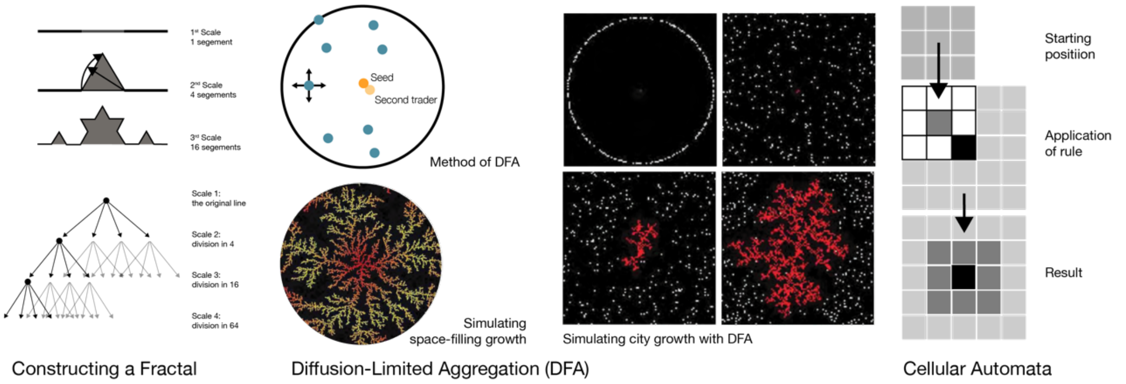

Fig. 1. Comparison of conceptual approaches (adapted from Batty 2008)

3.1.1 Fractals and diffusion-limited aggregation

Batty and Longley introduced the idea of fractal organizations in the urban scale first in their book 'Fractal cities' (1994). Fractals itself are an older concept, which describes the modularity, self-similarity, and hierarchy of many things. A well-known example is the question of the length of the British coast, which can be seen as infinite depending on the level of detail in which the coast is examined. If it is measured with a 1 m measuring rod, the length is much smaller than with one with a length of 10 cm. If this is done in measurements of far less than 1 mm, the length of the coast increases to a multiple of the original value. But how can this idea be applied to the city? One simple example of the modularity and hierarchy is the road system in most cities. Instead of one road in each direction from the center, several larger roads connect the main parts and split up into several medium-size roads, which again split up in small roads, etc. This hierarchical structure often occurs in a very similar way in different positions, why the term self-similarity is very important and makes the concept interesting to simulate organic growth (Batty and Longley 1994). One way to simulate this natural expansion is the Diffusion-Limited Aggregation (DFA; fig. 1), which is done by a computer program. A seed is in a random position and multiple 'traders' freely flow around the sphere until they touch another already 'settled' trader or the initial seed (Batty 2008). This can be done with various rules and parameters, but the standard principle can recreate organic growth of many sectors, including the historic city expansion as seen in fig. 1.

3.1.2 Cellular automata

Another interesting approach is the usage of free agents in a cellular space, which was famously presented by Portugali in his book 'Self-Organization and the City' (2000). It is based on the concept of an inter-representation network city, with internal (semantic) and external (environmental) networks (Portugali 2000). Fig. 1 (right) shows the basic principle. The starting position is a grid of cells, where each cell is either positive or negative. Next, a rule is introduced, e.g., that every cell needs to have one adjacent positive cell, with one starting positive cell. The surrounding cells become positive by each 'round', resulting in advanced structures. In comparison with the DFA, Cellular Automata has the advantage, that there is only one possibility of development due to defined initial conditions and set of rules while the traders in the DFA can move freely and random, why various results under the same conditions are possible. Further, both explanations might look not interesting due to their centrality. However, they can be used with several initial seeds or more advanced set of rules or more than two states of agents, which can result in very complex structures, often closely alike real urban shapes which grew over centuries.

3.1.3 Complex systems

While the above-mentioned concepts can already result in complex structures, complexity is a concept itself. Coming from other fields of science, it was already often transferred to the urban context. In general, a complex system is a process where many 'agents' perform as a group without outer control or a common plan. Small actions are multiplied and recreated by others which can result in positive feedback and a change of the overall structure. This can go up to a so-called 'Butterfly effect' where an action too small to be distinguished results in an enormous change (Batty 2008). A common example is a flock of birds, where no bird decides where to fly and no direct communication exists, but still advanced and complex movements as a whole result. Portugali analyzed this complex behavior as well in his book (2000). He uses the idea of a game, meaning that a model is tested in a neutral environment and seeks to discover or explain rather than to simulate or repeat reality's development. He also discusses the philosophical perspective, whether and how the unplannable can be planned? According to him, it is not directly possible, but it is better to plan 'just-in-time' instead of 'just-in-case'. Planning should still result in actual plans, but short-time, micro plans instead of postmodern presumably all-inclusive top-down planning approaches in the environment of growing networks (Portugali 2000). Concluding, complexity is a highly interesting and important concept for the digital, organic modeling and simulation approach, but complex in itself and brings some difficulties along. For example, small changes can have tremendous effects on the system. Therefore, it is very important to be aware of the impact and development and not see results as one right option but as one scenario of many.

3.1.4 Chaos theory

The last concept is the Chaos Theory. It exists for about half a century and can be applied to nearly every field of research to understand and explain highly complex systems in which everything is affected by events or actions in a 'chaotic' way, but one very similar event does not necessarily result in a very similar outcome. It combines perceived randomness of highly complex systems with distinct patterns and self-similar structures, which makes it attractive to study and dismantle its part to understand better, e.g., the behavior of humans in large societies, natural phenomenon, or every other kind of dynamic process, where not each decision is made 'rationally'. It has many similarities to complex systems but shows an even stronger dependence on the initial conditions. A commonly found summary is from Edward Lorenz:

"*Chaos: When the present determines the future, but the approximate present does not approximately determine the future.*"

Cartwright claims that this chaos theory has "major implications for planning. […] That noisy and untidy cities may not be as dysfunctional as we often assume, and that the need for planning that is incremental and adaptive in nature may be more urgent than we tend to think" (Cartwright 2007). Even if the theory itself brings along many unclarified issues, (too) complex interdependencies and advanced and not fully examined processes and for the planning spectrum uncommonly complex mathematical models, it bears a high potential and, I would argue, a required part if we want to simulate or plan cities which combine the much-loved assumingly 'random' and chaotic features of the past and combines them with our understanding of 'sustainable' cities today.

4 Conceptual framework

The main idea of the suggested Urban Framework it a new workflow of urban planning where the computational possibilities of today are actively integrated and help, mostly in the context of lacking resources, to reach a better and more efficient handling of the more complex tasks of planning for a sustainable urban future. Its application does bring along various challenges which need more time to be solved, but can ultimately, with the before mentioned concepts integrated, result in better-informed decisions and more adaptive and responsive layouts for our cities. Adapted from a contribution to a competition of the World Sustainability Built Environment Conference in Hong Kong (Gall et al. 2017), I want to propose a process, which mainly consists of five steps (fig. 2). The underlying step is the database, which includes all kind of relevant data. Next, various indicator-based sustainability assessments follow, which itself can already assist in more efficient planning practices. These should be extended by a spatial analysis, which adds information of the built environment to the database and assists to learn from the existing cities and the influence of their morphology on the sustainability and performance of the urban realm. The next step is the simulation of various options, scenarios, including various future predictions or testing assumptions of the positive or negative effect of certain events (e.g., natural events like droughts, sea-level rise, or a change in human behavior like choice of preferred housing type, mode of transport, density, and many more). The outcomes can be in the most straightforward form a more efficient decision-making tool, more advanced scenarios, and simulations, which help planners to evaluate various possible options, while a spatial, automatized, and organic growth framework is the most difficult but at the same time most exciting outcome. In the following, the different steps will be presented and discussed.

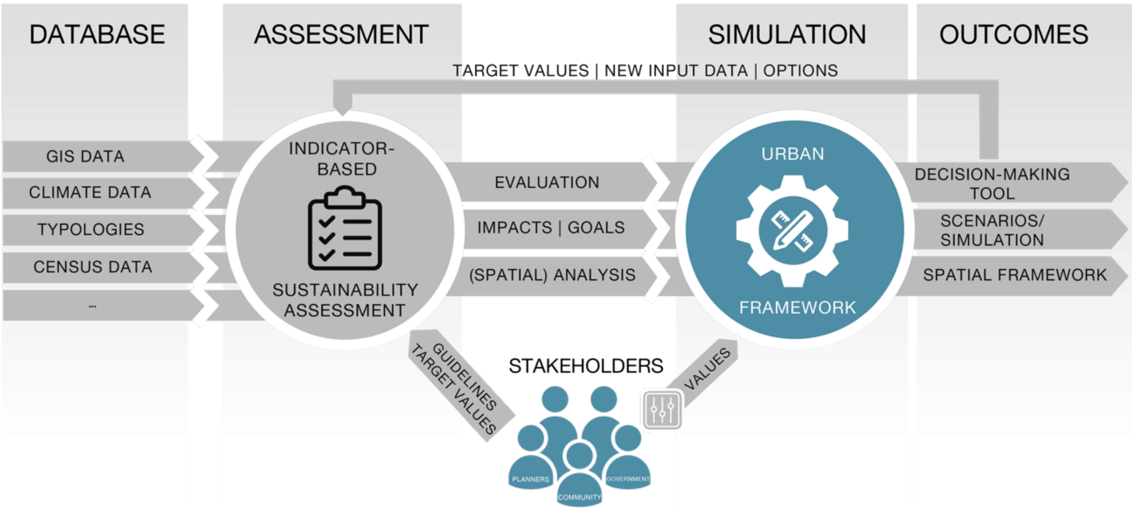

Fig. 2. Conceptual Framework (adapted from Gall et al. 2017)

4.1.1 Database and management

In the context of Big Data, the call for more open access, and globalizing databases, the planner faces an increasingly complex amount of data which can hardly be controlled or considered anymore in actual planning's decisions. However, its consideration is more important than ever before with climate change and rising global urbanization levels stressing the future of urban development. There is a lot of available global data from international organization through open-access databases, services like OpenStreetMap, or the Global Human Settlement Layer, while also national databases increase their level of sharing spatial data. In some countries like the Netherlands for example, information for each building are available and open up many new ways of evaluating relations and dependencies on a larger scale. The challenges are however the various regulations for each country, with many sub-Saharan countries unfortunately on the less analyzed and technically equipped spectrum. Additionally, endless different data-formats and the sheer amount of data makes it incredibly difficult to bring together all relevant information in a sufficiently spatial-referenced way. In the field of data management is currently a lot of innovation and improvement underway, however, due to the early stage in the urban realm, it will take some time to have an efficiently usable, global access to sufficient data.

However, at the same time, new methods gain track, like new ways of mining, processing existing data, available live data (e.g., movement data), participative collection and many more. Just to name one interesting approach, Maptionnaire is an online tool, which actively integrates the citizen to participate in the planning process and shows the potentials, which these innovative and participatory data-collection tools can bring (Maptionnaire 2017). Mostly in the context of countries in sub-Saharan Africa, these approaches provide promising tools to empower the voices of the population while simultaneously tackling the lack of information.

4.1.2 Indicator-based sustainability assessment

Building upon the described database, an indicator-based sustainability assessment needs to be done. Therefore, the different dimensions of sustainability (environmental, economic, social, and governance) must be considered. Multiple indicator-sets exist already. However, no standard has internationally prevailed so far. The ISO 37120 was the first attempt to standardize this but is not used on a larger scale. With the basis of an assessment framework (which is presented in the section 4.2.2), we tried to organize the existing indicators according to their type, their underlying data, and the goal they try to achieve. Even if the functionality strongly relies on a sufficient amount of data, the approach is an essential step in the overall concept and can help to make informed decisions, set projects' location with the highest impact, and evaluate and measure the overall urban development. The priorities and weighting of individual aspects are a fundamental part if simulations or scenarios are developed. Without a way of assessing sustainability and resilience or other factors, scenario-building or simulations cannot function.

4.1.3 Analysis, spatial evaluation

The indicator-based assessment can already provide a lot of information itself but can be even more efficient if paired with spatial analysis data. Therefore, tools are necessary which automatize the assessment of the built environment, again dependent on the available data, in this case, 3D-information of streets, blocks, plots, functions of buildings, etc. The smaller scale is described in one of the presented case studies, while it must be extended by advanced network analyses and large-scale spatial relations in neighborhoods, districts and the whole city. This helps to measure the impact of significant elements like rivers or airports on the development on the smaller scale. To reach a sufficient level of efficiency, global comparisons are needed which are contrasted with climate and societal information. An example would be the interdependency of social interactions/livelihood of people to the density and percentage of public space under the consideration of the overall social fabric, climate, and political situation. If there is a pattern or not is impossible to distinguish without proper analysis, but this example was chosen to show the potential of understanding urban space, morphology, and urban societies and their interrelations better than ever before.

4.1.4 (Scenario-)Simulation

If the database is sufficiently set and different kinds of assessment methods are set up, simulations and scenarios can be developed (an example of a 30-ha area in a self-planned settlement is presented in section 4.2.2 as well). Simulations can be done for nearly everything, while the spatial scenarios with a high level of detailing offer the best potential of usable, generated options. Two main aspects of this process are once an iterative process where a simulation is run many times and always evaluated and re-simulated with new and adapted base-values. On the one hand, this helps to understand what affects the evaluation most, while on the other hand, the possibility of a good simulation increases with the number of test series. Another interesting aspect for this, which considerations can provide even more exciting results, is the integration of artificial intelligence and machine learning. This idea will be shortly discussed in the application section. The second important part is to always combine the simulation-process with human (expert or citizen) input or selection. We are far from a digital model producing results which we can trust blindly (and probably never will), why the human interaction is one of the most critical parts of simulating urbanity.

4.1.5 Generating an Urban Framework

The last step is, as already mentioned before, the most challenging and at the same time most promising part. Generating an Urban Framework, which is based on all available data, considers the development and effectiveness of cities in similar conditions, takes future predictions into account, and is controlled and available for each citizen, seems to be a fascinating perspective as a basis for large-scale plans. It could fulfill the often-communicated need for an adaptive and responsive planning mechanism and at the same time work without too many resources. However, before all previous steps do not work correctly, this step will stay wholly conceptual. One project which goes in this direction is also presented in the case study section, but it leaves out much crucial underlying information and is built upon many self-made assumptions instead of statistically proven facts, which makes it not function as described in this paragraph.

4.2 Case studies

In this chapter, several projects and approaches are presented, which contribute to the realization of the digital and organic urban simulation. The first part concentrates on software and concepts, which were developed in the past or are currently gaining track, while the second part presents four of our attempts of the last two years, with each one concentrating on one of the steps of the previously presented conceptual framework.

4.2.1 What exists?

There is a growing number of attempts to digitalize and automatize the increasing amount of data, requirements, and pressure in the world of urban planning and development. With GIS-software becoming more advanced and data more open, the use of new tools rises already since over two decades. However, GIS software has three major issues, which slowly are tackled by some software companies. The first is the restriction to 2-dimensional information, which leaves various information only in connected databases but not visible or adequately accessible. The second issue is the user-friendliness; once most GIS-programs lack the possibility for the general public to access and work with the information (ESRI shows a good progress in the online availability of GIS-data), and secondly, the program structure itself is slowing the process down heavily. This results in an inefficient workflow and hinders the necessary trial-and-error process of planning scenarios. The software Urban Sim (www.urbansim.com) is the most promising approach, which allows combining significant amounts of data, simulations, and visualizations while having a fast workflow due to a cloud-based approach. However, it is still in an early stage, has a focus on the USA, and currently lacks more detailed simulation and modeling tools for smaller spaces. However, it has already today an advanced functionality and is worth to keep in mind.

Our own workflow is based on a combination of GIS and database software, 3D-modelling software (Rhinoceros) and an algorithmic modeling plug-in (Grasshopper). This has the advantage that the user has the highest amount of flexibility. However, the computing speed depends mainly on the available hardware, and the transition between the programs and different data-formats make it also still a very time-consuming process. A platform, where all kind of data comes together, various formats can be combined and managed, and efficient computing methods are available, is not existing yet.

4.2.2 Our approaches/applications

One of our first approaches was the development of an indicator-based sustainability assessment, which structure aims at the environment of cities in sub-Saharan Africa. It was presented at the ISOCARP conference 2016 and looked at the existing indicator sets. From them, over 1000 indicators where collected which can be sorted and structured by the developed assessment framework. The framework distinguishes amongst others between different sustainability dimensions, impacts, and goals, the spatial and temporal scale, as well as the type and characteristics of the indicator itself and the underlying data. An exemplary application was done with the indicator 'Reachability', where distances for Area 57 in Lilongwe, one of the largest self-planned settlements, were measured and graded to various functions with different priorities (fig. 3, left). Three different grading methods were developed which either use the administrative borders, a square-grid (fig. 3, right), or the individual houses (Gall 2016).

Section
5 min
15 min
30 min
Mode of transport
foot
bike
public transport

Functions	A	B	C	D	F
Public space	D	F	F	F	F
Public green (min. 0.25 ha)	D	F	F	F	F
Public transport	A	A	B	B	C
Retail	C	D	F	F	F
Nursery / elementary school	A	A	B	B	C
Secondary school	A	A	B	B	C
Civic services	B	B	C	C	D
Religious institution	A	A	A	A	B
Public green (min. 1 ha)	C	C	C	D	D
Shopping area / market	A	A	A	A	B
Office / workplaces	C	C	D	D	F
Cultural institution	C	C	C	D	D
Regional transport hub	C	D	D	F	F
Hospital / medical care	A	A	B	B	B
College / University	C	C	D	D	D
Library	D	F	F	F	F

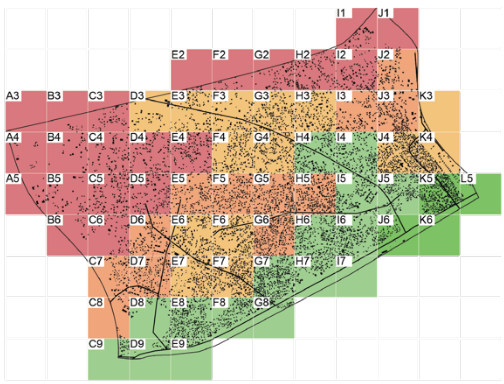

Fig. 3. Left: Assessment structure, right: visual representation of grid-grading method (Gall 2016)

This assessment method is still developed further with a focus on the measurability of the social dimension, instead of the currently predominant focus on economic values (e.g., GDP). In general, it aims at becoming a decision-making tool, which can measure projects' impact over time, locate most efficient intervention areas, and visualize the general development of an urban area over time.

Another approach to measuring and analyzing, concentrates more on the spatial features and extends the focus on 3-dimensional information. The project 'Urbanity in #' was part of a university project at the Institute for Urbanism and Design Methodology in Brunswick. It resulted in an automatized process where a spatial model with the information of blocks, plots, and buildings (with heights) was analyzed by ten values, including Floor Area Ratio, Site Occupancy Index, Shell/Volume area, distance to road center, etc. Even if the numbers itself are not innovative, the easy calculation for large urban areas combined with the rising amount of open-access 3D city-models made it effective to compare districts from four cities (Boston, Barcelona, Rio de Janeiro, Brunswick) and visualize the distribution of values, estimate the regression lines and apply the values of one area to another (fig. 4, 5; Gall 2017a). In the tested scale, it has limited functionality; however, if combined with the social, environmental, and economic data of the indicator-based assessment, it allows the user to distinguish interrelationships between the spatial and socio-economic background data on a global level. This can assist the planners to discover hidden information on how to influence, e.g., the social interactions of a place, by spatial regulations.

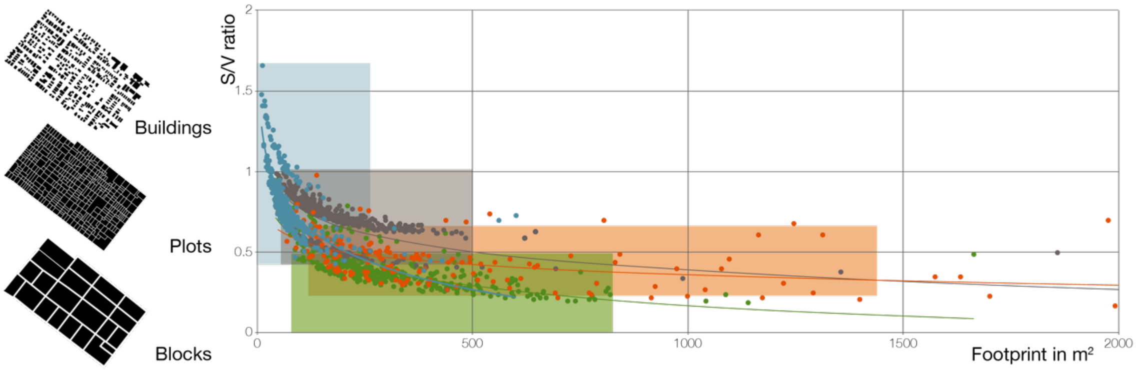

Fig. 4. Left: Underlying data, right: distribution of footprint / S/V values for four cities (Gall 2017a)

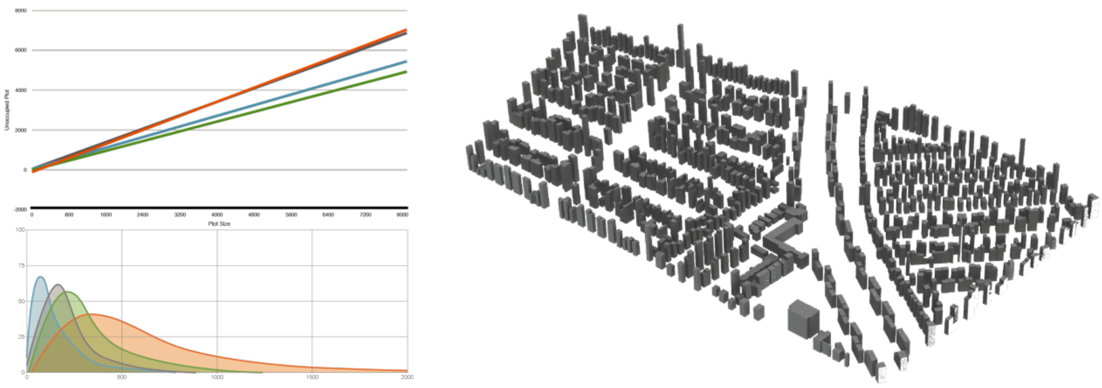

Fig. 5: Left: Trendlines and distribution of footprint / S/V, right: exemplary transfer of values (Gall 2017a)

Additional to the two presented analytical tools, two projects, once on the city-wide and once in the neighborhood scale, were done. The first approach was my bachelor-thesis in 2015 at the Institute for Sustainable Urbanism, which attempted to produce an urban framework in which the city of Lilongwe can grow from about one million inhabitants today to up to eight million in the second half of the century. This framework was developed based on the existing infrastructure, the blue and green network, and different preexisting characteristics of the urban areas. This underlying information combined with a set of rules regarding, e.g., the walkability, green and public space per inhabitant, and over 60 typologies, resulted in a generated city for eight million people, 1.36 million new units, 644,000 new plots and 460,000 new 'placeholder-buildings' (fig. 6, left). The whole process was automatized, reacts to changes of rules or typologies, or assumption, e.g., regarding the expected population growth, and resulted in a simulation over time which considers the incremental and exponential increase, spatial spreading, and densification over time (fig. 6, right; Gall 2015). Important to note is, that the developed plan shall not be seen as a master plan, but rather a growth framework with various options and variant diversity which on the one hand allows the planners to test different scenarios and on the other hand can guarantees a long-term development where certain standards (density, main infrastructure, percentage of public space, etc.) are met.

Fig. 6: Left: Growth Lilongwe, right: densification over time in one of eight new districts (Gall 2015)

The last spatial project was an adaptive and responsive design for the community of Chinsapo, Lilongwe, on an area of 30 hectares. After initial consultations with the councilor and the community through several stakeholder meetings and community workshops, a basic structure of public space, green space, and infrastructure was set (fig. 7, left). Additionally, various typologies for different household sizes and their distribution according to the distance to the public functions and infrastructure were developed. For the actual spatial scenarios, a distribution of household sizes was assumed, which in reality needs to depend on the actual families, who plan to live in the area. Additionally, ownership and responsibility were divided into different categories (fig. 7, middle), where the foundations are provided to guarantee a sufficient level of resilience and the houses itself being built self-responsible. An autonomous and sustainable water and electricity layout was designed, which primary parts are block centers in each area, providing sanitary functions, electricity generation and distribution, as well as interaction spaces. Small changes of the input data have a significant impact on the system. However, one exemplary option was generated with the growth over ten years (fig. 7, right), which was further detailed to show its theoretical functionality (Gall 2017b). The project aims to show, that simulated districts, even on a small scale, can result in functional and attractive areas and are not necessarily defined by rigid layouts.

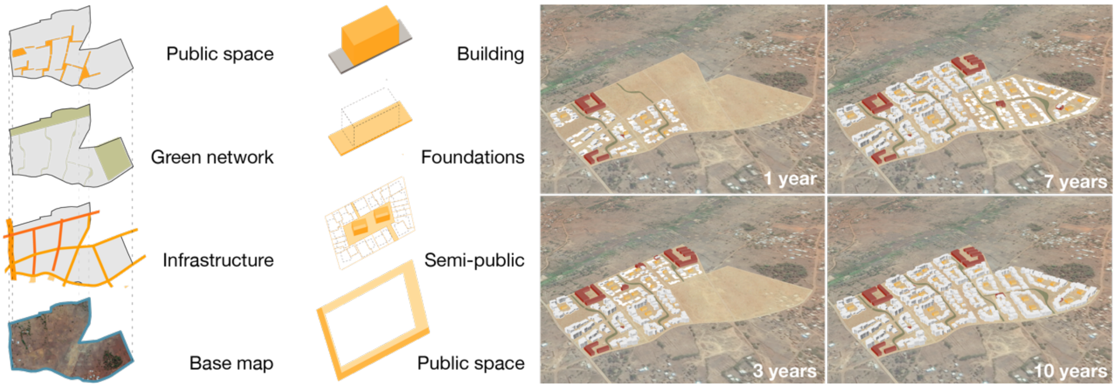

Fig. 7: Left: Growth framework, middle: layer, right: development over 10 years (Gall 2017b)

5 Application and vision

Some exemplary ways of applying the presented method were already mentioned. However, in this part a short and more detailed description of three principal potential uses follows, including scenarios what could be possible. Afterwards, it continues with a few ideas of future developments and some visions.

The first idea, as already described, is a continuously updated assessment system of numerous individual and aggregated indicators to determine best locations for intervention, measure success or the effect of projects over time, and have a general 'sustainability-' and 'development-index'. The possibilities of application in this area are endless and some of them are already in use around the world. However, to have one platform where everything is combined and accessible would be a great step towards better informed planning decisions. Another advantage is the opportunity to compare neighborhoods around the world on the spatial level and draw conclusions based on similarities and variations.

The second possibility is the simulation of different scenarios based on various assumptions of e.g. population growth, which shows how the city could react if certain decisions are made or interventions are done. It would make it possible to show changes and developments faster and automatically, while visualizing the impact of many aspects in a better accessible way.

The third and most exciting but also most challenging application possibility is generating an Urban Framework according to the expected developments over time etc., which is constantly changing and adapting to the real-life situation, includes the participatory involvement of various stakeholders, real-time data, and leaves enough room for 'organic' and human detailing of the smaller spaces in a larger scale network of a functioning, sustainable and resilient city. Organic grid and fabric generation can be a second step, which provides alternatives and design options for governmental institutions and the private sector.

Additional to these three possibilities, parts of the conceptual framework are also promising in itself. 'Techno-participation', for example, is a necessary aspect of several of the steps. It can be done in many different ways, including online polls, guerilla mapping, motion tracking, online idea and critic boxes, and many more. Taiwan already uses very promising participatory tools. They introduced a public participation policy in 1993, extended it over time and recently started an I-Voting model. It is an online participation model where the citizens can decide between various option to solve Taiwan's challenges of 40 years without approved plans and half of the population living 'illegally' (Lefevre 2016). This shows the potential to integrate the population in the decision-making process but has many more potentials, which will surely grow extensively in the next decades.

Another idea with much potential is the concept of performative scripting, which is in the building scale described in Burry's book 'Scripting Cultures: Architectural design and programming' (Burry 2011). It talks about the need and potential of active performance adaptation. Even if he refers to the smaller scale, there are many potential possibilities in the urban scale as well. In general, the concept of performative scripting is to use models which have a strong focus on the city's performance and use its parameter as the driving force of making decision. He further divides between passive and active performance. The first only tries to cope with the existing situation, while the latter actively contributes something to the system. An example for the passive could be the optimized urban layout to minimize the urban heat island effect, steer air movement efficiently or define plots regulations based on their potential buildings effect on the climate in general through, amongst others, shading and heating effects. Examples for the active performative part are more difficult to find, because they do not really exist yet. In general, it would mean a city or urban district, which does contribute more to, e.g., the ecosystem than it uses itself but not just in a way of reproducing a certain number of trees but in a way which would not exist without the city. Burry for example gives the example of mosses which utilize the building's facades. But his idea is not about the idea itself but the design and planning process, which starts with innovative ideas, which, assisted by the automated and scripted process, result in the design and actual shape instead of integrating 'sustainable' elements later to fulfill regulations or a quota.

Artificial Intelligence (AI) and machine (or deep) learning (ML) are the last part of the visions and the concepts we want to examine in the future. In general, AI is nothing to be afraid of and has nothing directly to do with a computer making decisions. It is mainly about the computer not just adding 1 and 1 but gaining a deeper understanding of relations, dependencies, and recreate them in complexities which the human is not able to do. The most common approach, which is already accessible for people with little understanding of programming, is machine learning. A computer 'sees' for example a certain number of photos which he analysis according to e.g., depth, color, and composition, and combines them with human input, e.g., if the photos show qualitative urban spaces. With a sufficiently high number of photos and human inputs, the computer would increase steadily the accuracy in defining urban quality according to the questioned human participants. Jean Oh tested this for defining different types of roads in Boston in her paper 'Finding Main Streets: Applying Machine learning to urban design planning' (Oh 2015). Her approach showed that the process does not need to be very complex and can outperform other models to define objects or relations in the urban realm. The application possibilities of AI will further increase and slowly, despite the 'fear' of many, find its place in the planning practices; mainly because it opens new methods of analyzing and provides insights of interrelations which we can only assume but not prove scientifically. In which ways and scope depends less on the possibilities of the technology, which will advance anyhow, but largely on the planners’ willingness to integrate it into their work and move it from theory to practice.

6 Limitations and outlook

To conclude, a quick consideration of the limitations is necessary as well as an outlook on how to continue. To partly answer the question "How far can a computer plan?", I want to argue that in the end much better and more inclusive! It allows more access for everybody, a stronger reliance on data, more democratic decision-making processes and decentralized control, easier participation in several layers, less manual/analog work to get the necessary information, and therefore more time for conceptual planning. However, this only becomes a reality, if specific standards are met, if the system is thoroughly overlooked by humans, and if the underlying data is sufficient to make realistic simulations and informed decisions.

In more detail, it can be divided into two challenges: once the technological part and once the philosophical question.

6.1 Data, access, and use of technology

One of the most critical difficulties at the moment, mostly in countries like Malawi, is the low availability and bad access to data which is crucial to develop a functioning system. However, this also bears the potential to start with a smaller amount of data and extend it over time according to the most substantial areas instead of starting with an uncontrollable amount of data. The latter makes it even more difficult to decide, what is essential and where the priorities are. Another aspect is the access to the system. If it is only used by a small group of planners, the planning process becomes even less understandable for the average citizen. One necessary part is, therefore, the availability for everyone to access the data, the assessment tools, the simulations, and the tool itself, to understand and partake in the process. On the other hand, the technical requirements must be realistic to ensure that not only people with high-speed internet, high-performance computers, or expensive software licenses can access it. The last aspect, which should be considered, is the growing technical complexity of such endeavors. A simple and easily understandable user-interface is vital to guarantee a high level of usability and widespread access. The current development in the software and programming world makes it already much more comfortable for many to access digital tools without advanced technical knowledge, but there is only a small gap between a simple enough tool and the limitation of individual adaptations when developing such a tool.

6.2 Human vs. computer

The next question is the philosophical part: Who shall plan? What happens if we give 'away' our decision power? In the end, it is a question of ideology, which cannot be answered for everyone. However, in my perspective, there are several reasons speaking for it. The lacking resources in many planning departments with rising urban scales and information complexities already call for a change. Additionally, the decision shall always stay with the human as well as the power to use a tool in whatever way needed. A more general argument would be the 'anti-globalization' of planning, where more time to concentrate on the targeted urbanity evolves and can lead to a better adaptation to local contexts by distinguishing differences and variations (culturally, spatial, climate-related, …). Furthermore, it creates new and more just ways of participation. Coming back to criticism of the beginning, simulating cities can bear many dangers but at the same time also many advantages. The development towards even more technology in every part of our lives will continue. Therefore, I would prefer to utilize it in the best imaginable way and adapt and improve it over time instead of fearing its consequences while getting buried under the increasingly data-filled and complex scope of urban planning.

6.3 Way forward and missing pieces

As already mentioned several times, the technical realization still lacks in many places, which we continue to try to solve step by step. A general digital upgrade is necessary, defining which program is best for which use, how to improve the interfaces, standardize data formats and improve the speed and workability. Currently (also due to varying personal program literacy), there is a strong focus on Rhinoceros and Grasshopper. However, less calculation-intensive methods are required to handle the amount of data. Additionally, cloud-based processes are needed in real-life applications to decrease the hardware requirements, which result in problems in countries with lacking high-speed internet access; working against the idea of making it accessible for everybody. Summarizing, many construction sites are left, but with time and a better understanding of the advanced programming part, it should be able to produce a functional prototype of the presented conceptual framework.

7 Conclusion

To briefly wrap up this papers' primary aspects, I want to come back to the original starting point of how digital methods can be integrated without neglecting the local contexts, memory, and identity of the planning environment. This paper tried to present various approaches, theoretical and practical, and combine them in a conceptual framework. Its application in our planning reality still needs more effort in the technical dimension as well as in the willingness of planners and institutions to move forward into the practical spheres. However, two things seem to be inevitable: *Master plans and top-down approaches lost their place* in the planning scope and will gradually disappear. At the same time will *digital and automatized tools become a necessary part of dealing with the growing contextual complexity* and the pressing issues of making our cities sustainable and resilient for the future. The planners responsible should, therefore, be to move away from 'only' creating plans towards facilitating these tools, combining them into their work, and utilizing new concepts and participatory models to achieve a more democratic, locally adapted, and responsive **Urban Framework**.

8 References

Alexander, C., 1966. A city is not a tree. In: City, 122(1), pp.58–62. [online reprint]. Available at: http://www.chrisgagern.de/Media/A_City_is_not_a_tree.pdf [Accessed December 25, 2017].

Barthelemy, M.; Bordin, P.; Berestycki, H. and Gribaudi, M., 2013. Self-organization versus top-down planning in the evolution of a city. [online] In: Nature Scientific Reports 3:2153 2013). Available at: https://arxiv.org/pdf/1307.2203.pdf [Accessed November 27, 2017].

Batty, M. and Longley, P., 1994. Fractal Cities: A Geometry of Form and Function. London: Academic Press Ltd.

Batty, M., 2008. Generating cities from the bottom-up: using complexity theory for effective design. Cluster Editions, pp. 1-14. Available at: http://www.complexcity.info/files/2011/07/batty-cluster-magazine-2008.pdf [Accessed November 20, 2017].

Bettencourt, L. M. A., 2013. The kind of problem a city is: new perspective on the nature of cities from complex systems theory (SFI working paper: 2013-03-008). Santa Fe: Santa Fe Institute. Available at: http://samoa.santafe.edu/media/workingpapers/13-03-008.pdf [Accessed November 20, 2017].

Burry, M., 2011. Scripting Cultures: Architectural Design and Programming. Chichester: John Wiley & Sons Ltd.

Cartwright, T. J., 1991. Planning and Chaos Theory. In: Journal of the American Planning Association, 57:1, 44-56. Available at: http://www.tandfonline.com/doi/pdf/10.1080/01944369108975471 [Accessed November 20, 2017].

Folkers, A. and Perzyna, I. eds., 2017. The Beeker Method: Planning and Working on the Redevelopment of the African City. Retrospective Glances into the Future. Leiden: African Architecture Matters.

Gall, T., 2015. Lilongwe: Urban Framework. [thesis at Institute for Sustainable Urbanism, Prof. Dr. Vanessa M. Carlow]. Brunswick: Technical University of Brunswick.

Gall, T., 2016. Tackling urban challenges in sub-Saharan Africa through indicator-based Sustainability Assessment. [ISOCARP Conference "Cities we have vs. Cities we need"]. Durban, September 12-16, 2017.

Gall, T., 2017a. Advanced Urban Analytics: Urbanity in #. [project at Institute for Urbanism and Design Methodology, Prof. Uwe Brederlau]. Brunswick: Technical University of Brunswick.

Gall, T., 2017b. Urban Design Chinsapo. [design studio at Institute for Sustainable Urbanism, Prof. Dr. Vanessa M. Carlow]. Brunswick: Technical University of Brunswick.

Gall, T.; Hitzegrad, J.; Hemminghaus, S. and Gallandt, G., 2017. Urban Framework. [IYC entry, World Sustainable Built Environment Conference 2017 Hong Kong].

Hillier, B., 2007. Space is the machine. London: Space Syntax.

Lefevre, Q. 2016. Usage du numérique et participation citoyenne à Taiwan. [online] Available at: http://www.revuesurmesure.fr/issues/villes-usages-et-numerique/usage-du-numerique-et-participation-citoyenne-a-taiwan [Accessed December 03, 2017].

Maptionnaire, 2017. Maptionnaire home page. [online] Available at: https://maptionnaire.com [Accessed November 27, 2017].

Oh, J., 2015. Finding Main Streets: Applying Machine Learning to Urban Design Planning. [online] Available at: https://www.researchgate.net/publication/242356525_Finding_Main_Streets_Applying_Machine_Learning_to_Urban_Design_Planning [Accessed November 27, 2017].

Portugali, J., 2000. Self-organization and the city. Heidelberg: Springer.

Sevtsuk, A., 2013. Networks of the built environment. In: D. Ofenhuber and C. Ratti, eds. [De]coding the City – How Big Data Can Change Urbanism. Basel: Birkhäuser.

Stolk, E. and Broemmelstroet, M. t. eds., 2009. Model Town: Using Urban Simulation in New Town Planning. Amsterdam: Sun Architecture.

Vince, O., 200?. The Death and Life of Simulated Cities. [online] Available at: http://meminsf.silverstringmedia.com/art/the-death-and-life-of-simulated-cities/#archiveiii [Accessed November 14, 2017].