D.U.M.

Dynamic Urban Model

Data-Based Urban Prediction Toolset

Pavel Paseka

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1. Assignment, Abstract, Declaration

Assignment

České vysoké učení technické v Praze, Fakulta architektury

2/ ZADÁNÍ diplomové práce

Mgr. program navazující

jméno a příjmení: Pavel Paseka

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ústav: 15116 / Kabinet modelového projektování

vedoucí diplomové práce: doc. Ing. arch. Miloš Florián, Ph.D.

téma diplomové práce:
Dynamický model rozvoje měst – Datový nástroj pro predikci vývoje městského prostředí
Dynamic Urban Model – Data-Based Urban Evolution Prediction Toolset

zadání diplomové práce:

1/ popis zadání projektu a očekávaného cíle řešení

Současné způsoby plánování měst stále aplikují zjednodušené modely, které redukují společenské interakce a zanedbávají chování jednotlivců a jejich vztahu k prostředí. V souvislosti s novými výzvami, jimž města nyní čelí, je nutné zaměřit se na sledování jemných způsobů chování mezi lidmi, mezi lidmi a prostředím, či také mezi lidmi a přístroji, které dennodenně využívají. Potřebné nástroje nám poskytují digitálně řízené technologie, jež cíleně dovolují zkoumat nekonečné množství změn, při nichž mezi lidmi a okolím dochází. Máme šanci tyto změny sledovat, shromažďovat data o chování lidí v prostředí a na jejich základě navrhovat nové a lepší uspořádání měst a obecně prostředí. Pro výzkum a návrh byla zvolena dvě města globálního významu: Londýn a New York.

2/ pro AU/ stavební program

Predikovat rozvoj městských struktur na základě datově řízeného modelu. Tento dynamický model bude schopen identifikovat potenciál růstu či úpadku částí městské struktury. Bude také schopen definovat konkrétní pozemky, kde dojde k stavebnímu rozvoji. Poté na základě analyzování detailnějších datových vstupů na nich navrhnout takovou zástavbu, jež bude nejoptimálnější pro obyvatele a uživatele konkrétní lokality. Celý proces modelování od predikce rozvoje/úpadku až po návrh konkrétních objektů je tak postaven zcela na uživatelích a obyvatelích měst a jejich virtuální stopě. Celý proces modelování se neustále updatuje dle průběžně dodávaných vstupních dat.

3/ popis závěrečného výsledku, výstupy a měřítka zpracování

Rešerše, analýzy:
Udržitelná města a jejich plánování, Města jako komplexní systémy, Městská data a otevřená data, Smart Cities, Modelování měst a predikce rozvoje měst, Městská Dynamika, Sociální fyzika a dynamika, Parametrický urbanismus

Dynamický model rozvoje měst:
-schémata širších vztahů
-řešení modelovaného území (1:5 000 nebo 1:10 000)
-schémata datových zdrojů, identifikace rozvoje/úpadku částí měst apod.

Identifikované zástavbové území:
-prostorová zobrazení (vizualizace)
-výkres návaznosti na okolní zástavbu (1:500 nebo 1:1000)
-půdorysy, řezy či řezopohledy (1:250 až 1:1000)

Schémata řešení:
-schémata dynamického chování měst, využívání datových zdrojů, výstavby apod.

4/ seznam dalších dohodnutých částí projektu

-model území (1:1000 až 1:5000)
-video prezentace (ukázka dynamiky městského prostředí, využívaní vstupních datových sad, predikce rozvoje měst a návrh zástavby na konkrétních lokalitách)

Datum a podpis studenta
29.2.2016

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29.2.2016

Datum a podpis děkana FA ČVUT

Registrováno studijním oddělením dne
1.3.2016

Declaration

CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF ARCHITECTURE

AUTOR, DIPLOMANT: Bc. Pavel Pasela
AUTHOR OF THE DIPLOMA WORK / DIPLOMA PROJECT
Academic Year 2015/2016, Summer Semester

TITLE OF THE DIPLOMA WORK / DIPLOMA PROJECT
DYNAMICKÝ MODEL ROZVOJE MĚST – DATOVÝ NÁSTROJ PRO PREDIKCI VÝVOJE MĚSTSKÉHO PROSTŘEDÍ

TITLE OF THE DIPLOMA WORK / DIPLOMA PROJECT
DYNAMIC URBAN MODEL – DATA-BASED URBAN EVOLUTION PREDICTION TOOLSET

LANGUAGE OF THE DIPLOMA WORK / DIPLOMA PROJECT: ENGLISH

Diploma Work / Diploma Project Supervisor	Ústav: 15116 / Kabinet modelového projektování doc. Ing. arch. Miloš Florián, Ph.D.
Diploma Work / Diploma Project Opponent	Mgr. Art. Peter Buš, Ph.D.
Key Words (English)	Urban Evolution Modelling, Adaptive City Planning, Responsive Urbanism, Urban Data, Complex Self-organising Systems
Annotation (Czech)	Adaptivní, flexibilní a responsivní model rozvoje městského prostředí, jež lze chápat také obecněji jako systém prostorového plánování, který bere v potaz skutečné a aktuální požadavky obyvatel a uživatelů měst. Každý z nás za sebou denně zanechává jakousi virtuální stopu, která podrobně vypovídá o našich životech v městském prostředí. S pomocí navrženého modelu D.U.M. je nyní možné číst tyto virtuální stopy, lépe pochopit každodenní chování městských populací a jejich požadavky na prostředí. Tyto poznatky pak následně překlopit v adekvátní formu zástavby pro konkrétní lokality a pozemky. Role architekta-plánovače se tak posouvá do více abstraktní a strategické roviny. Jeho úlohou se stává pochopit socio-ekonomické vazby ve městech, zkoumat chování obyvatel měst a stanovit vazbu mezi lidmi - počítačovým programem - a samotným návrhem prostředí.
Annotation (English)	Addaptive, flexible and responsive urban model, which can be further extended to more eligible spatial planning system which proceeds from actual requirements of urban population. From demands of inhabitants, residents, labourers and visitors of specific locality. All these individuals and groups leave every day, every hour and every second a virtual footprint through their behavior and acting in the urban environment. With the help of this proposed model – D.U.M. – it becomes possible to read this virtual breadcrumbs, understand behavior of urban populations and translate it to suitable virtual site speific design. The role of an architect-urban planner is then moved to more abstract and strategic level. His job is to understand the socio-economical relations, investigate urban population behaviour and set the correct connections among people-software-design.

The Author´s Declaration
I declare that I have elaborated the submitted diploma work / diploma project independently and that I have stated all the used information sources in coherence with the "Methodological Instruction for Ethical Preparation of University Final Works".
(The complete text of the methodological instruction is available for download on http://www.fa.cvut.cz/En)

In Prague on 25.05.2016 ……………………………………Signature of the Diploma Project Author

2. Research

2.1 Sustainable Cities and Urban Planning

At the beginning of this new century, we are experiencing some of the most profound and accelerated transformations in the history of humanity that have great effect on the economy, politics, society, and the human habitat and in general environment we live in. Technological innovation and the development of telecommunications and informational technologies are facilitating the emergence of a new global economic order. This is reinforced with the progressive reduction of trade barriers, the creation of large economic blocks, and the expansion of global markets.

Growth of cities
Cities have the responsibility to sustainability of the whole planet. And this responsibility still grows as grows the urban populations and urban areas. But we can not see the cities as problem of our era, but rather the solution of the 21st century challenges, such as climate change. The habitats of globalization are the cities and the urban systems. Today, more than 50% of the world population lives in cities - in 20 years, that figure will be 75%. Over that period of time, almost 2000 million people will be born in, or will move to live in cities, especially the larger cities in the developing world. There will be more than 500 cities with more than one million inhabitants (Fundacion Metropoli, 2015).

Giving a coherent response to this unprecedented challenge and opportunity has become the central issue, not only for urbanism and architecture, but for the economy, society and culture as a whole. These challenges we are trying to manage through the urban planning. Current practise of urban planning is complex discipline of land spatial management. It is not just about urban structure organization and arrangement. It is about applying long term vision, strategy and common shared values in it.

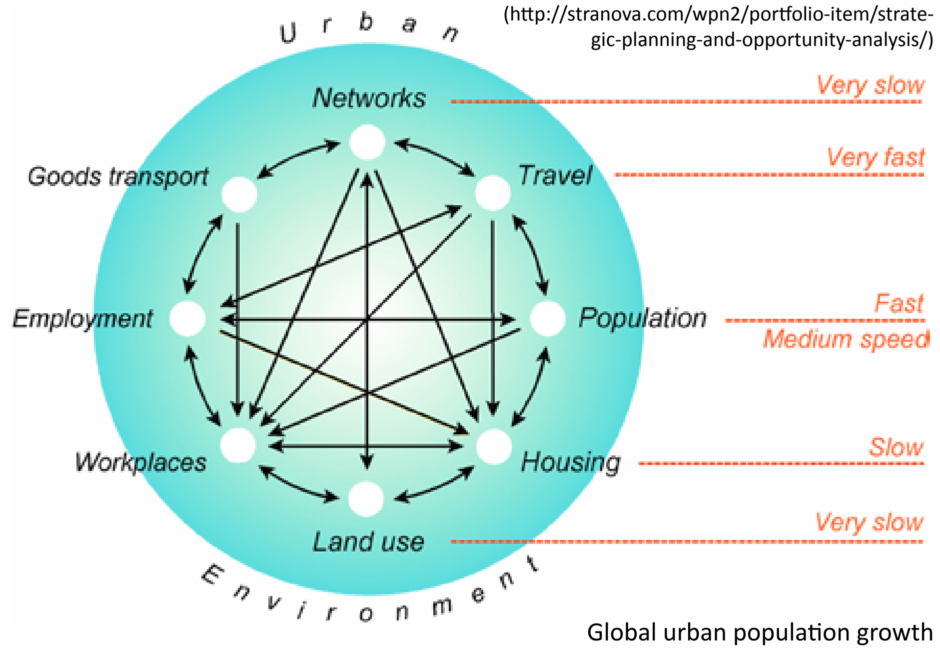
Modern urban planning
Modern urban planning is or at least should be about processes, about tactic implementation of strategy which should lead to secure long term sustainability and regimentation of development energy in urban environment. To be able to manage these challenges urban planning needs its own specific instruments and procedures. These instruments have to reflect current state of cities. Its urban dynamic, dynamics of its inhabitants and communities, the necessity of competitiveness on national, regional and also local level. These advanced instruments have to be able to predict changes, understand this dynamics, be flexible and able to react if necessary (Doleželová, 2015:12).

We are in the Age of cities. The World is undergoing urban renaissance as people are moving to the cities in ever greater numbers to build better lives.

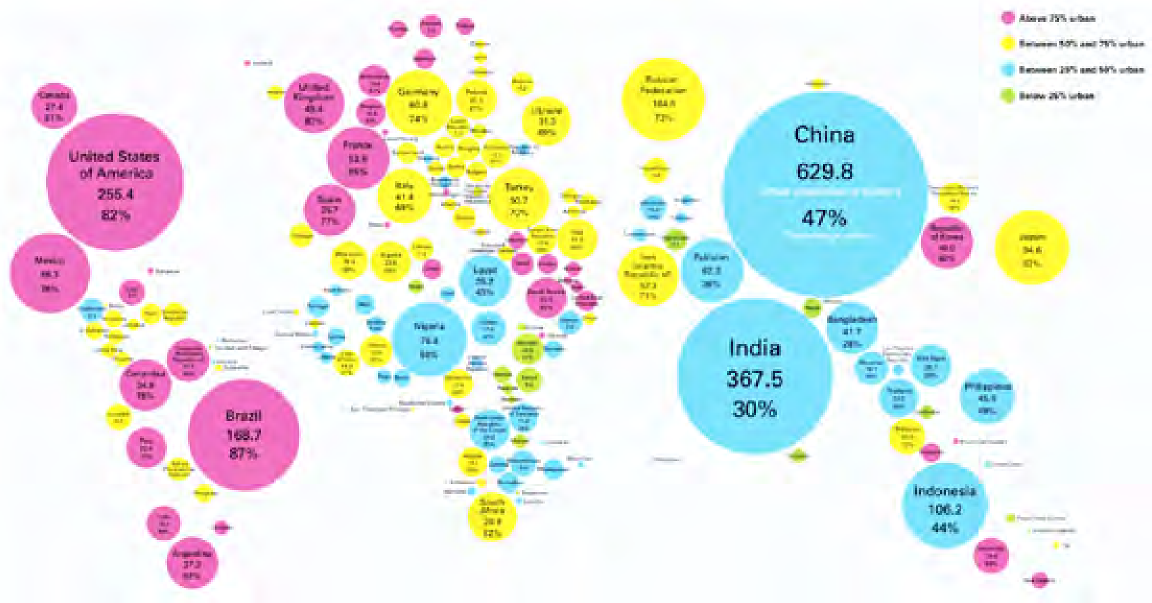
Sustainability is a term that brought long term dimension and feedback loop in the time horizon of urban planning. This sustainability is effected mostly by two main factors – Resiliency in the form of stable urban structure and Adaptability represented mostly by flexibility and dynamic adjusting of city functions. In the terms of urbanism meaning different land uses (Doleželová, 2015:12). Relationship between urban structure (urban fabric, spatial city arrangement) and content components (land use, urban functions) may be called distribution of activities in the city. And precisely these activities are what matters most. This is what makes city a social and economical achievement of times and what architects and urban planners should take care about.

Allocation of activities
This distribution of activities in urban environment is determined by two main factor as Gunilla Lindholm mentioned on AESOP annual congress in Prague. If we simplify them these can be called as Localization of common services in public interest and Allocation of sources for maximal gain (Lindholm, 2015). Difference is of course between type of stakeholders or actors

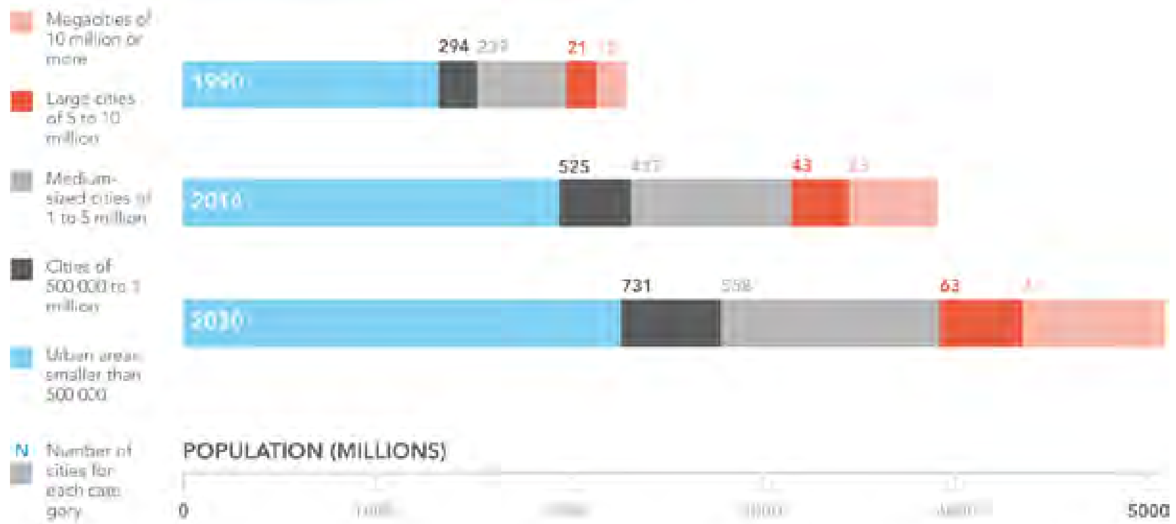
Urban systems and speed of their change
(http://stranova.com/wpn2/portfolio-item/strategic-planning-and-opportunity-analysis/)



Global urban population growth
(http://morphocode.com/data-urbanism/)



Global urban expansion
(http://morphocode.com/data-urbanism/)



in the urban development and also between processes and mechanisms they use to decide and reach their partial interests. In the firs case we can identify inner tendencies for location of activities such as economies of scale, the benefits of even spatial arrangement, search for balanced state between efficiency and equity, optimizing the location of public facilities.

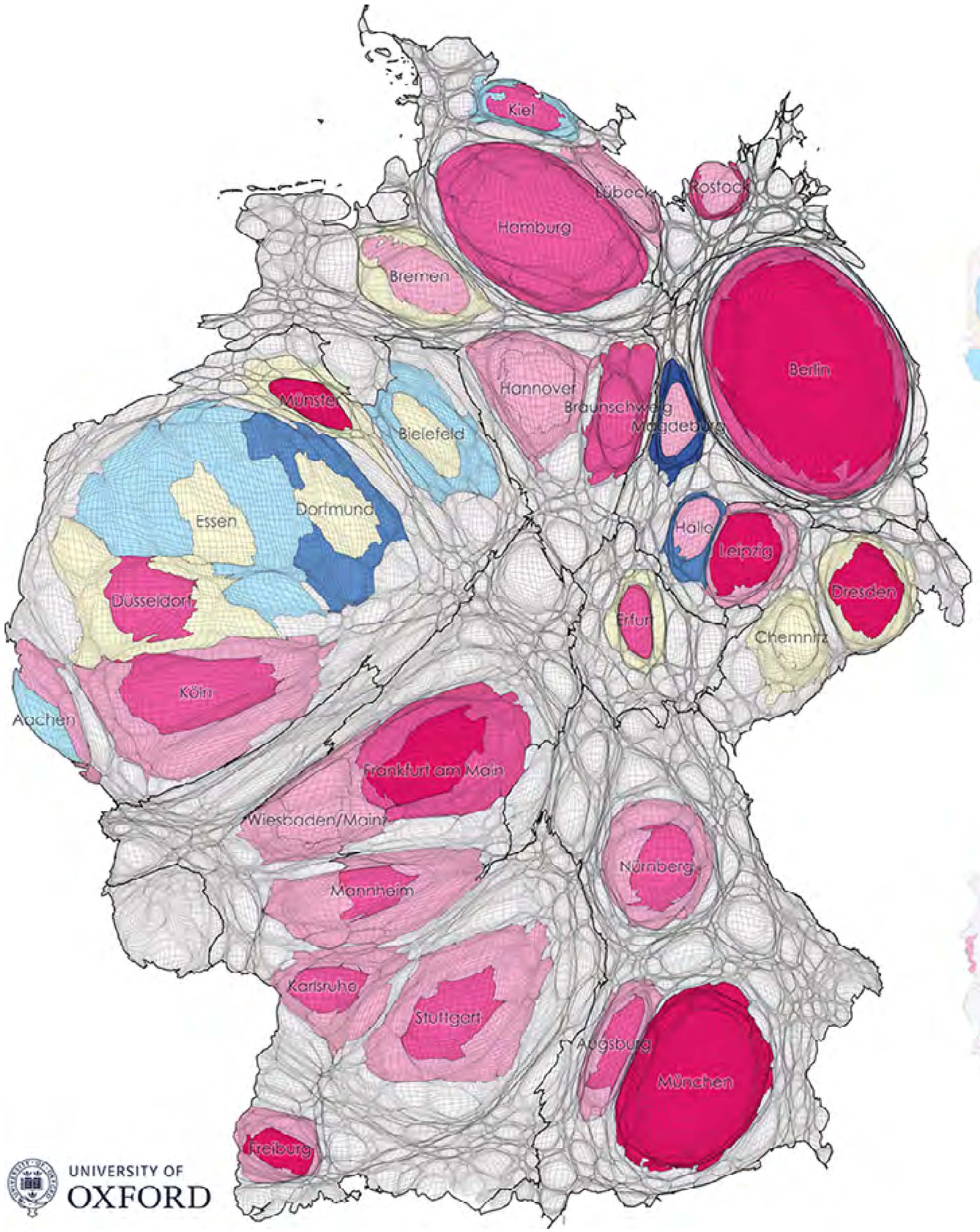
In the second case of Allocation of sources for maximal gain (individual deciding process for maximal yield in the case of commercial activities) the guiding tendencies, of course according to the specific type of activity, are for example availability, agglomeration and aggregation, competition, economy of scale. On the other hand the problem is unbalance distribution of social and economical advantages and benefits, load of environment and problematic realisation to the planning instruments possibilities (often restrictive character of them). These mechanism are crucial inputs for localization of activity and the setting of process of deciding the localization.

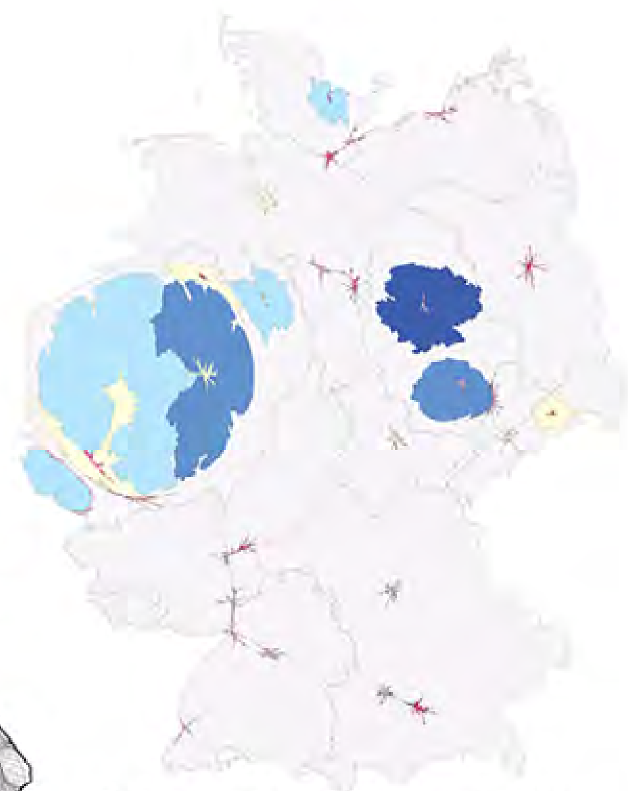
Growth of urban areas
Another theme connected with localization of activities and investments within the cities is the growth of urban areas. This allocation of development is guided strictly by market rules and by strategy named as Allocation of sources for maximal gain, which is described above. Regulations of governments are trying to force this development into already build-up area but cities are still growing and consuming the land. That is of course connected with land management, land ownership and facilitating the evolution of the city where it is really necessary and not just where it is the best for investors. To keep sustainable, economy and competitive cities its is really important to think about reusing of urban area, not just use and leave somewhere else. Such a city can be more pleasant for its inhabitants, can have better image for investors and can be less expensive to run and govern. This strategical approach is called Circular Flow Land Use Management or also CircUse (Birli, 2011).

BIRLI, Barbara. CircUse Teaching Material. Vienna: Environmental Agency Austria, 2011.

DOLEŽELOVÁ, Šárka. Distribuce klíčových aktivit v území – nástroje plánování. Published in Urbanismus a Udržitelný rozvoj, Brno: Ú&UR, XVIII – 6/2015.

LINDHOLM, Gunilla. The Urban Landscape as a Complex of Localizations. Accepted abstract for the AESOP conference. Prague: AESOP 6/2015.





Cartograms of population changes: Urban agglomerations resized proportionally according to absolute decline (above) and growth (below)

Expansion of population in urban regions.
Data visualization project of University of Oxford
(http://www.viewsoftheworld.net/?p=4625)

2.2 Urban Data, Open Data and Data Driven Society

Today's cities and governments still operate according to principles developed two centuries ago, during the beginning of the Industrial Revolution. To address 21st-century problems such as exploding population growth and climate change, we need new thinking. Big data and Urban data can deliver that thinking. The digital breadcrumbs we leave behind as we go about our daily lives—which reveal more about us than anything we choose to disclose—provide a powerful tool for addressing social problems. Yet concerns about misuse of this data are of course valid. Before data mining can deliver a healthier, more prosperous society. We need to crate such a security precaution on Data that gives individuals far more control over their own information which are today real-time accessible.

We are a sociaty driven by data
(http://ComputingNow.computer.org)

It is obvious that whole new economy is forming around managing, sharing and analysing of big data. Urban data are sometimes called society's nervous system (Petland, 2013:33). The digital traces we leave behind each day reveal more about us than we know. This could become a privacy nightmare or it could be the foundation of a healthier, more prosperous world. Of course we need to keep our privacy, but we have an unique opportunity to use these data to understand today's society, cities and design them for better future.

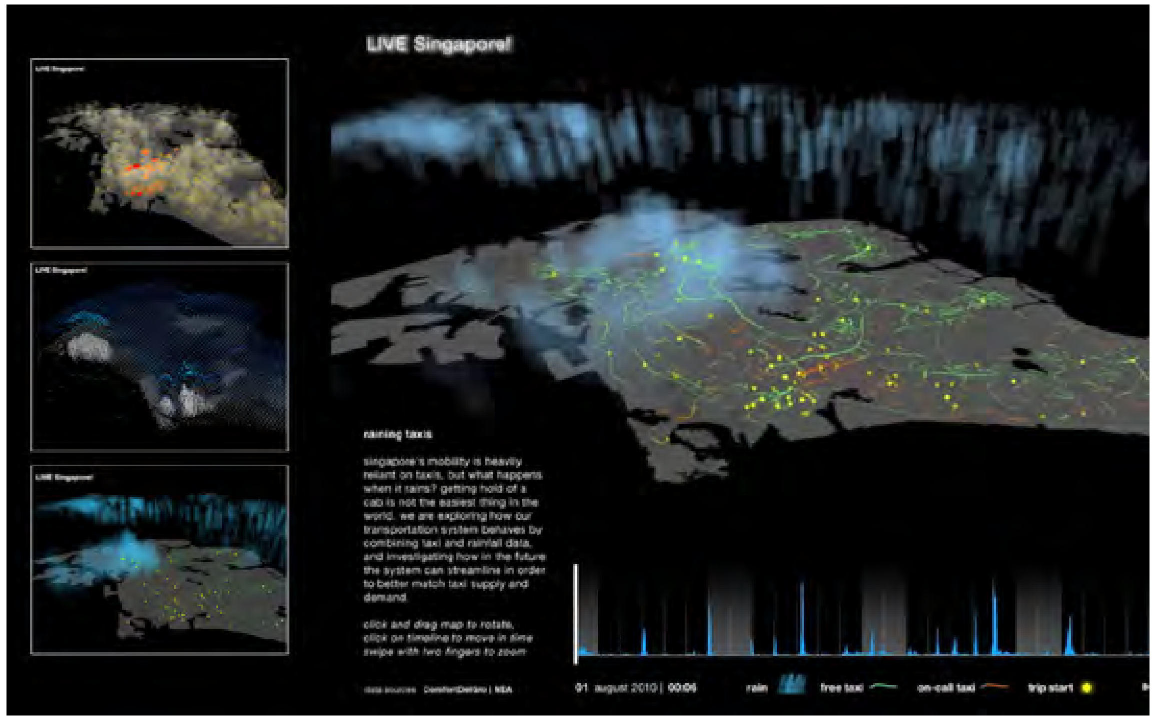
New thinking for new cities´ challenges

By the middle of the 19th century, rapid urban growth spurred by the industrial revolution had created urgent social and environmental problems. Cities responded by building centralized networks to deliver clean water, energy, and safe food. To enable commerce, facilitate transportation, and maintain order or to provide access to health care and energy. Today in this century are these old solutions increasingly inadequate. Many of our cities are jammed with traffic. Our political institutions are deadlocked. In addition, we face a host of new challenges like most notably, feeding and housing a population set to grow by two billion people while simultaneously preventing the worst impacts of global climate changes. These new and unique 21st-century problems demand 21st-century thinking. Urban data can provide the base for this thinking.

Data provided by mobile phone networks, new infrastructure of sensor, data from devices and internet of things and other digital infrastructures are providing us with a God's-eye view of ourselves. For the first time, we can precisely map the activities of large numbers of people as they go about their daily lives. An based on this mapping we are able to predict the behaviour of society. For whole world´s population the hope is that we can use this new in-depth understanding of human behaviour to increase the efficiency and responsiveness of industries, governments and cities. For individuals, the attraction is the possibility of a world where everything is arranged precisely for our convenience. A health exam is scheduled as we begin to get sick, the bus arrives just as we get to the stop, and there is never a line at city hall.

Through data and analytics, city leaders, stakeholders and citizens can gain vital real-time insights from multiple secure data streams (traffic, social media, devices and sensors that make up the Internet of Things-IoT) to make more accurate decisions, achieve greater efficiencies, and respond faster in emergency situations.

We can analyse the "digital breadcrumbs" people leave behind as they go about their daily lives to dynamically model aggregate human behaviour. This process is called Reality mining as combination of term Data mining and Real-time data accessibility (Petland, 2013:40). For example, GPS data collected from drivers' cell phones in a city can provide minute-by-minute updates on traffic flow, allowing for more accurate detection of road congestion and driving time estimates. Watching these kind of data we are able to watch mobility and appearance patterns within a cities.



Senseable City Lab MIT, LIVE Singapore! Using real-time data
(http://senseable.mit.edu/livesingapore/research.html)

Digital public space and live urban data

Let´s describe more these data expressions and how we can read them and use them for understanding, reading and designing cities. A fine and clear analogy was made by Ratti and Offenhuber. Think of an encounter with a friend on the street. You both stop and exchange information – greetings, personal anecdotes, the weather, etc. In the conversation you choose your words based on your knowledge of the subject matter, as well as your knowledge of your friend's background. When he frowns, you understand that he disagrees; his gesture informed you he wanted to intervene and respond. You stop to give him an opportunity to speak up. You note that your friend is getting impatient when he looks at his watch. He sees that you have noticed his impatience and explains he has an appointment to catch. All of this happens in real time, based on the exchange of many tiny signals. We are able to capture the dynamics of such interactions effectively, given the signals exchanged are perceivable, strong enough to be registered, and are understood by the recipient (Ratti; Offenhuber, 2014:82).

We adapt to environmental information similarly. However, it becomes more difficult with growing distance to the phenomenon of interest, or when its signals cannot be registered by the human senses. Now, consider being able to read all these sources of environmental information and base decisions upon them, just as effectively as in the conversation with your friend.

Urban space today is pervaded by digital networks and systems, creating information that represents human activity. While most digitally managed urban systems generate operational data for their own purposes, they normally do not share those data directly with other systems or the public. As a result, digital information representing human activity in the city exists in many different places, locked within their specific domain. If we are able to developed an open platform for the collection, combination, and distribution of large numbers of such real-time data sources, encouraging developer communities to use these data streams for the creation of meaningful and beneficial civic tools. The available data used can be divided into three groups by its source (Ratti; Offenhuber, 2014:85):
- data as a by-product of existing networks;
- data collected with tags or sensors;
- data actively shared by people.

Urban data and individual privacy

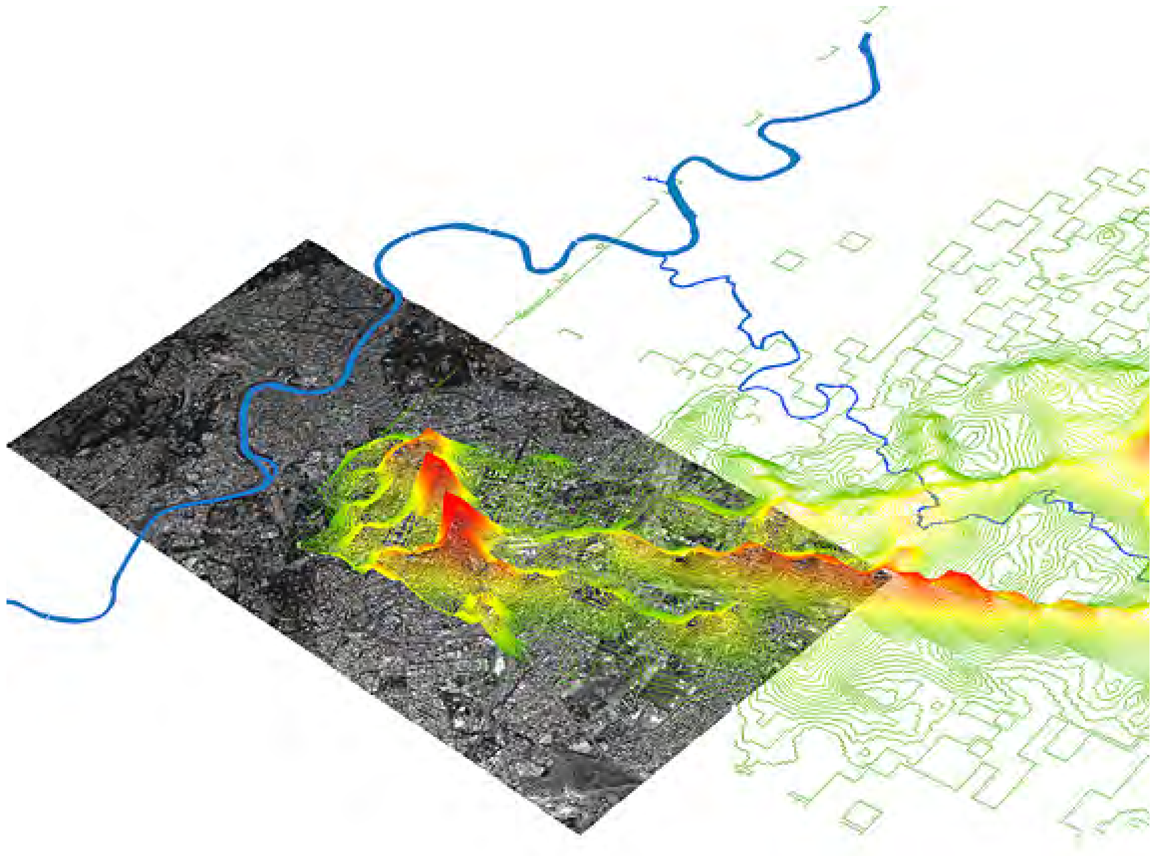
As we refine these new capabilities through more sophisticated statistical models and pervasive sensing systems, we could well see the emergence of a quantitative, predictive science of human society and organizations (Petland, 2013:45). At the same time, these new tools have the potential to make George Orwell's dystopian vision of an all-controlling state a reality. Consequently, we must think carefully about the growth and increasingly broad usage of personal data to drive societal systems, and particularly about the safety, stability, and fairness of their design.

Relevant questions are of course regarding data ownership and individual privacy. Perhaps the greatest challenges posed by pervasive sensing systems relate to data are these ownership and privacy issues (Petland, 2012:41). Advances in network data analysis must balance creating value for data owners with protecting users' privacy. That is essential. This data structures must not become the exclusive domain either of private companies, in which case it will not contribute to the common good, or of the government, which will not serve the public interest of transparency.

The digital traces we leave behind each day reveal more about us than we know. This could become a privacy nightmare, or it could be the foundation of a healthier, more prosperous world.

Similarly, we should enforce the use of anonymous data and, when possible, aggregate results. Such results will not be able to be connected with individual person who provided them. Robust collaboration and data-sharing models must guard both consumers' privacy and corporations' competitive interests. As Petland writes in his studies, You have the right to possess data about yourself, you have the right to full control over the use of your data and also you have the right to dispose of or distribute your data. This is really key topic reaching political and economical intrests which must not be underestimated.

Using virtual networks is an integral part of our lives
(http://evolllution.com/opinions/using-data-to-drive-successful-learning-partnerships/)



Senseable City Lab MIT, Real Time Rome. Data visualization
(http://senseable.mit.edu/realtimerome/)

Possibilities of open data

Open Data are the raw material for a new industrial revolution (Boček; Mráček; Mynarz, 2012:4). Open data is available to all without distinction. With each use their value is increased. By simply exposing these data on the Internet become multiplying their value. The most interesting way how to use your data invent someone else, is worded one of the reasons for opening them. It is impossible to predict whether it will be a small or large firm, the research team or a state institution. With certainty, we know that the location on the web gets public and private sector an opportunity to assess the data. These statements are related with data from institutes, companies or government data. Letting them open and enabling anyone to use them is the first step to facilitate dynamic growth of growing business and as result create an attractive and comfortable conditions for urban populations.

Regarding government data, when government opens them it say something about its attitude to the public. All these data can be used unlimited, all is transparent. Czech republic is lacking this attitude comparing to other countries like USA, Germany, Austria or Estonia. This type of data can be a catalyst for a new way of competitiveness. Competitiveness of the Czech Republic in the last five years has stagnated or decreases. There is an agree on that study by the Ministry of industry and trade, NERV and the OECD. They agreed on the fact that one of the impulses to revive is the openness of the government authorities. Compared to other solutions in addition by far the cheapest. These mechanisms of the growth of competitiveness are the improving the quality of public services, greater transparency and openness in public administration, data as a new source of business opportunities, improve communications agencies together (Boček; Mráček; Mynarz, 2012:12-14).

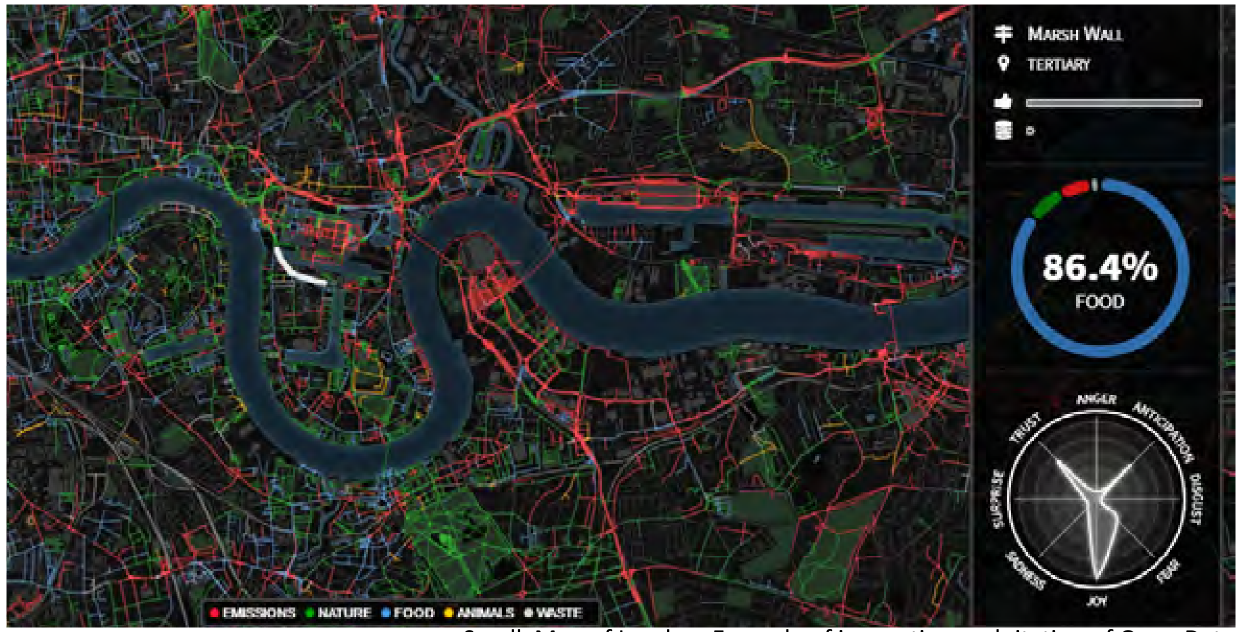
As an example we can list a few world open data projects (Pirnerová ; Tošovský, 2015:16-17) like Numberhood (UK), which combines more than 70 statistic information about locations. Brings together data on local level like crime, unemployment, or quality of health care. Walkonomics (UK) An application that finds most pleasant walking path between two points. Includes walks parks and alleys. Besides London, it operates in six other cities, for example, Paris or New York. Or another application to be mentioned is CrimeReports (USA). This is a map through which the user can enter a crime that was just committed in the immediate neighborhood and also to monitor the current situation. It is also possible to see the history of crime in the city, so you can easily guess where to go and where you'd rather not. This can also be helpful for scheduling police patrols or even for optimizing distribution of the police stations.

BOČEK, Jan; MRÁČEK, Jakub; MYNARZ, Jindřich. Otevřená data: Příležitost pro Českou republiku. Prague: Open Society Fund, 2012.

PETLAND, Alex. Society's Nervous System: Building Effective Government, Energy, and Public Health Systems: IEEE Computer Society, 2013. Available at: http://ComputingNow.computer.org

PIRNEROVÁ , Helena; TOŠOVSKÝ, Michal. Otevřená data: Jak česko umí využít potenciálu, který má internet. Ekonom. Prague: Economia, 2015.

RATTI, Carlo; OFFENHUBER, Dietmar. Decoding the City: Urbanism in the Age of Big Data. Basel: Birkhäuser, 2014.



SmellyMap of London. Example of innovative exploitation of Open Data
(http://goodcitylife.org/smellymaps/index.html)

SOM. Real-time visualization of bikeshearing data
(http://skidmoreowingsmerrill.tumblr.com/post/115597699049/beautifully-mapping-bike-share-data-big-data)

2.3 Smart Cities

Smart cities appeared in late 80s as a means to visualize urban context and they evolve fast since then. Smart cities can also be synonymous with intelligent cities, information cities, data cities or virtual cities. But always the meaning of this title is connected to data and theory that brings much more immediacy to our understanding of urban environment. In the history of urban studies and planning, most theories and their applications have focussed on the long term. On what happens in cities measured over months and years, certainly not over hours, minutes or even seconds. Such a data sets which are now available are certainly enriching our experiences of how cities are functioning, and it is offering many new opportunities for social interaction and more informed decision-making with respect to our knowledge of how best to interact in cities.

A smart approach to architectural and urban design could have a profound effect on our cities and communities, on how they are designed and how they look and operate once they are designed. An intelligent use of data could help to design places which respond effortlessly to public need or reduce and reuse excess energy. From an architectural perspective the clear benefits from using data. This could help to realise better designed places and better design processes. Such a smart approach can develop a common language and accessible platform that would enable datasets to be evaluated in relation to one another. That could help designers and architects understand and respond to dynamic changes in urban environment.

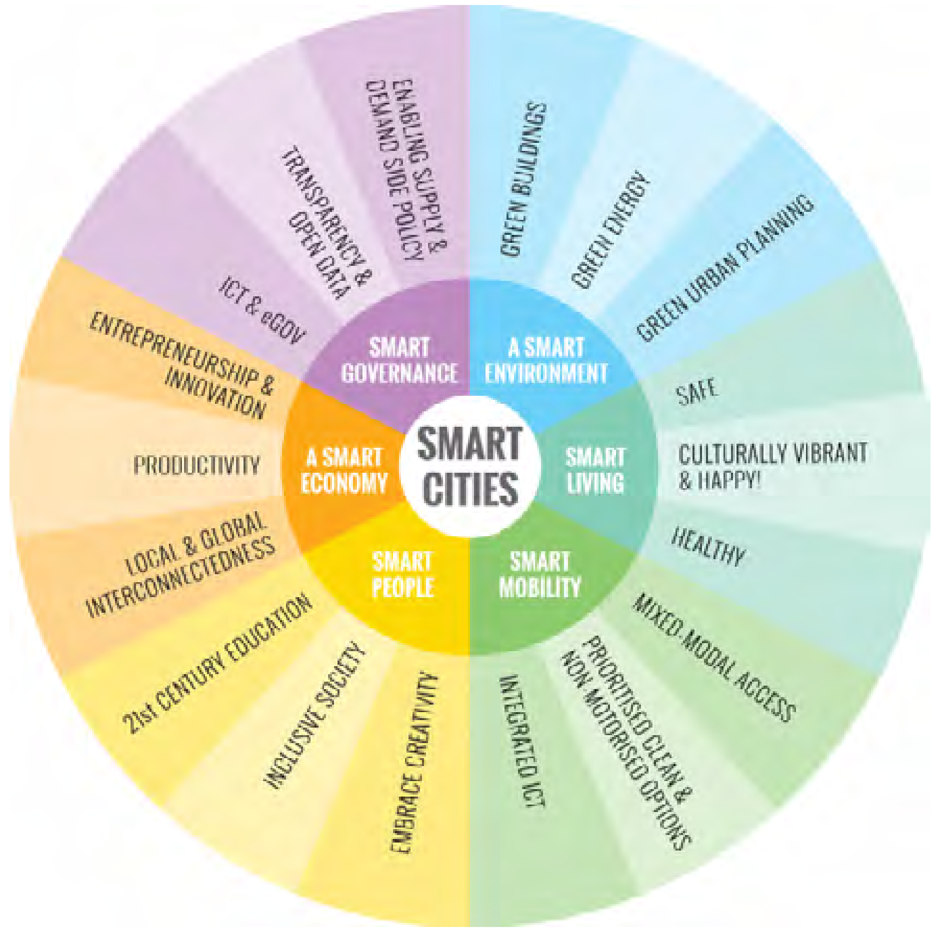
Why Smart Cities?
Against the background of economic and technological changes caused by the globalization and the integration process, cities in Europe face the challenge of combining competitiveness and sustainable urban development simultaneously. Very evidently, this challenge is likely to have an impact on issues of urban environment quality such as housing, economy, culture, social and environmental conditions. So these are the key areas of interest of Smart Cities.

The models of Smart Cities can be applied on a city or town of every scale and every. Although the metropolitan areas and cities in them are the most appropriate for application of such a theories due to amount of data which is produced in such urban areas, number of data sources and dynamics of these cities which need a let us say „smart approaches“. The term Smart City has became a kind of buzz word these day. Politicians, architects, activists and businessmen are using it how they want and how is advantageous to them. Therefore in more pragmatic way we can evaluate the level of Smart Cities, we can benchmark them and continuously adjust the strategies and processes. Through such evaluation we can understand what smartness of cities is really about and that the term „Smart City“ is not just a fancy word.

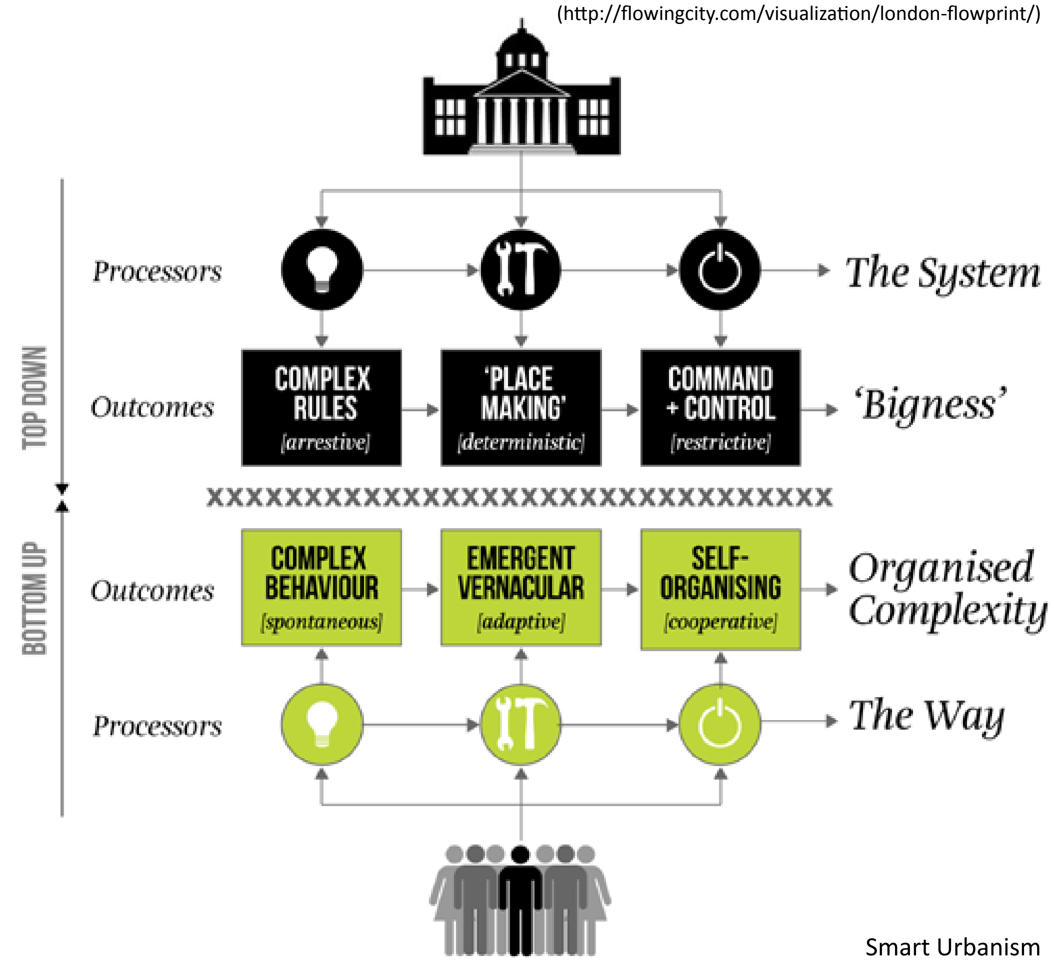
Dimensions of Smart cities through its data instruments meet built environment and refer to the following: Environmental protection (Quality), Resources' capitalization (Capacity), Coherent regional growth support (History and Landscape).

Evaluation of smartness
There are several possibilities of how the level of smartness can be evaluate. More evaluation processes are emphasize social environment, happiness of urban population, other focuses more on environmental qualities of cities. In this theses let me introduce the evaluation model that explores the matter comprehensively. At Vienna University of Technology, Department of Spatial planning (TUV, 2015) they have developed a process of evaluation and benchmarking of Smart Cities based on clear and obvious factors. On this department the scientists and architects are dealing more with European cities. But their results can be adjusted and applied also on cities all around the world. The partial results of evaluated cities can be seen and benchmarked on their website.

This city evaluation model defines a Smart City is as a city well performing in 6 key fields of urban development, built on the 'smart' combination of endowments



Interconnected principles of Smart Cities
(http://flowingcity.com/visualization/london-flowprint/)



Smart Urbanism
When top-down systems evolve to be conducive to bottom-up
(http://www.smarturbanism.org.uk/)

and activities of self-decisive, independent and aware citizens: Smart Economy, Smart Mobility, Smart Environment, Smart People, Smart Living and at least Smart Governance.

So for every single city there is a 6 key factors, 27 domains and for them 90 indicators. As the indicators evolve in time so does the final level of city. So to enforce the quality development and achieve a good position, the cities have to aim on identifying their strengths and weaknesses as well as to identify their chances for positioning and to ensure and extend comparative advantages in certain key resources against other cities of the same level. City rankings are a tool to identify these assets . Although they are quite common in recent time, current rankings are very different in their approaches or methods.

Platforms for Smart Cities

The challenges civic leaders are facing today can negate some of the elements that make cities attractive in the first place. While these challenges are not new, their scale and intensity are increasing. Even more difficult can be trying to address these issues in the face of financial constraints, administrative complexity, and expectations of rapid return on investments. Within individual city domains, the stark challenges and rising citizen expectations include: Digital cities challenges, challenges of safer, healthier and educated cities or these related with sustainability

It is not surprising world-leading companies in the field of network communication and IT are aware of importance and possibilities of Smart Cities. While cities are already well on their way toward modernizing their technology infrastructures, they will continue to face growing challenges as migration trends and citizen demands for services increase. Microsoft CityNext is the platform to help cities meet these challenges and provides solutions that focus the most important technology trends—cloud, big data, mobile, and social technologies:

Through the cloud, cities can connect public and private data sources with the privacy, security, interoperability. Through data and analytics, city leaders can gain vital real-time insights from multiple secure data streams—such as traffic cameras, social media, and devices and sensors that make up the Internet of Things (IoT)—to make more accurate decisions, achieve greater efficiencies, Through secure mobile devices such as sensors, smartphones, and tablets, cities can reach citizens anywhere, anytime, and on any device. Citizen-centric applications enable people to directly engage and interact. Through social media such as Twitter, Facebook, and Skype, cities can open two-way dialogues with citizens and businesses to better inform them and understand their needs.

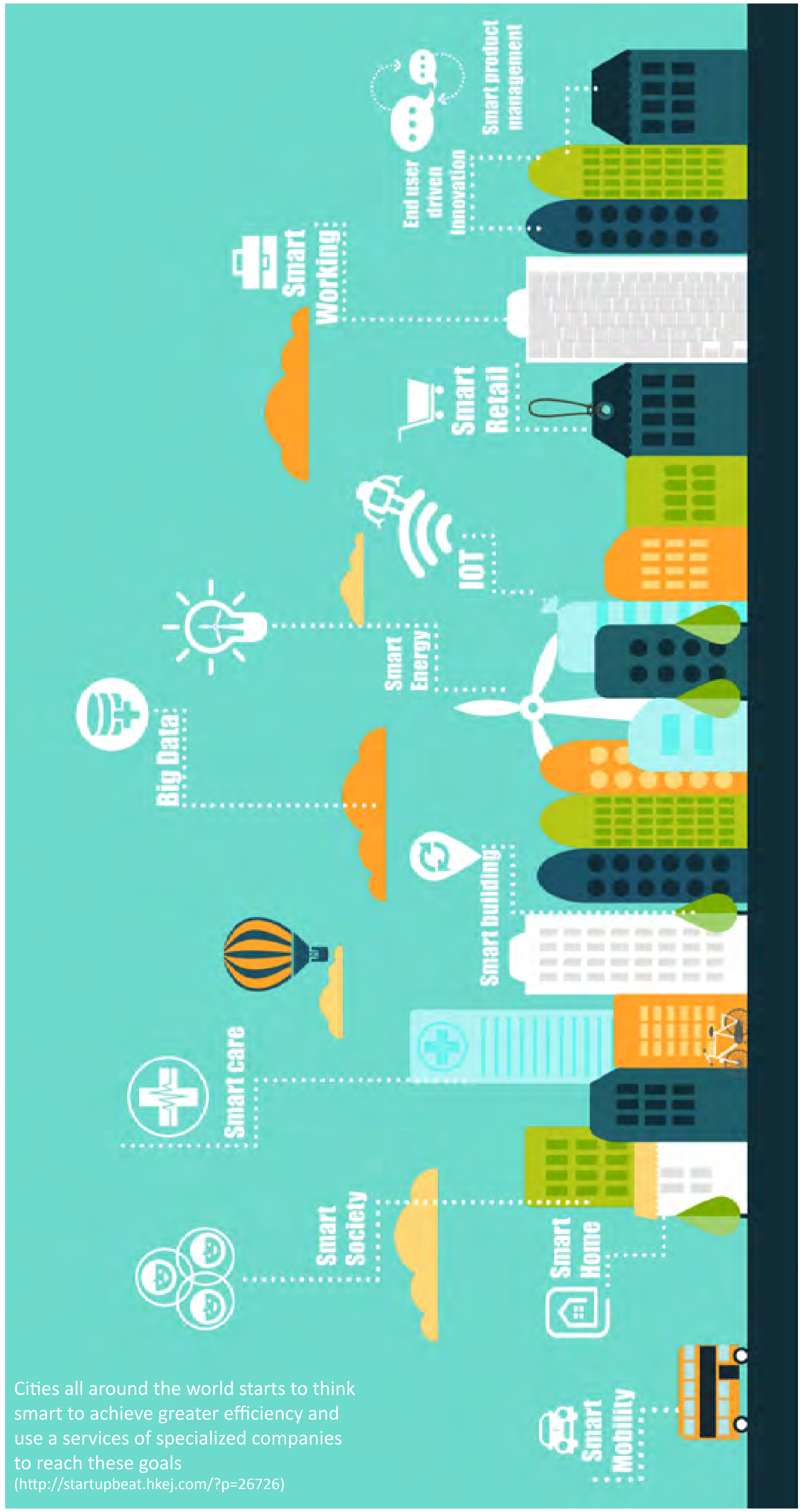
The informational platforms (similar provided also by Cisco or Siemens) can help the cities to get the most out of these technology trends and can help to transform a city's operations and infrastructure, engage citizens, and accelerate innovation to create more sustainable cities - places where citizens, businesses, and governments can communicate and work with one another.

How to became a Smart City

There are great opportunities for designers and planners to use data and digital tools for better design. Of course including making data available, opened, and developing tools to use that data in design. Royal Institute of British Architects formulated three basic recommendations for British cities to begin this process, which are possible to apply also on other cities (RIBA, 2013, 18-19). These recommendations are intended more for governments and city managements as the main force in the field of urban planning:

Better coordination between government departments to work together to realise a smart future. The focus is operational and needs to look beyond the management of cities to their design and development. Government departments therefore need to talk to each other to ensure data duplication is avoided and that gaps in data collection are identified. This would help the government develop a more holistic framework for smart data capture and analysis that incorporates lower level data, particularly that relating to the built environment.

Facilitate the digitisation of the planning . As part of its Open Data initiative the government should model and explore the potential benefits of a digital planning process. Government should scope how it can standardise the digitisation of all information submitted for planning, and of standardising design data collection across local authorities. This public data should be open to unleash economic growth. And local authorities should be encouraged to use open data to inform local planning strategies.



Cities all around the world starts to think smart to achieve greater efficiency and use a services of specialized companies to reach these goals
(http://startupbeat.hkej.com/?p=26726)

The national governments should commit to work with professionals to incorporate and develop smart design data specific to the built environment. To oversee the digitisation of planning governments needs to work closely with the built environment industry. The Departments, Communities and Local Governments along with organisations dealing with Open Data or Smart Cities should jointly set up a working group with built environment professionals and academics.

Planning Smart Cities

What is most interesting about Smart cities theory in relation to this thesis is how it can be applied in and translate to urban planning, spatial development and more quality urban design. Throughout any process huge amounts of data is assembled. Sometimes these are site specific, such as density and area calculations, but often have wider technical relevance to variables like transport accessibility, air quality, noise or flood risk assessments. Although many of these information are available online, these tend to be buried in scanned documents and PDFs. Thesw data could be used more intelligently if they was collected and stored in more appropriate formats. This level of smartness is still missing. Every planning authority across the country is scrambling to evaluate land supply and make strategic decisions about where housing should be located, but policy makers do not necessarily have sufficient base information to make good decisions about site suitability or housing quality. If essential data were available and accessible, we could build a much better process for delivering build-up environment quality.

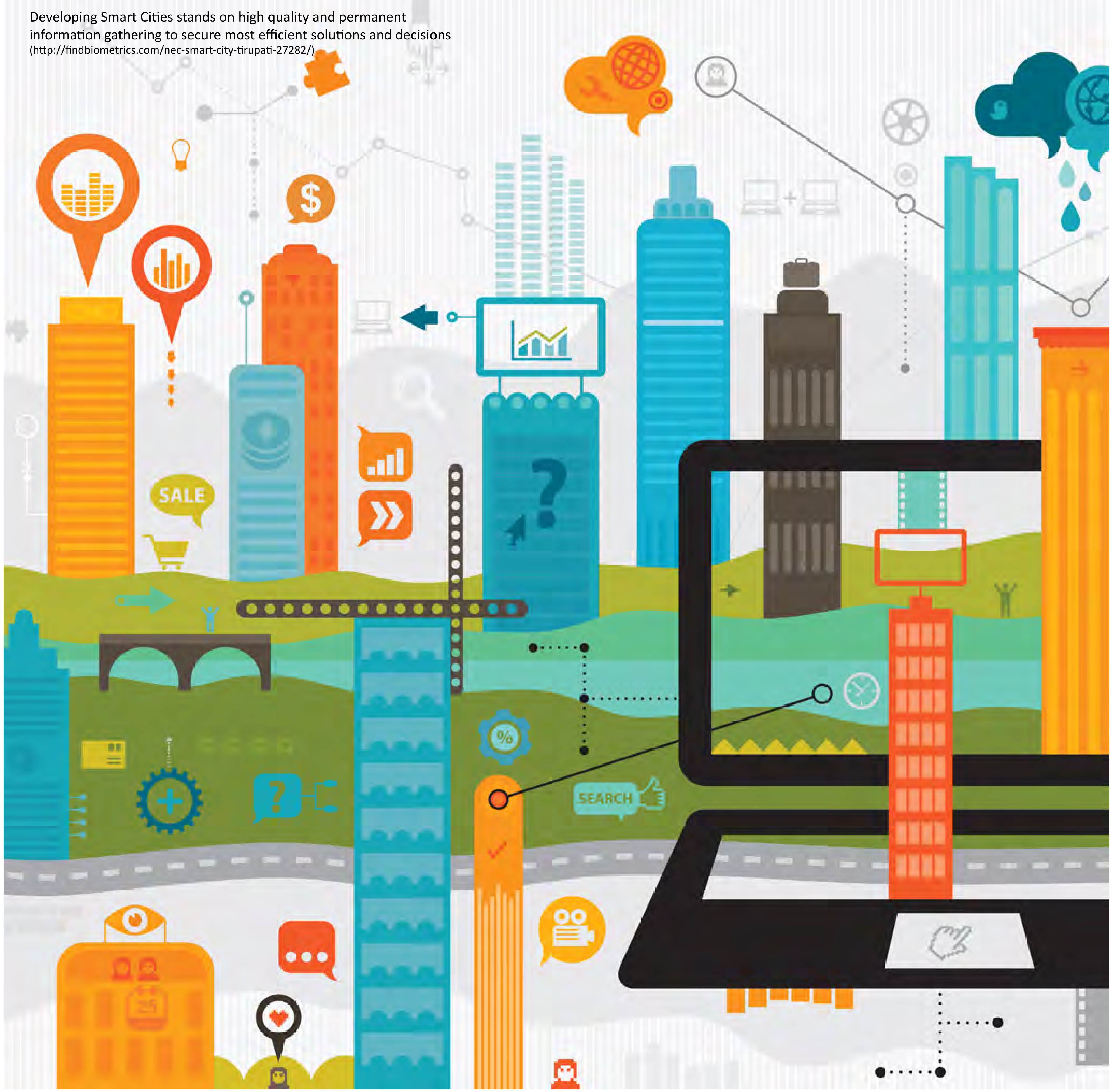
And we can go even further. If we deal with a city as a smart one, why not to use these informations and public-private cooperation for more flexible and responsive urban planning, urban design and even building construction processes? Why not to push further the meaning of smartness to have more sustainable, flexible, compact and liveable city environment forms?

Microsoft CityNext. Empowering Cities and Citizens. Microsoft Corp., 2015.

RIBA - Royal Institute of British Architects. Designing with data: Shaping our future cities. London: RIBA and ARUP, 2013.

TUV - Vienna University of Technology, Department of Spatial Planning, SRF - Centre of Regional Science. EuropeanSmartCities 4.0. TUV, 2015. Available at:
http://www.smart-cities.eu/?cid=5&city=47&ver=4

Developing Smart Cities stands on high quality and permanent information gathering to secure most efficient solutions and decisions
(http://findbiometrics.com/nec-smart-city-tirupati-27282/)



2.4 Urban Modelling, Urban Prediction

Urban modelling systems are not widely used in middle Europe planning practise. The benefits of its using are rather used in western European countries or USA, where these have much greater tradition. We can divide the urban environment models into two main groups regarding the scale and complexity. First group is Complex urban simulation methods and second are more flexible and more simple systems which are dedicated to help or attest local spatial planning activities. An other distinction can be based on the predestination of modelling results. There are models which are more dealing with Emergent or self-organising behaviour and its consequences for build-up environment, others are more or less considering the urban planning, land use definition or building regulations as strict elements controlling territorial development. But always the key theme is available data structures which can be used for evolution simulations.

Urban Models are representations of functions and processes which generate urban spatial structure in terms of land use, population, employment and transportation, usually performed in computer programs that enable location theories to be tested against data and predictions of future locational patterns to be generated. (Maier, 2012:211)

It this term Urban Modelling is the process of identifying appropriate theory, translating this into a mathematical or formal model, developing relevant computer programs and then confronting the model with data so that it might be calibrated, validated and verified prior to its use in prediction.

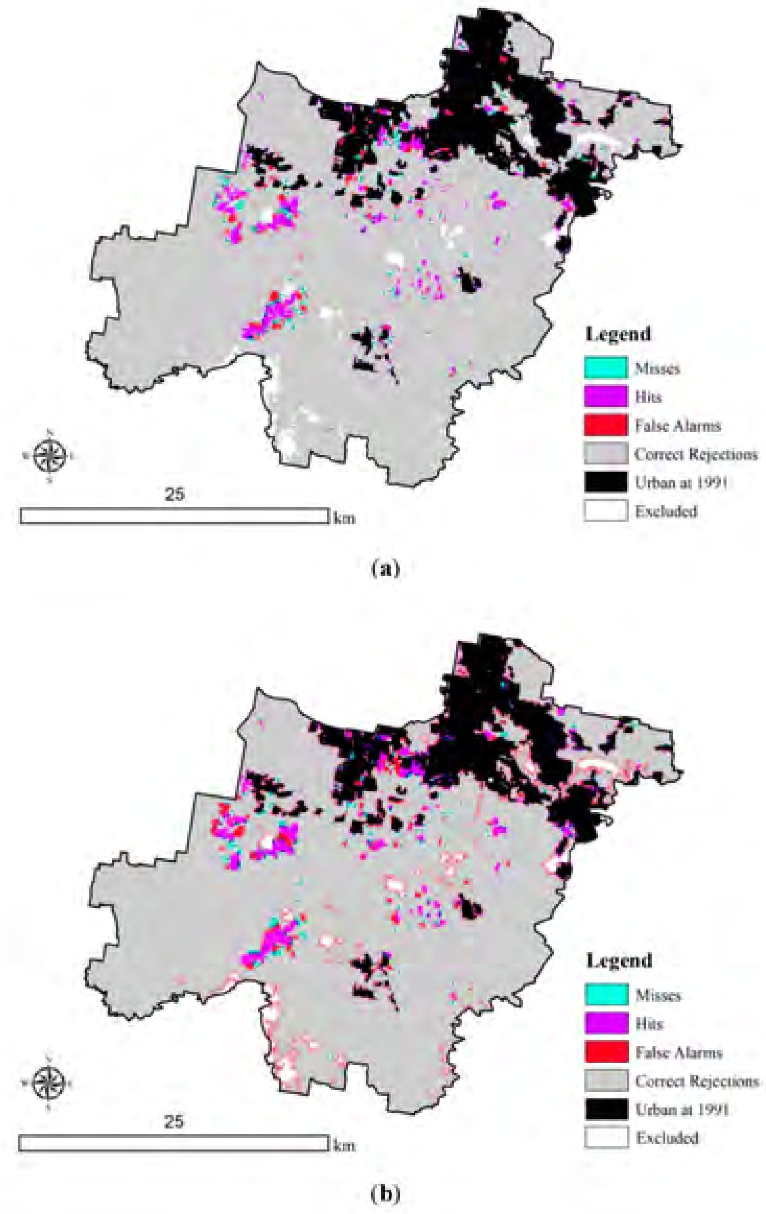
First urban planning computational models appeared already in 50. and 60. of 20th century. The rise of these models were caused by several reasons. According to Maier we can identify three main of them (Maier 2012:207). First was general change in urbanism theories and thinking, which transferred from spatial consequences perceived as art design to urban planning as applied scientific method. Planning of cities and regions became complex scientific discipline considering social-economical aspects, traffic solutions, public services or housing and recreation. Computational modelling methods were manifestations this theoretical shift.

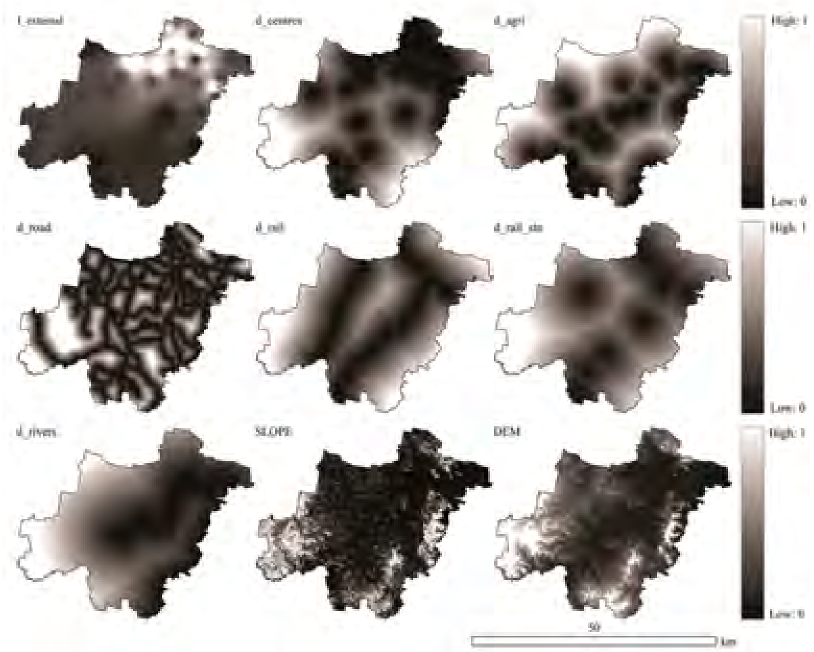
Another reason was of course development of computers and information technology solutions. This aspect enabled the formation of many mathematical or geometry theories latter used also in urbanism such as cellular automata.

Third factor which affect the rise of urban modelling systems was the huge increase of transport especially individual transport. Increased mobility of people and goods and relative reduction of distances lead to expansion of cities and unprecedented growth of built-up environment. Also to an expansion of functional regions and in some cases the transformation of city to scale and importance of region. So the first generation of models was dedicated for metropolitan areas in USA which were in the first place dealing with traffic issues.

Models are simplifications of reality, theoretical abstractions that represent systems in such a way that essential features crucial to the theory and its application are identified and highlighted. Models act in accordance to enable experimentation of theory in a predictive sense, and to enhance understanding which may be key to predictions of situations in the future.

Simulation models used in practise and also the theoretical or academic models are always based on specific kind of data. As mentioned in previous chapters urban data are really key topic to understand and enhance today cities. Regarding urban modelling we can identify several sets of commonly used data: prognostic data (population growth, economic activities etc.), socio-economic data (regarding households, relocation, location of jobs and housing etc.), real estate market data (market valuation and its dynamics), housing stock data (informations about the development of occupancy).





Spatially-Explicit smulation of urban growth through self-adaptive genetic algorithm and cellular automata Modelling.
Liu, Feng, Pontius, 2014
(http://www.mdpi.com/2073-445X/3/3/719)

In terms of cities, the kinds of urban theory that are basic to the development of computer models are those that are traditionally called location theories. theories that propose mechanisms that enable industries, services and households to locate in space within economic constraints of income and profitability. Later these traditional models have started beeing considered as loosened their link between theory and acctual city. In essence, theories of the city system were found wanting in that they did not reflect the diversity and heterogeneity that was very evident in modern cities, nor did they reflect the comparative volatility of urban dynamics suggesting that this dynamics could be absorbed within a wider equilibrium. (Batty, 2009:8) During the 1970s and 1980s, the aggregate static approach to theory of city and urban evolution modelling began to switch around to more bottom-up, decentralized or we can say emergent dynamics.

Introduction of urban plannig model

Now let´s introduce several urban models and their empirical applications. According to Michael Batty we can identify three such classes (Batty, 2009:14-16). First let´s say something about Land Use-Transportation (LUT) Models. This class of models is built around the aggregate static models of economic and spatial interaction. Theoretical backgroung of these models is rooted in regional economics, location theory and the new urban economics (classical macro and micro economics equivalent), and in certain way also in social physics as this can be said to embody social theory. These models have been slowly adapted to simulate dynamic change although they still tend to generate the entire activity pattern of the city. Probably the most highly developed of these models currently is the UrbanSim model (Waddell, 2002:297-314). Among others let´s point out the MEPLAN, TRANUS and IRPUD models.

Urban Dynamics Models is another class to be introduced. First i tis important to say very few aggregate dynamically temporal urban models have been applied empirically. After first attempts in late sixtees the focus has been on theoretical developments of non-linear growth and change which generate discontinuities through coupled non-linearities, threshold effects, or random perturbations (Allen, 1997). Generating a urban growth on micro-level through random perturbations of non-linear structures and integration of spatial interaction in models.

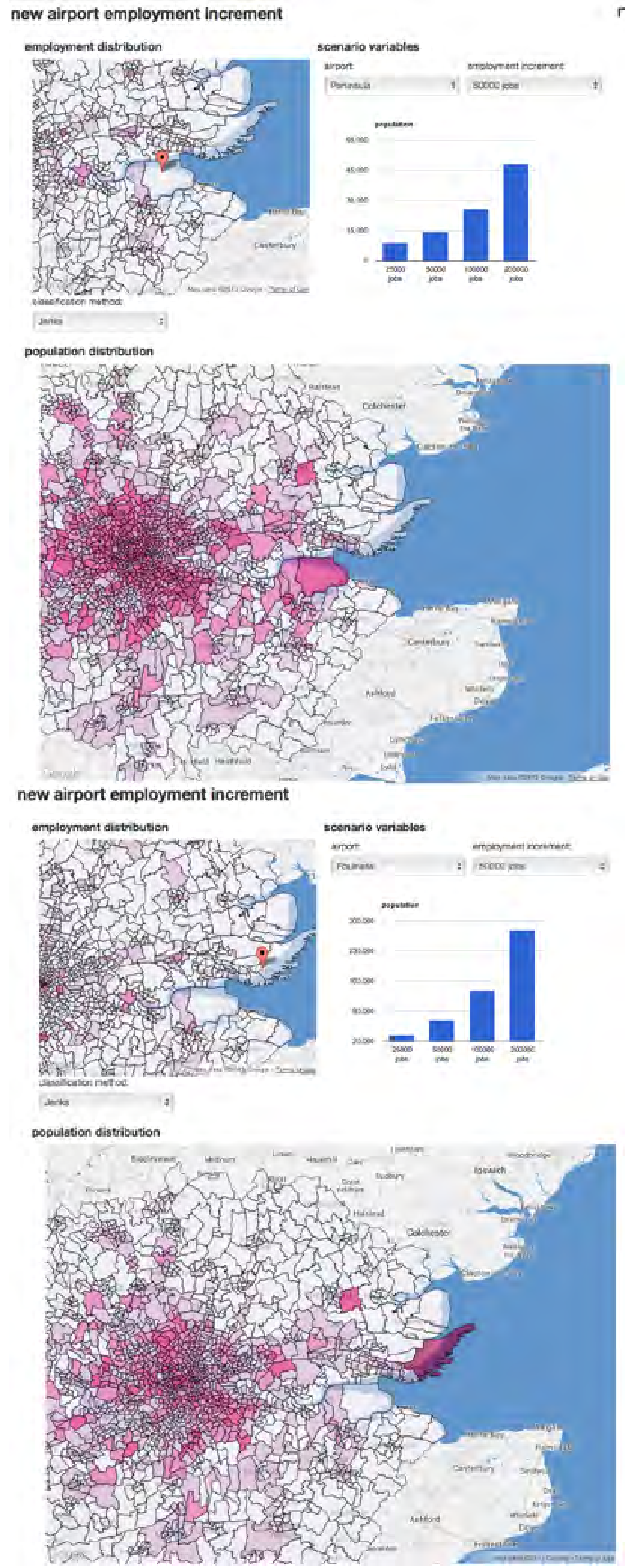
Various attempts have been made to link such models to ecological dynamics (models of predator and prey). Other attempts have also been made at fusing the chaos of the logistic into spatial dynamics. But in one sense, all these attemts regarding dynamics were less applicable to the kinds of urban processes that are characteristic of cities. As such they were simply the path to more micro models and have been eclipsed somewhat by spatial simulations of dynamic processes whose scale is at a much more individualistic level as embodied in agent-based modelling (Batty, 2003:10-14).

The third class is Cellular Automata (CA), Agent-Based Models (ABMs) and Micro-Simulation. This last class which is attracting the greatest attention at present involves models built around representing the actions and behaviour of individual agents located in space. As might be expected, there have been various predecessor models in this category. Housing market models constructed around individuals, market processes, and developer decisions were developed already in seventies. Other popular type of model which has been applied empirically but has not been used much for policy-making is that based on cellular automata where agents are in fact cells which change their land use cell state according to spatial ralations or characterictics of neighborhood. Among thi substantial number of applications few havebeen used to test urban policies. One of the reasons is that transportation is not taken in account or is even excluded in such models. The main focus is of course on urban growth and these models are tending to be indicative rather than predictive. The other issue is such models are primarily physicalist and almost ignore features of the spatial economy such as house prices, wage rates, and transport costs.

Urban models should be rather frameworks for assembling relevant information, frameworks for formal and informal dialogues where they are essential tools in much more consensual and participative processes of decision support.

An example of Land-use / transport interaction model (LUTI) for determining corelations among airports and rate of employment.
(http://www.mechanicity.info/research/land-use-transport-interaction-modelling/)

Simulation of airport location impacts. A large-scale activity-location model of the Greater London region is being developed in which all stages of the model-building process—from data input, analysis through calibration to prediction.



There are some agent-based models on the land use or activities level which enable predictions of future urban patterns, but the main focus is at the very micro-level where local movements in terms of traffic are being simulated. For example TRANSMIS as a hybrid of agent-based simulations and urban activities.

One of the most important models is Michael Batty´s and Yichun Xie´s, DUEM (Dynamic Urban Evolution Model) wich is based on combination of GIS data and cellular automata simulations. Authors present ways in which land uses are structured through their life cycles, and ways in which existing urban activities spawn locations for new activities. They also define various decision rules that embed distance and direction, density thresholds, and transition or mutation probabilities into the model's dynamics. Designed software produces efective urban simulations consistent with GIS data inputs, outputs and related functionality and of course evolution in time (Batty, Xie, Sun, 1999:206-208).

Another model to mention is Swarm Urbanism project by Stuart-Smith, Snooks and Podborsek (Leach 2009:56-63), which is theoretical swarm-based model that resonates closely with the logic of emergence. For example, authors refer extensively to multiplicities, to packs of wolves and to the logic of the crowd. The idea is that the population is not the individual. This model touches upon the logic of the city itself as a space of flows. Of course there is a lot more agent-based models (AMB) with different role of agents, using different emergent algorhytms, with different relation to data implementation, transportation systems or with ability to market simulations or urban design configuration.

If we look back on the part describing using urban data and its benefit for society understanding and predictiong of its behaviour, we can interconnect it with urban modelling theme in a way to design fully data-driven spatial and socio-economical models of cities. Basic principles of such a models should be (Petland, 2013:42):

- Dynamics of models, so that they can be used constantly and continuosly in a modeled system

- Reflect the structure of the phenomenon being modeled meaning human social networks in most cases

- These models should be driven almost entirely by real-time, real-world observations.

According to Petland these three principles imply that social models should incorporate continuous observations of both agents and their network and their mutual influences. Models that combine these three principles consistently should perform better than traditional agent models or machine-learning math algorithms. Unfortunately, most human behavioral models are either agent models built largely from psychological data or machine-learning models such as support vector machines that do not capture the structure of human social networks. Implying this real-time data source shold enhance the prediction quality agent-based models.

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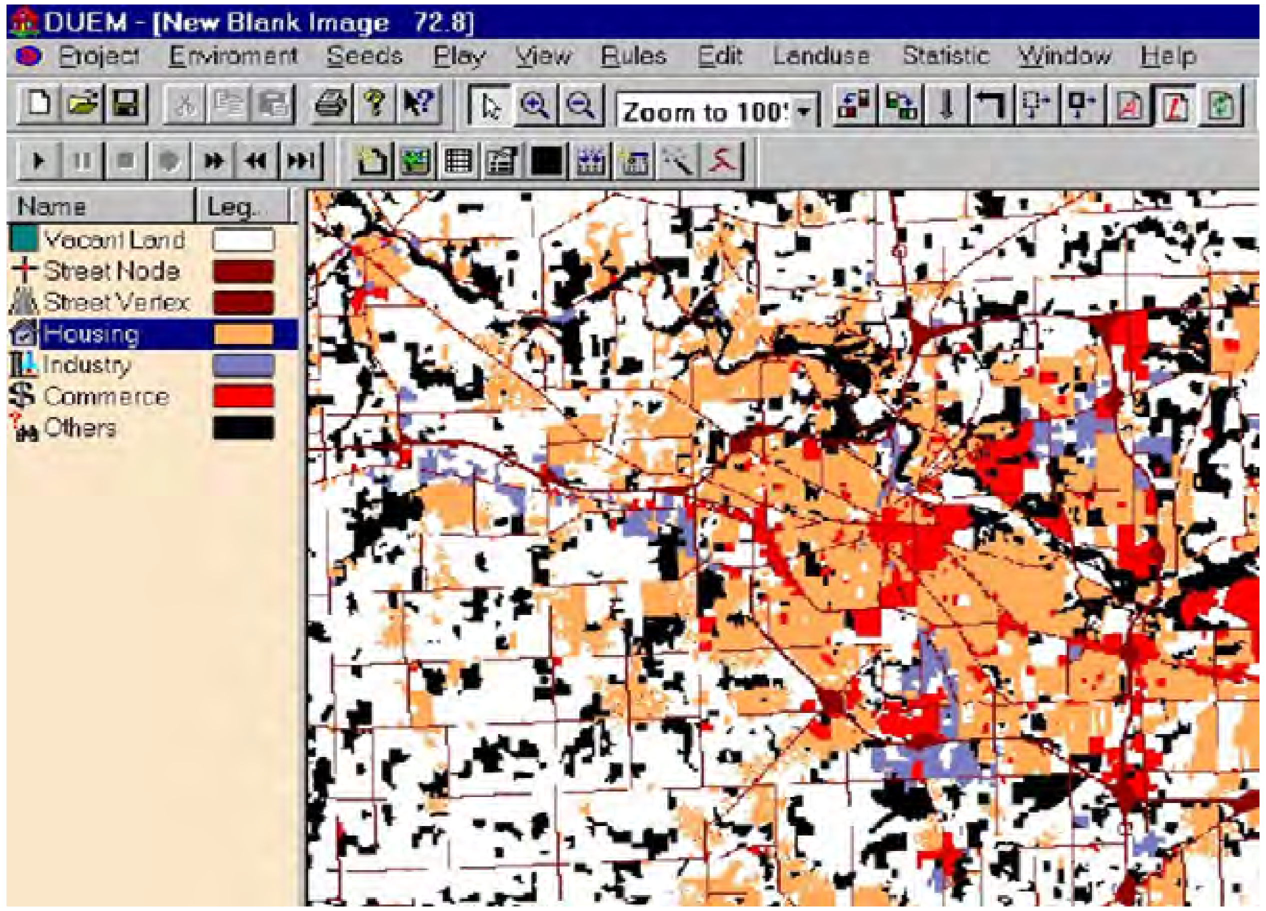
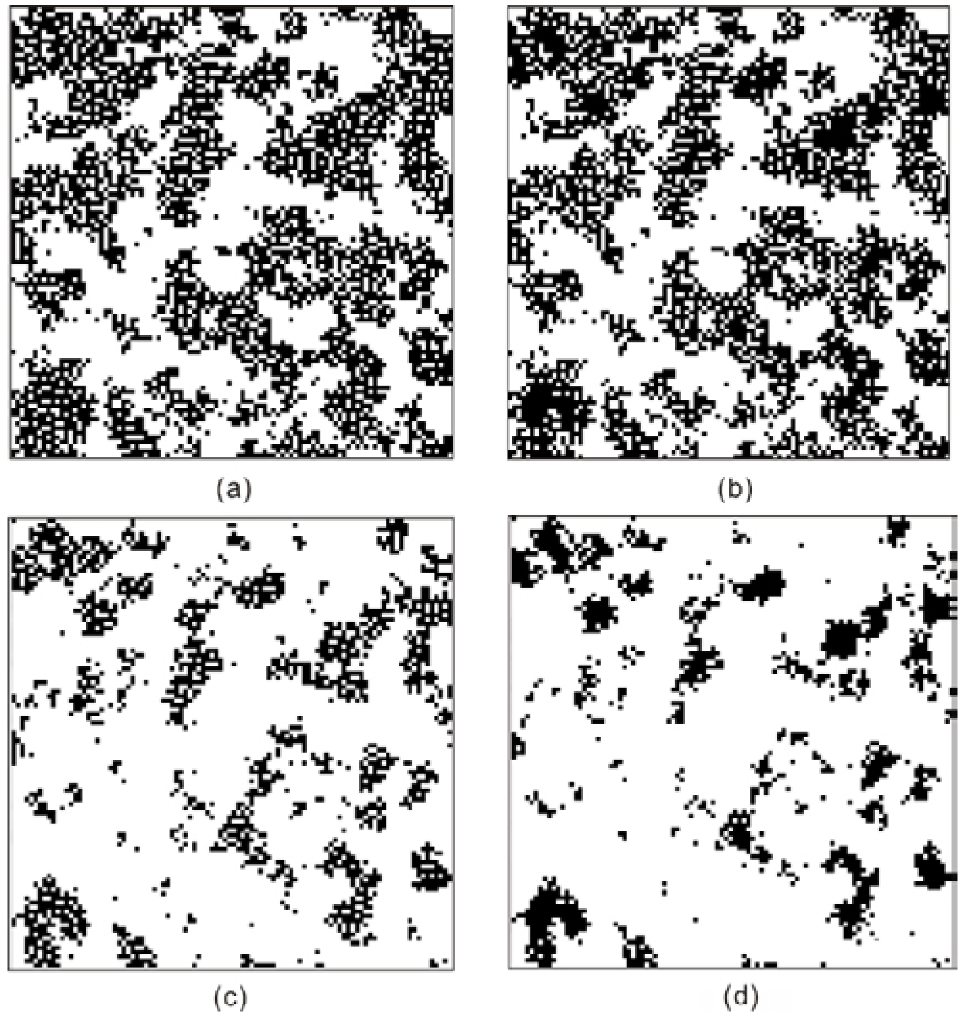


Dynamic Urban Evolution Model (DUEM) users interface



Dynamic Urban Evolution Model (DUEM) based on cellular automata and GIS data inputs

(BATTY, XIE, SUN .Modeling urban dynamics through GIS-based cellular automata.)

2.5 Cities as Complex Self-Organising Systems

First lets clarify what is Complexity and what is its meaning for a City. Over the last twenty years, in science and social science, and in policy analysis, indeed in general, we have realised that the world is an infinitely complex place, not quite as understandable as we once thought it was through science. Hence the rise of the complexity sciences. Key to this is the notion that systems and societies build and evolve from the bottom up, and are not planned from the top down. This has happened because of many different forces coming together: the demise of centralised economies/societies, The miniaturisation and individualisation of technologies such as the computer, the car, even mass housing, the growth of globalisation, the network economy, the idea that all of us acting individually make a difference and the fact that systems grow from their elements (Batty, 2011:2-3).Of course its important to understand than when we are talking abou complexity in cities, there is always some kind of top-down interventions and decidios, in oder to secure public investments and genereal public wealth.

The thing we have to is the Enter Time. Especially when we are dealing with Generic Models, Multi-Agent Systems, Cell Systems and their application in Cities (Batty, 2013:34-40). In the past most of this science considering cities has been a timeless science. A world in equilibrium, and the reasons are obvious.

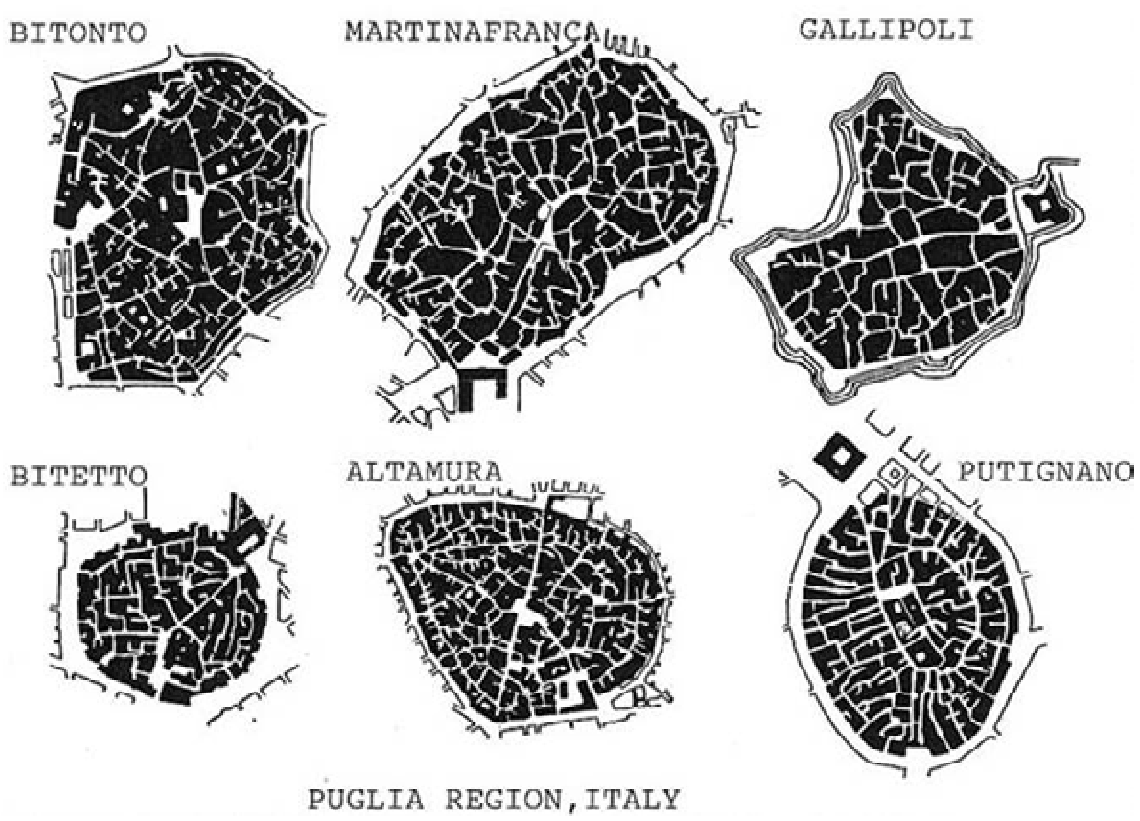
Cities look like they are in equilibrium physically because of the inertia of the built environment, temporal data were really hard to get and so on. In the 1970s, there were many flirtations with Chaos and Catastrophe theory (studies of the behavior and condition of dynamical systems that are highly sensitive to initial conditions - small differences in initial conditions yield widely diverging outcomes for such dynamical systems which makes long-term prediction in general impossible)(Kellert, 1993:32). Or with Bifurcation theory (theories of changes in the qualitative or topological structure if a change is made to the origin parameter values – which is causing a sudden change in behaviour) (Blanchard; Devaney; Hall, 2006:96) and some models were developed theoretically.

These researches and tendencies led to integration of the phenomenon of the Time in the urban sciences and generely in how we currently think about the cities. But in the seventies and eighties the progress was slow and as probably the most significant we can mark the embedding of predator-prey models theory into simulating rapid growth (non-linear, differential equations frequently used to describe the dynamics of biological and ecological systems in which two species interact, one as a predator and the other as prey - according to these equations the populations change through time) (Hoppensteadt, 2006).

But by far the most significant were notions made bit later about how urban structures might be generated similar to the way fractal structures grow. These fractal theories were explaining urban growth using fractal models. In fact a good deal of this was anticipated in the early quantitative geography movement beginning in the late 1950s where there was a concern for morphology. And the implementation of these ideas was generally based on cellular automata kinds of algorithm (Batty, 2013:35).

Relying on multiple examples from biology and physics, the studies show that systems which follow emergent morphogenesis processes (action and adaptation) such as cities arrive at complex forms.

To conclude, we have seen that urban planning is a response to scale problems created by spontaneous urban growth. Urban planning then creates its own inverse scale problems. Naturally complex structures, which work at every scale simultaneously, are the outcome of emergent geometric rules. Therefore, each aspect of the urban development process must be redesigned with such rules to achieve an emergent urbanism that will resolve all scale problems. So when we are talking about Complexity in the cities, we can conclude it into these three main factors (Héllie, 2010:42):
-Complexity means solving problems at every scale.
-Emergent geometric rules are necessary to create complex cities.
-Each aspect of the urban development process must be redesigned.



Characteristics of organic urbanization
(Héllie. Emergent Urbanism: The role of urban complexity in the practice of urbanism. 2010.)

Application of complex theory to science of cities is than obvious. So here is a question now: how can we now incorporate an emergent urbanism to city planning and decision making? We have to redesign the role of each actor in planning and designing process or more general in the production of cities, and the rebuild whole process starting from the small-scale and extending it to the large-scale (Héllie, 2010:32). Individual actors and their decisions and demands are crucial to understand an incorporate to whole planning process to secure an adequate spatial organisation. As Héllie sets, we have to:
- Rethink the role of the homeowner in house building
- Rethink the role of the developer in subdivision
- Rethink the role of public works in the network
- Rethink movement entirely

An most important conclusion should be architects and urban planner should not design and draw the plans anymore, they should be designing and developing system. The complex planning system which respects processes and interconnections of modern cities and their dynamics. In previous chapters challenges of modern cities were mentioned and a attitudes how to face them (see chapters Smart Cities or Urban Data, Open Data and Urban Dynamics). To be really able to face them and secure resilient and adaptable cities, complex and more holistic point of view have to by applied in every level of spatial planning and architectural design.

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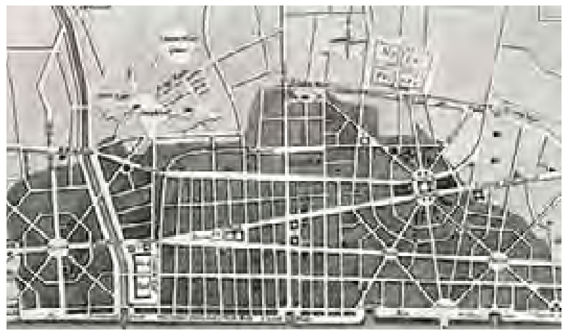
Characteristics of evolution of urbanization of urban space organization
(Héllie. Emergent Urbanism: The role of urban complexity in the practice of urbanism. 2010.)



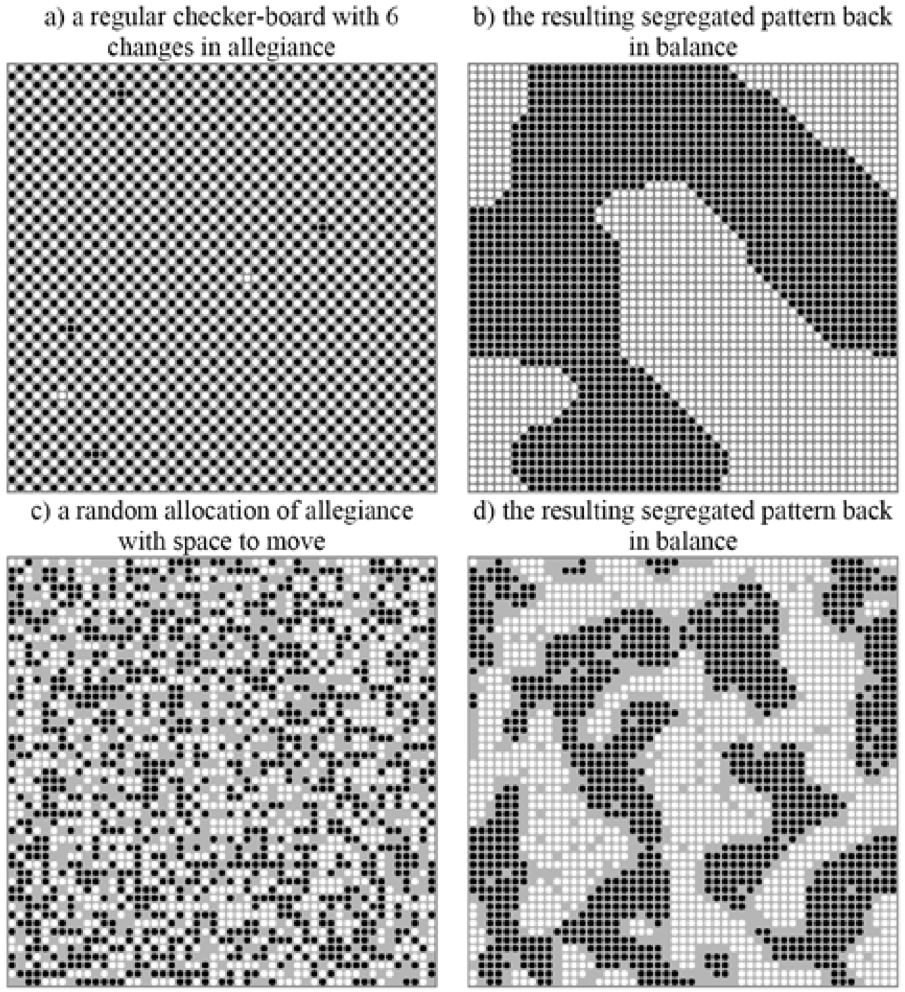
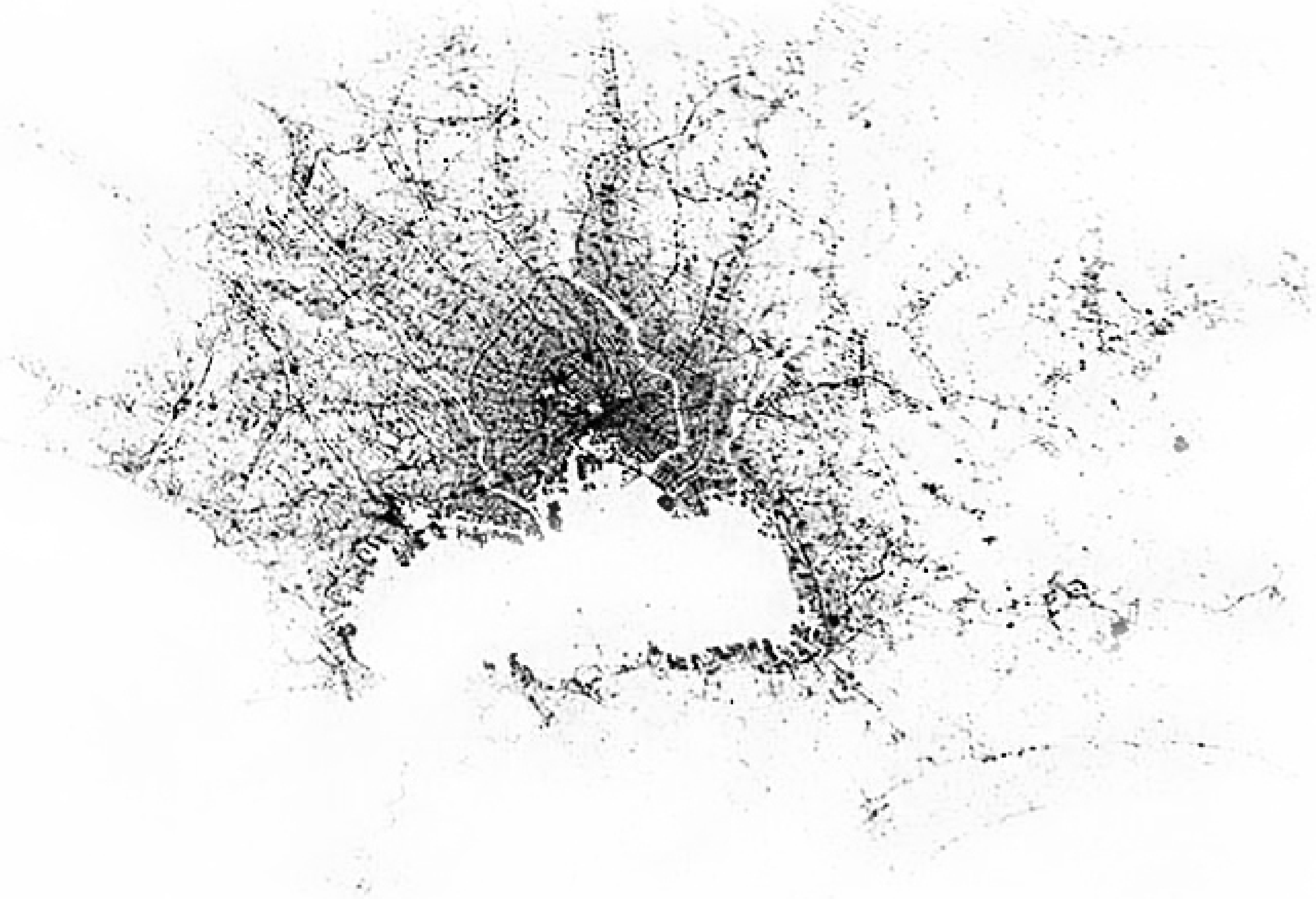


Figure 7: Emergent Segregation: A Fragile Equality (a) gives way to Segregation (
A Random Mix with Available Space (c) gives way to Segregation (d)



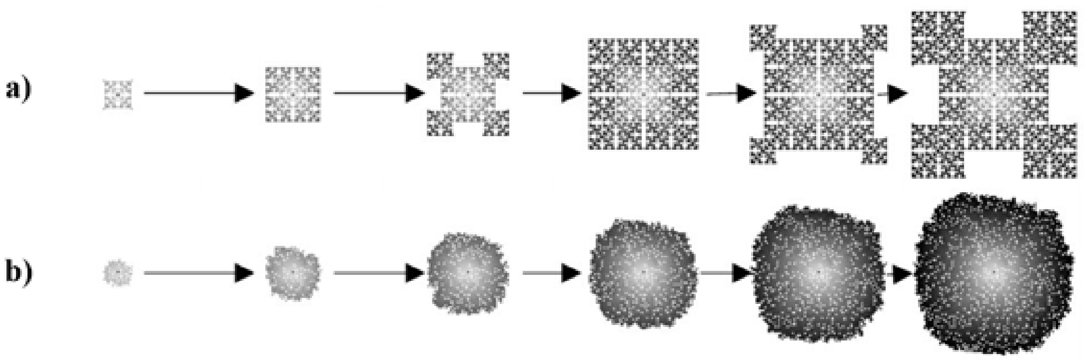
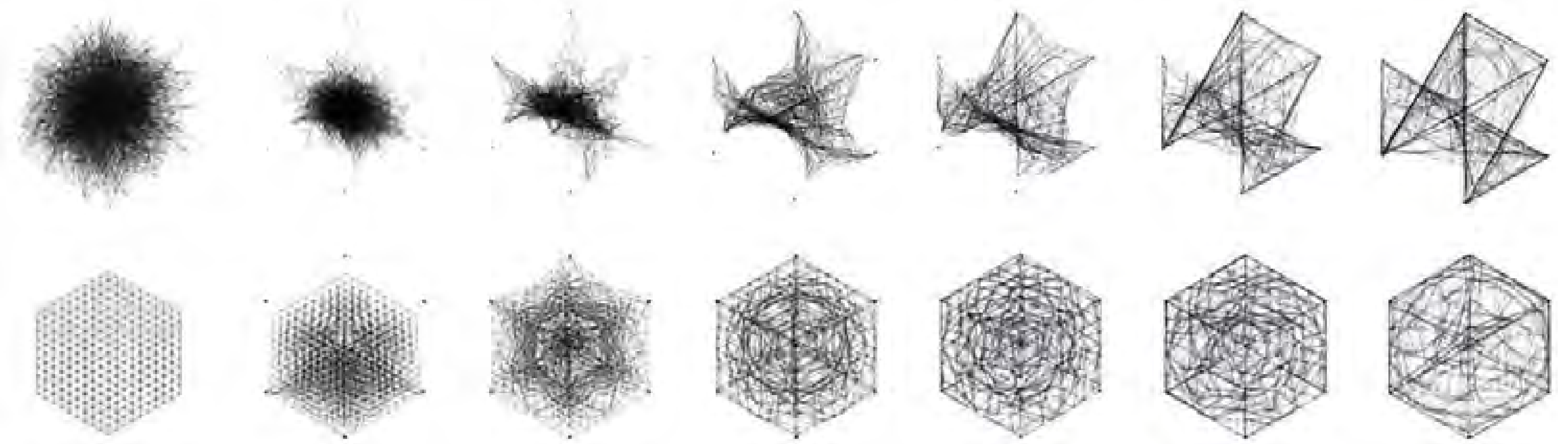


Figure 11: Growth from the Bottom Up

a) deterministic growth based on developing cells if one and only one cell is already developed in their 8 cell adjacent neighborhood, and b) stochastic growth based on developing cell if any cell is developed in the adjacent neighborhood according to a random probability



Diagrams showing how we can understand cities as complex systems
(Batty. Science of Cities. London: Centre of Advanced Spatial Analytics, UCL, 2013.)

2.6 Urban Dynamics, Social Physics and Dynamics

Social physics as a term is over two centuries old, yet the challenges are really contemporary and modern as they relate to ethical dimensions surrounding Big data and policy making. According to Alex Pentland, it is a quantitative social science that describes mathematical connections between information and idea flow on the one hand and people's behavior on the other hand. Social physics helps us understand how ideas flow from person to person through the mechanism of social learning and how this flow of ideas ends up shaping the norms, productivity, and creative outputs of our companies, cities, and societies. This Social physics theory is accopanied with an extensive use of Big data, available about all aspects of human life.

Social Physics is when social science meets big data. As big data from cellphones, badges, credit cards or various sensors becomes available, it's a little bit scary for society, but it's a gold mine for social science and understanding of human behavior.

Humans have basicly two types of thought: one is Habitual, second is Attentice. In the first type process of human behaviour is fast, parallel, automatic and associative. In second type of attentive thought system is the behavioral process slow, serial, controlled and rule-based. The field of Social physics is dealing with first type of system, with dynamics of Habitual system. This al lis happening in certailn context, and also meaning of time is importatnt (past-present-future acting). In this context we can say that people mostly learn by examples, not arguments. Their behaviour is affected by this context.Social Exposure Predicts Behavior. We can see these networks for example by using sensors in smart phones. For example Proximity Network, Call Network, Friendship Network or Co-location Network.

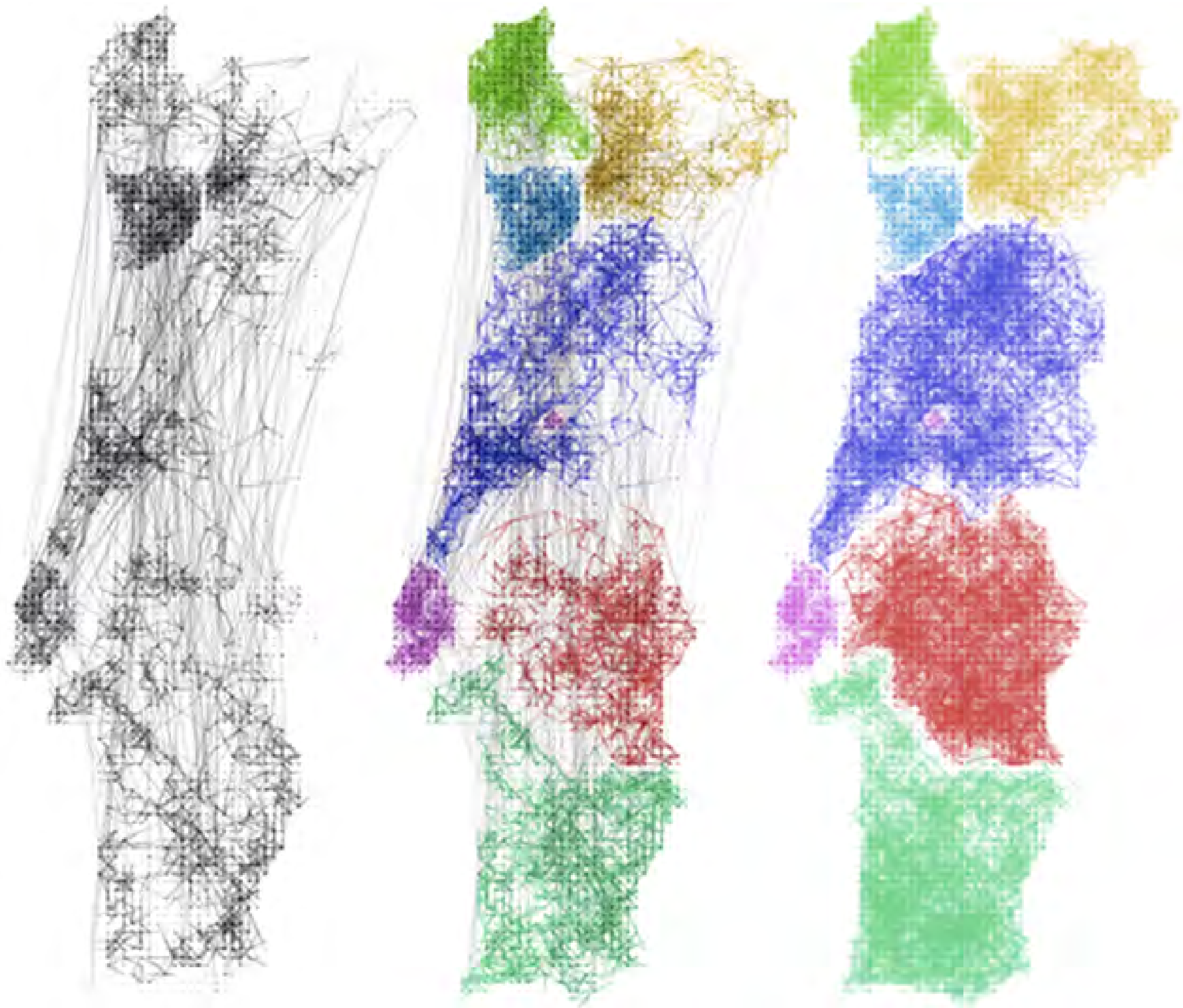
Shaping Social Networks - Incentives that leverage social influence. In this case one need to count with global and localized externalities of group behaviour – rewards that one gain from behaviour of others. This phenomena is known as Peer rewars incentive. These ideas were demonstrated on social financial trading research social based financial trading was examined and trading was considered as collaborative problem solving. On these research is possible to see Idea-Behavior Flow and there is also possibility to count the probability of it and see the influence of social network on it. This can be later use for prediction of return on investments. In this case it is known that decision accuracy dependes on diversity of informational sources. The patterns of social ties and their importance on effectivity of performance of whole group was also explored. We can associate this with effectitity of businisses, companies, or also nighborhoods, clusters or even whole cities. In this case a level of engagement is the key factor. Density of sharing of information within group. Also the meaning of Big data phenomenon and its importance for social studies and studies of urban behaviour is underlined in Petland´s research (Petland, 2013). We can use these data to understand the needs and the behaviour of city users and the dynamics of this behaviour. Also understanding people's interactions in the generated social networks. But first we need to collect adequate amount and quality of data from individual´s devices, smart phones etc.

In Summary, Social Physics is a serious attempt to benefit from big data about transaction of people. It generate new interesting results concerning human behavior. To study idea flow is essential for understanding social change. Many aspects of human behavior are more related to the frequency of interaction than to the content of communication. Still to understand social change one has to study also novelties, innovations and intellectual breakthrough.

Critiques of Petland´s work such as Antti Hautamäki postulates that we need also "slow sociology" studying deviations and creation of new knowledge – the impact of thinking. To practice Social physics alone means dehumanization and naturalizing social sciences. There is a question how is knowledge created. It's created in the process of collaboration and it is a result of co-creation. In this sense taking idea flow as a central concept of Social physics is appreciated. But new knowledge is also a product of individual thinking, of individual capabilities (Hautamäki 2014:6).

HAUTAMÄKI, Antti. Social Physics studies idea flow by big data. A critique of Alex Pentland's new book. Helsinki : University of Helsinki, 2014.

PETLAND, Alex. Reality Mining and Shaping Behavior. Mitchigan: MIT, 2013.



Personal data and how to use them to understand modern sociaty
(WEF ITTC-Personal Data, Report 2011)

3. Design Tools

3.1 Multi-Agent Systems (MAS)

These systems are in general simulated environment where there are interactions among individual actors – so called agents. These interactions are among particular agents as well as among agents and surrounding environment. Whole process is simulating intelligence, behaviour and decisions much greater than separated individuals. The importance of these systems and simulations is in the resulting behaviour of whole system. Sometimes are MAS understand as new paradigm for conceptualization, design and implementation of software systems especially these in open environment (such as virtual environment or internet). Thanks to the interactions during simulations the final behaviour of system is different every time the simulation starts. Agents are always reacting to current state of all algorithm inputs. MAS are resembling living ecosystems such as flocking of the birds or fishes (Petrš, 2013:50-51). In some MAS the intelligence and strategy of individuals is often suppressed (more importance is given to the behaviour of crowd as whole), in others these individual tactics and strategies are base of the whole modelling (Game theory, Mechanics design theory). During developing of D.U.M. both of these systems were used.

Of course it depends on the setting of behaviour, level of interactions, amount of agents and surrounding environment. Through these systems it is possible to simulate decisions of crowd, which is of course composed of individuals. Therefore these systems are used for modelling of crowd behaviour in all kinds of spatial conditions, decisions in economical systems, transport simulations etc. Sometimes MAS are considered as the most simple form of artificial intelligence. Main features of MAS are:

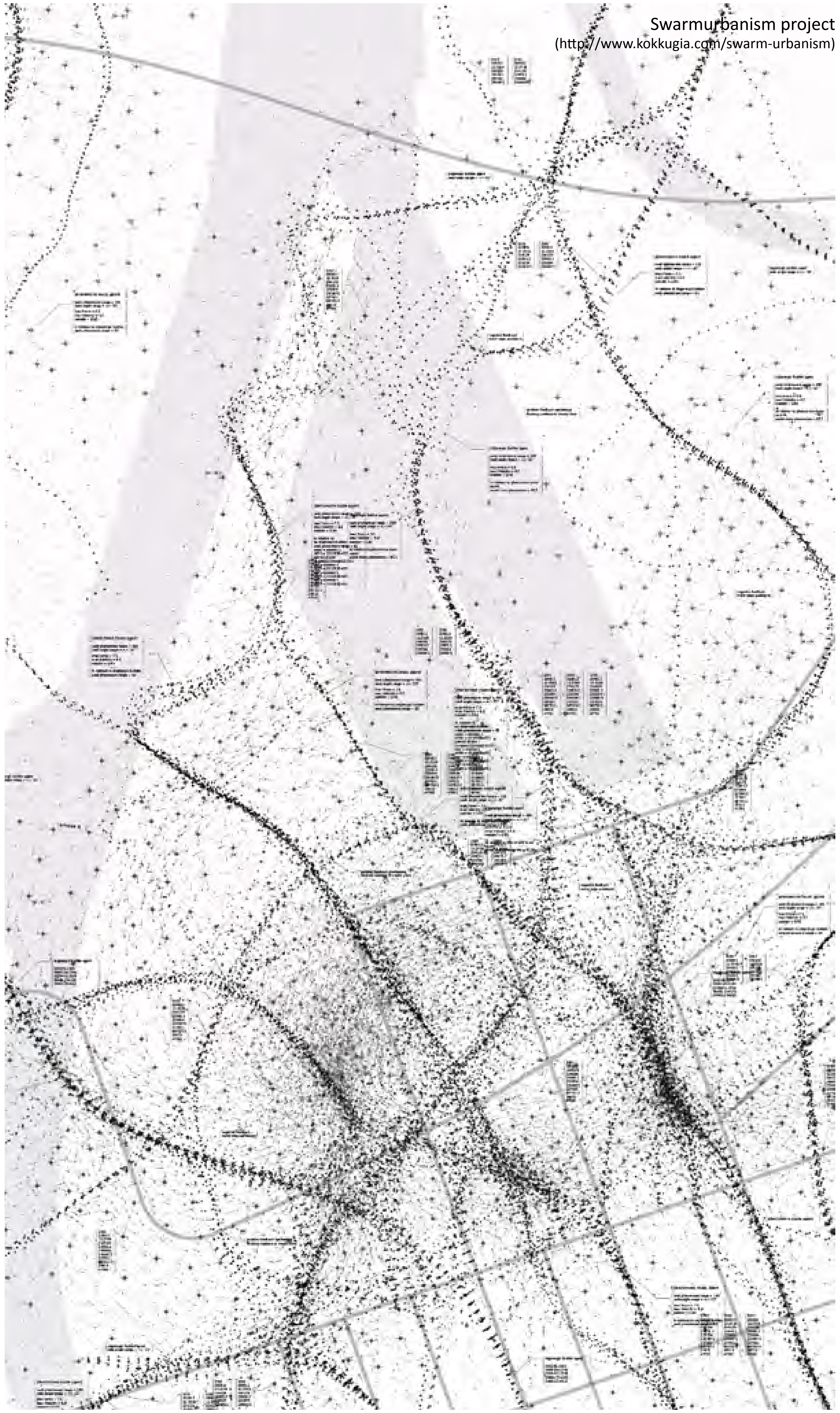
-Each agent is autonomous
-Each agent has limited and incomplete informations or abilities of problem solving and has just limited point of view
-There is no global guidance of the system simulation (agents are acting by themselves)
-Data, according which agents are deciding, are decentralized
-The calculations in algorithm are processed in asynchronous way

Today we can say than MAS has grown to the level of their maturity. They are used in many fields as mean of communication between human and computer. These fields are for example flying (driving non-pilot systems like drones), logistic and transportation (simulating and planning of traffic or transportation of energy and materials), social networks, economics (behaviour of crowd) and also architecture and urban design, nowadays rather in their experimental form. In the future MAS are anticipated and planned for construction of structures which are composed of self-assemble units. MAS have already been used for guiding of drones which are constructing specific designs of structures and buildings. There are also intentions and tests of combining 3D printing technologies and MAS.

MAS are capable of modelling how individuals interact and how structures emerge through such interactions, in terms of both the social and physical environment of cities.

The MAS employed in this work are also called Boids. It was invented and published by Craig Reynolds in 1987. The name of the MAS is derived from term „bird-like-objects". As other MAS this system is based on interactions among agents and environment. The main regulations of behaviour are Separation, Cohesion and Alignment. Other main rules which are used in designed script are Seeking (Attracting) which is something what the agents are searching for and also in some simulations Obstacle (Barrier) which are some areas from which the agents have to stay away.

Separation is a parameter that serves for preventing of segregation of individuals from the flock. Cohesion


Swarmurbanism project
(http://www.kokkugia.com/swarm-urbanism)

represents the behaviour of individuals moving into the center of gravity of the flock. Alignment is a parameter to track other individuals in the flock and stay with them

Strategic behaviour of agents

The agents employed for simulating of decisions of investors with specific demands for allocation of their investments designed in D.U.M. script are based on protocol for strategic agents called Mechanism design. Unlike MAS based on Social choice theory, which are non-strategic (these systems take the preferences of the agents as given, and investigates ways in which they can be aggregated). Mechanism design is a strategic version of Social choice theory, which adds the assumption that agents will behave so as to maximize their individual pay-offs (Shoham & Leyton-Brown, 2010:273-280). For example in an election individual agent may not vote their true preference but what is best for his yield. We are assuming that the agents are self interested, in general they will not reveal their true preferences. As a designer of D.U.M. the intention is to find an optimal outcome with respect to the true preferences of individuals (agents). So the further procedures, when all is done in accordance with the declared preferences, will not in general generate any objections. And that is why strategic Mechanism design principles are used for prediction of allocation of private investments.

Let´s explain the term Mechanism design bit more. It is a field in economics and game theory that takes an engineering approach to designing economic mechanisms or impulses, toward desired objectives, in strategic settings, where players act rationally (Börgers, 2008). It has broad applications, from economics and politics (markets, auctions, voting procedures) to networked-systems (internet inter-domain routing, sponsored search auctions).

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PETRŠ, Jan. The Swarm Tower. Diploma Project FA CTU. Prague: CTU Faculty of Architecture, 2013.

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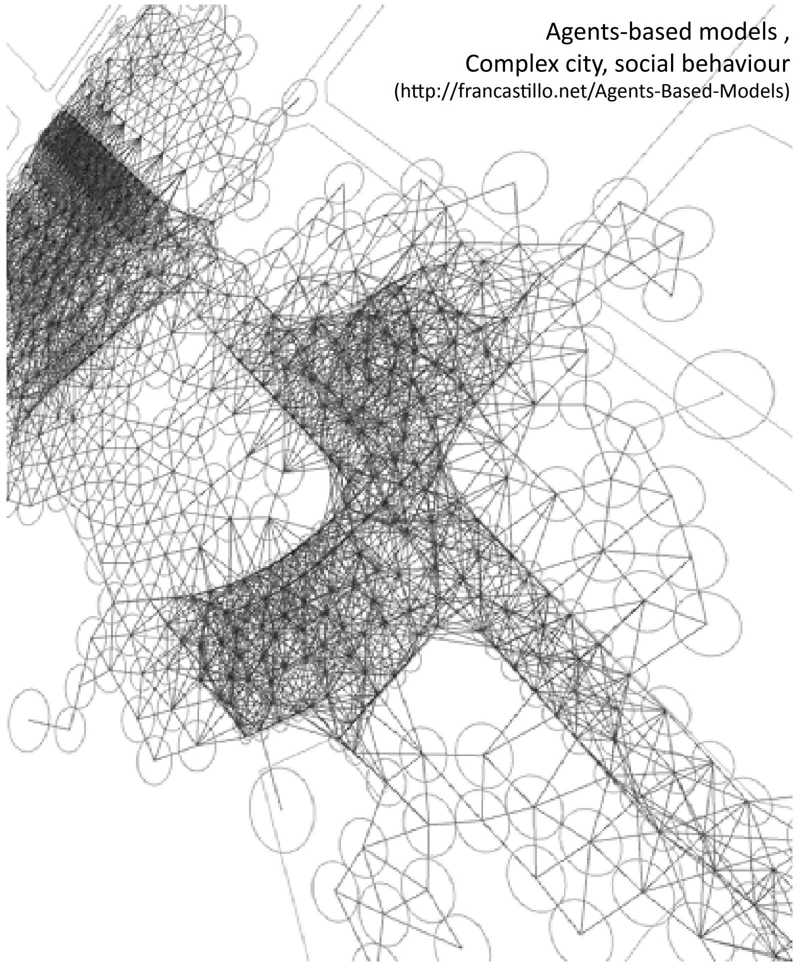
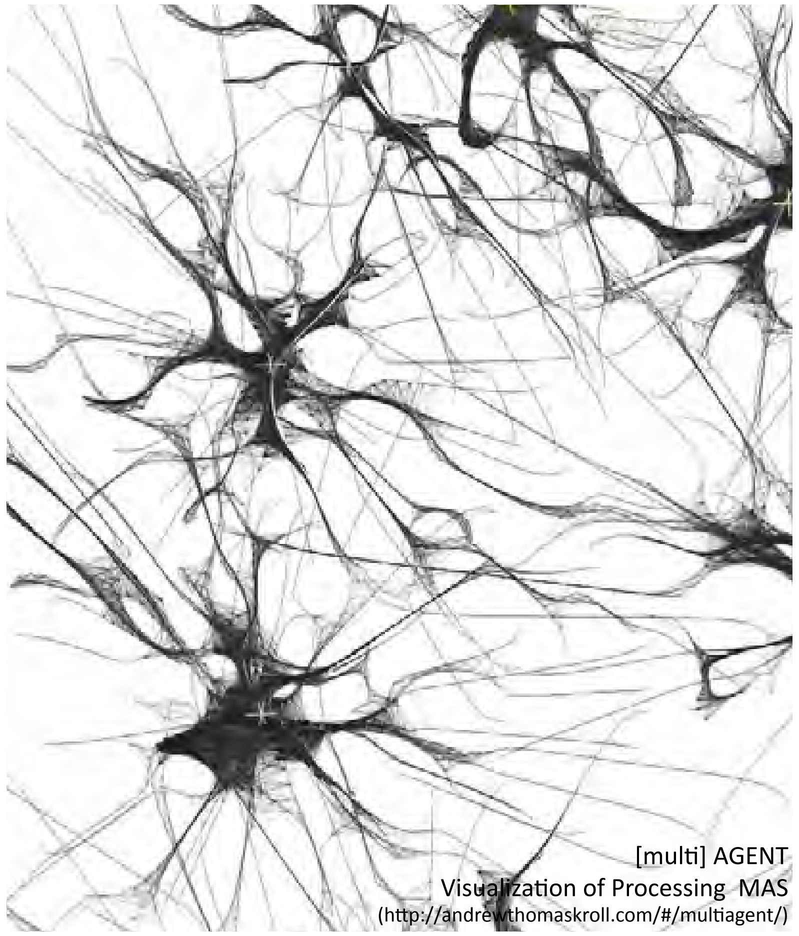
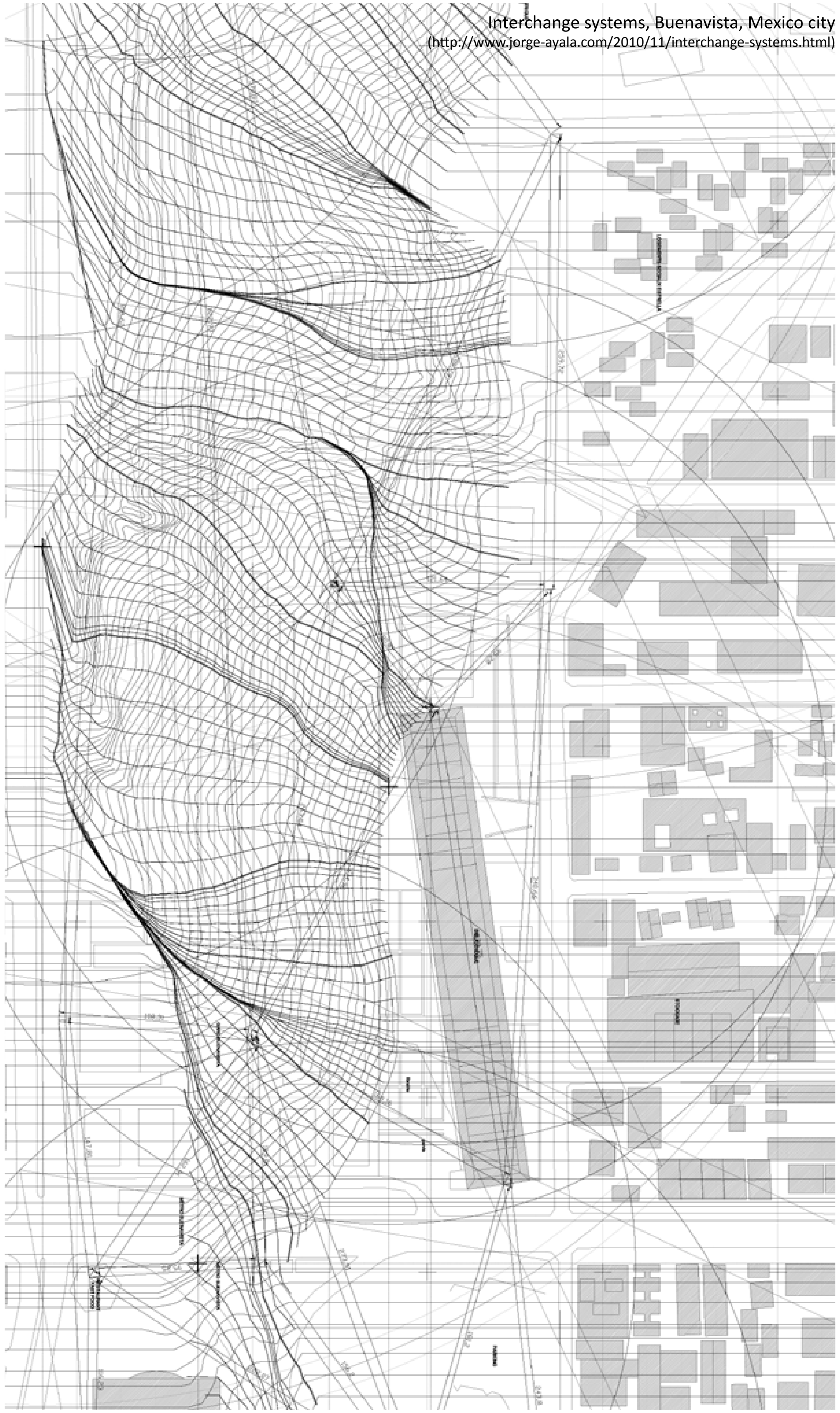


Agents-based models ,
Complex city, social behaviour
(http://francastillo.net/Agents-Based-Models)



[multi] AGENT
Visualization of Processing MAS
(http://andrewthomaskroll.com/#/multiagent/)



Interchange systems, Buenavista, Mexico city
(http://www.jorge-ayala.com/2010/11/interchange-systems.html)

3.2. Big Data Analytics

What actually is big data? We are all aware of the term big data but not everyone knows what it means, and even fewer people know how to manage and analyse it to improve decision making. And this is related to any field you can imagine. When we search for people working with data to explain what it means to them we discovered it means different things to different people. We typically think about big data in terms of volume or the amount of data. We know we are facing problems as a result of the ever increasing availability of data or the data explosion. But let´s not look at this enormous amount of data as a problem. Let's perceive it rather as a new possibility. The promise of Big Data Analytics is to help us to answer specific problem, which can then be used to make informed decisions.

However, we might already begin to see it is much more. We can also think about big data in these terms (QUT, 2016):

- Variety: data in many forms. Different types (structured, unstructured), data sources (internal, external, public), data resolutions.
- Velocity: data in motion. Speed of data generation, speed of data handling and processing.
- Complexity: different sources, different formats, different forms. Data can be small in size but very complex, so it pushes the boundaries of current computational and analytical algorithms.
- Veracity: data in doubt. The varying levels of noise and processing errors.
- Value: cost of data

Many organisations know how to manage and analyse data that are familiar to them that might seem 'big' to others. For example, geospatial specialist might know how to manage satellite data or land cover data. Hospitals might know how to manage Computed Tomography or Magnetic Resonance Imaging scans. Business analysts might know how to analyse social media data. However, when the number of satellite images or medical scans increase and their resolution improves, or the amount of social media data explodes, even these familiar data sources become inconveniently large.

Moreover, when the analyst wants to use satellite images to improve business intelligence, or the hospitals have the opportunity to use social media to learn about patient experiences and outcomes, then they lack experience in dealing with these inconvenient data sources. Importantly, our traditional data tools are no longer sufficient. We need new ways of managing and analysing the data. And that is the same problem we face also in the terms of urban planning, urban design and architecture. Inconvenient data sources and relating them to our area of expertise.

Now what to do with data? In general way, firs we need to analyse them. According to wikipedia Analytics is the discovery and communication of meaningful patterns in data. Or more precisely in our commercial world predictions used to recommend action or to guide decision making rooted in business context. Analytics requires many tools used in science such as data modelling, machine learning, optimisation algorithms, visualisation, etc.

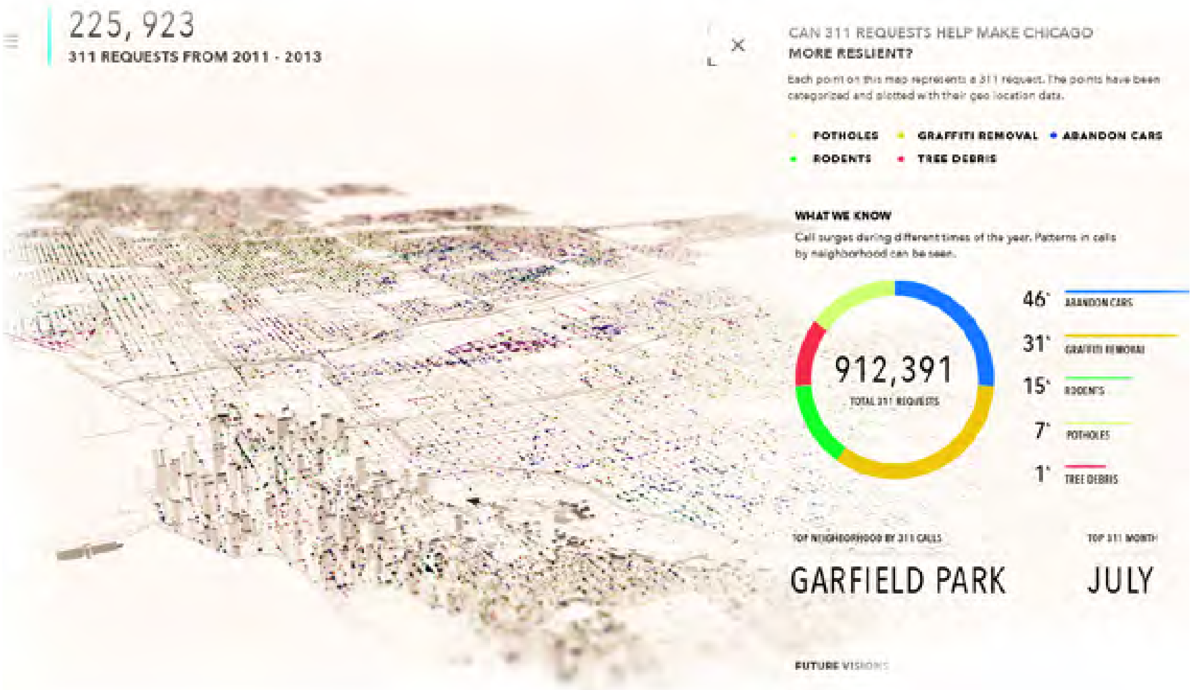
Big Data is like having an access to the whole box of crayons. With the right know how and skills this allows to construct a complete and detailed picture.

Data to decisions

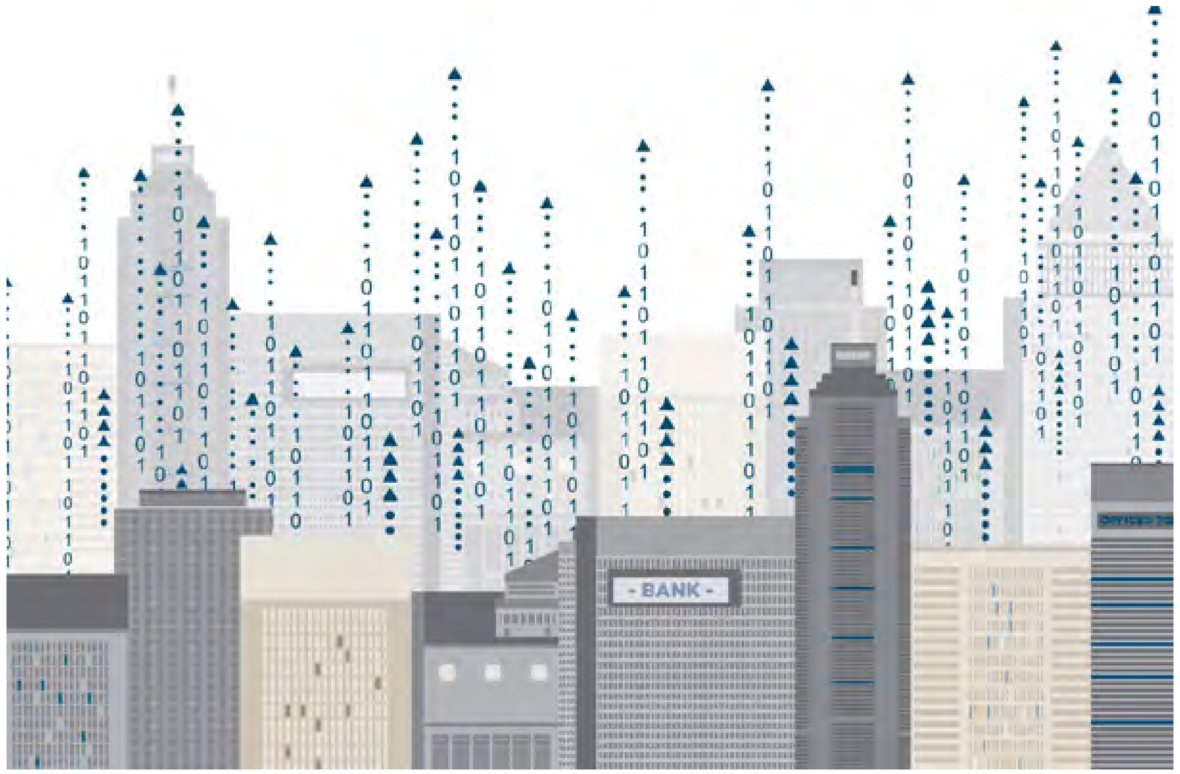
Analytics and integration support decision making based on data. The data to decisions model provides us with an insight into the data types, models, tools and processes that support the pathway shown in the big data wheel. We begin with the scientific data layer, the foundation that includes all of the data being generated in structured or unstructured formats, from various sources such as sensors, images, point clouds, social media, etc. This is our big data.

On that we can build our analytics layer, which includes all of the models that are doing the processing or computing. They can be statistical functions, feature

Chicago - the city of Big data
(http://dataconomy.com/chicago-city-big-data/)



Cities and Big data analytics
(http://raconteur.net/big-data-2013)



extractions, image analysis, etc. As an outcome, the data size is slightly or substantially reduced.

The integration layer is responsible for putting things together, parts of different compute algorithms, results to interplay with each other to give a final result for the decision-making layer, in the form of visualisation, or a number that can be presented (for example, on the web in a mobile app).

There is no doubt that we are facing a data explosion. At first need to stop confusing data and information. Data is the collection of observations. Information is the intelligence we gain by processing this data with relevant tools. Big data as a means are useful for exploring the hidden connections among the multitude of complex, non-linear and interconnected systems which surround us. We have so much data available now that standard statistical and mathematical techniques are not well suited for managing such large quantities of them. With respect to modelling, the focus has turned from traditional statistical and mathematical models to more scalable techniques that can more successfully accommodate the large sample sizes and high dimensionality (QUT, 2016).

The Great Barrier Reef Example
Big data is everywhere, and is for everyone. But, how can we actually use big data to make decisions? A field that can benefit greatly from the use of big data is the environment. And it doesn´t matter if it is urban or natural environment. Both have their specific qualities and elements to measure, but in general it is always the environment that surrounds us. Let us take a closer look use on Big Data analytics on a natural environment. These data are related to the Great Barrier Reef. Australia is home to the world's largest coral reef system, the Great Barrier Reef. Composed of over 2900 reefs and 900 islands spanning over 2300km, it is one of the most diverse ecosystems on the Earth. However, due to its large size, monitoring different trends in the reef becomes very difficult. Difficult but still possible.

At QUT researches are developing mathematical and statistical models that use big data to better understand environmental impacts and trends in biodiversity on the Great Barrier Reef. They obtain data from a variety of different sources including observations, sensors, images and the internet (Great Barrier Reef Program, 2016).

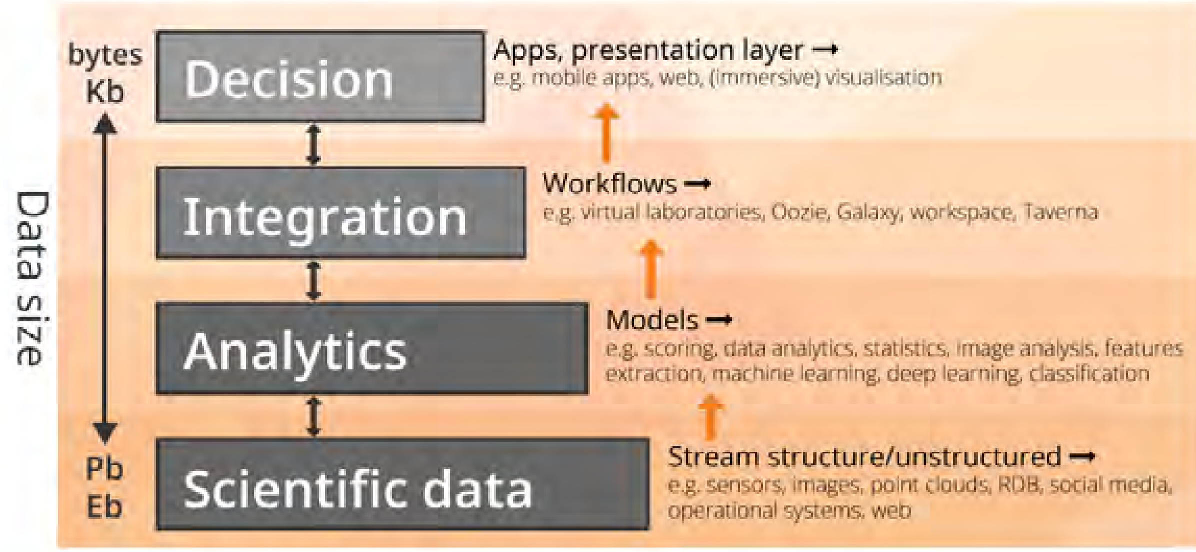
From this data scientists are able to make predictions about evolution and decisions about how a man should or should not impact into this complex natural system. The program enables anyone who visits the Great Barrier Reef to contribute to its long-term protection by collecting valuable information about reef health, marine animals and incidents. For this purpose a several applications have been designed. These apps also helps to draw the public deeper into environmental issues.

Complexity and organics of the Great Barrier Reef is without any doubts or discussions. And in spite of this fact, through big data analytics people are able to describe key processes, understand the evolution trends and finally make a decisions how to react on all that stuff. If this is possible in such an organic and complex system which evolves itself regardless the instigation of humanity, why these procedures can not be used to assess the urban environment and cities?

BOLLIER, David. The Promise and Peril of Big Data, Washington, DC: The Aspen Institute, 2010.

Great Barrier Reef Program. 2016. Available at: http://www.gbrmpa.gov.au/managing-the-reef/how-the-reefs-managed/eye-on-the-reef

QUT, Queensland University of Technology. BIG DATA: From Data to Decisions. Online education course. 2016.



The data to decisions model supports our big data wheel
(Queensland University of Technology. BIG DATA: From Data to Decisions. Online course.)

How to deal with data - Big Data wheel
(Queensland University of Technology. BIG DATA: From Data to Decisions. Online course.)

3.3. Complex Urban Design and Parametric Urbanism

Some planners are calling for a shift away from rigid, conventional approaches towards more complex, flexible ones. They say, we have to rethink concepts of planning (Flint, 2015). We as an architects and urban planner have kept on believing we could control growth by building elegant and liveable neighborhoods. But issues connected with global phenomenon of urbanization are much more complicated. Since conditions in current cities are connected with great uncertainty, planning and design in extension must be more versatile, flexible and adopting more methodologies. This involves concepts bottom-up, crowd-sourced self-organization and understanding of spontaneous order. One key how to compete with current challenges is flexibility and not being restricted by a strict and rigid plan. Another key is then so called „letting-go approach", in terms of traditional structured urban planning thinking (Flint, 2015). When we cross these boarders of our minds, we will be able to focus more on processes, organisation and life of the cities themselves. The role of an architect or urban planner as an all-world creator must be abandoned to handle contemporary and future challenges.

The central idea is that cities are first and foremost large social networks. In this sense cities are not just large collection of individuals and their particular needs. The are agglomeration of social links. Space, time and infrastructure play a fundamental role in enabling social interactions to form and persist. In this term cities can be demonstrated like they are natural systems that evolve spontaneously in human societies under very general circumstances, whenever there are open-ended advantages to human sociality. In this sense they are as natural as beehives or coral reefs, and should not be thought of as a human artefacts to be redesigned at will. An when natural systems have been mentioned, why not to adapt findings and methodologies from natural sciences to understand complex interactions of urban environment? In previous chapter The Great Barrier Reef example was mentioned, but that is just a top of an iceberg. For understanding, characterization and modelling of almost any population in the nature whole sets of measurable indices were developed which can be incorporated to complex urban theories.

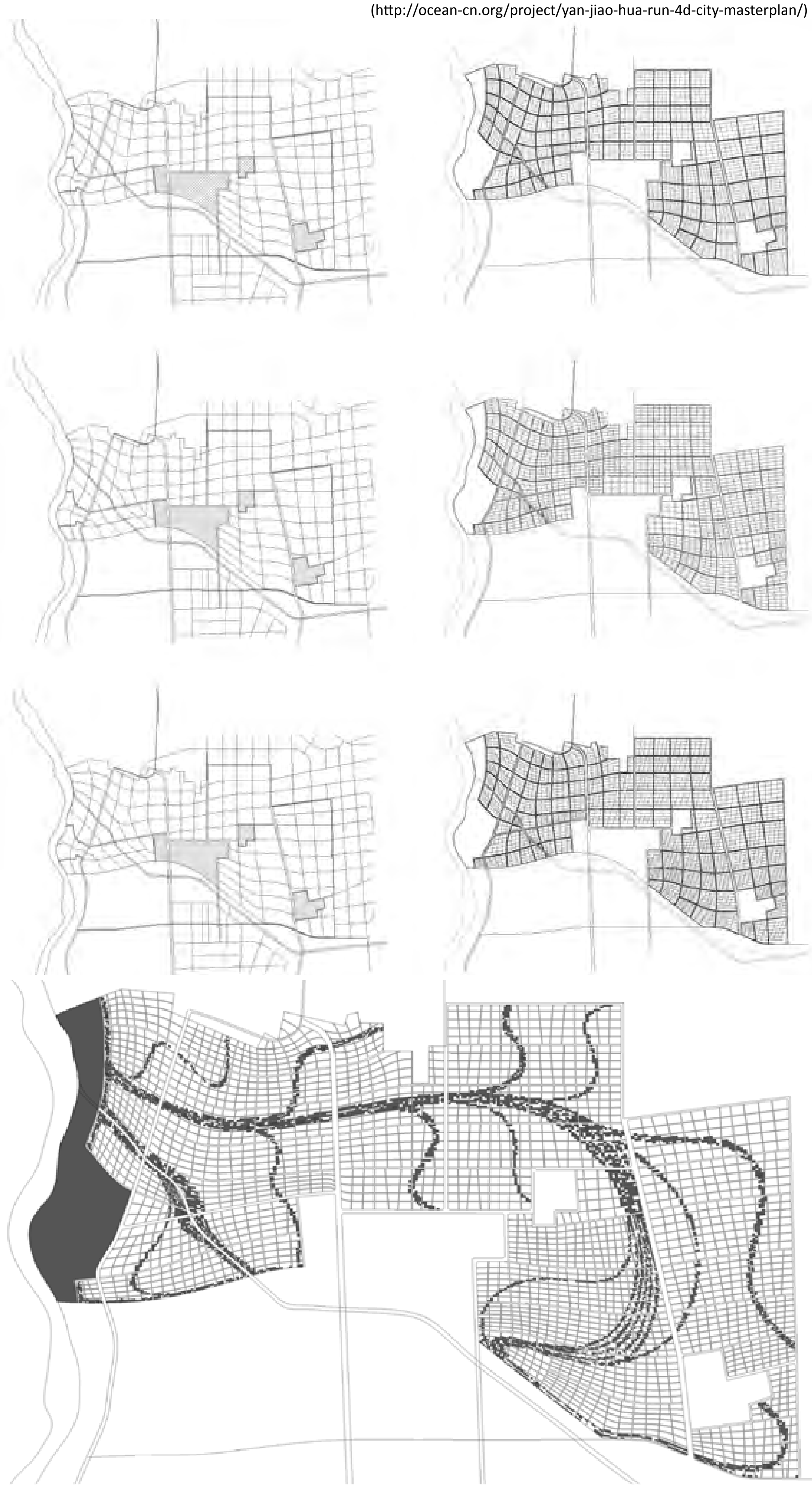
And there is no longer much of an excuse to ignore many of measurable properties of the cities these days. In terms of urban planning and urban design this conceptualization of cities emphasizes the importance of generative models, where local structures remained to be developed by agents possessing particular goal and information. But must also be constrained by the function of the city as a whole, as open-ended network of social interactions, kind of „social reactor" (Bettencourt, 2014). On this theoretical background and also on measurable empirical findings of the science of cities, geography and complex system, the proposed D.U.M. is developed.

The inherent limitations of the linear models of expansion become apparent both in terms of the ecological, the socio-economic, as well as the urban crises of the 1970s (Schumacher, 2010). The theoretical answer was developed in the form of Complexity theory. That came from analysing and simulating self-regulating systems like evolving ecosystems. The same theoretical resources and computational techniques that allow meteorologists to reconstruct and predict the global

Cities are integrated social networks embedded in a space and time, and require general adaptable properties for their open-ended land use and infrastructure planning and development.

weather system and scientists to speculate about the earth's evolving climate are available to contemporary urbanists and architects in their effort to meet the challenges posed by the ongoing socio-economic dynamic. The task is to project the growth and transformation of cities as a rule-based, largely self-regulating morphogenetic process (Schumacher, 2010). This emergent preconditions of the city are "designed" via computational processes involving both generative processes as well as in-built selection criteria in D.U.M.

Ocean CN, Yan Jiao Hua Run, 4D City Masterplan
(http://ocean-cn.org/project/yan-jiao-hua-run-4d-city-masterplan/)



It is not possible anymore to solve all issues of cities in this complex and dynamic processes. A quite helpful tool is computational urban planning. We should think about this approach more as a tool to current urban planning methods. Tool that can fulfil formalized design of urban environment automatically. These tools or systems already developed and tested are based on solving complex task with the help of self-orginising system and parametrical or also computational methods.

Adaptive urban planning

As an example of such computational urban planning system let´s mention a system called DSE framework developed by research team at Future Cities Laboratory, FCL in Singapore (Koenig; Klein, 2016), where authors have used several data clustering algorithms like self-organising maps and evolutionary many-criteria optimization based on evolutionary algorithms. As a result of their initiative a human-computer interaction concept of evolutionary optimization tool has been developed (see conception on the right). Another example of such an a adaptive and responsive parametric urbanism is a work of Tom Verebes, who is trying to implement dynamics of urban population into proposed physical structures of planned built-up areas. As the author calls it masterplannig of adaptive cities. Also the connection human-software-design is underlined in his work (Verebes, 2013). This is an attitude that is strongly emphasized also in this diploma thesis and proposed D.U.M.

As authors of FCL computational urban planning system are admitting, in their future work they want to expand the integration of urban data in the planning process, as the D.U.M. project is trying to, because in future city planning, algorithmic modelling approaches will likely gain in importance as they have the potential to exploit various large urban data sources. This would enable us to achieve an even more holistic planning perspective. So all models or toolsets similar to DSE or D.U.M. should be designed in a way that allow the integration of new urban data types by adding new generative and evaluation algorithms. The research approach presented in this diploma thesis shall be considered to develop design support and urban planning tools that lead to a more adaptive and human-oriented design approaches.

All is happening very quickly in current cities. Exploitation of data and a more scientific approach to cities will certainly help and therefore must by applied. But the ultimate challenge for all of us involved in urban planning and urban design is to translate, apply, and further develop these new ideas. And also to promote such a types of urban environments that can encourage and support the full potential of our social creativity, targeted at sustainable and open-ended human and cultural development.

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FLINT, Anthony. Is Urban Planning Having an Identity Crisis? CityLab, 2015. Available at: http://www.citylab.com/housing/2015/07/is-urban-planning-having-an-identity-crisis/398804/

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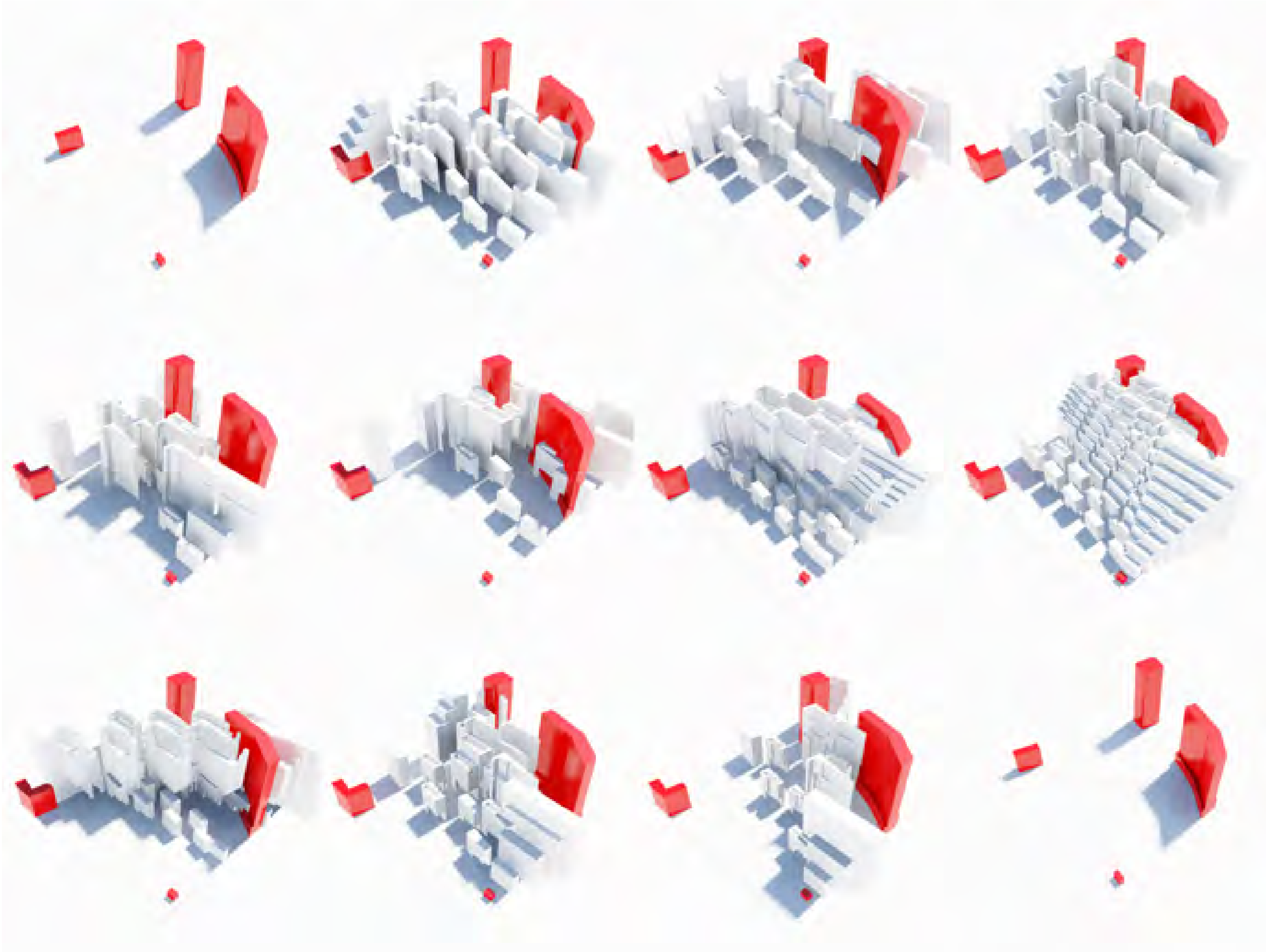
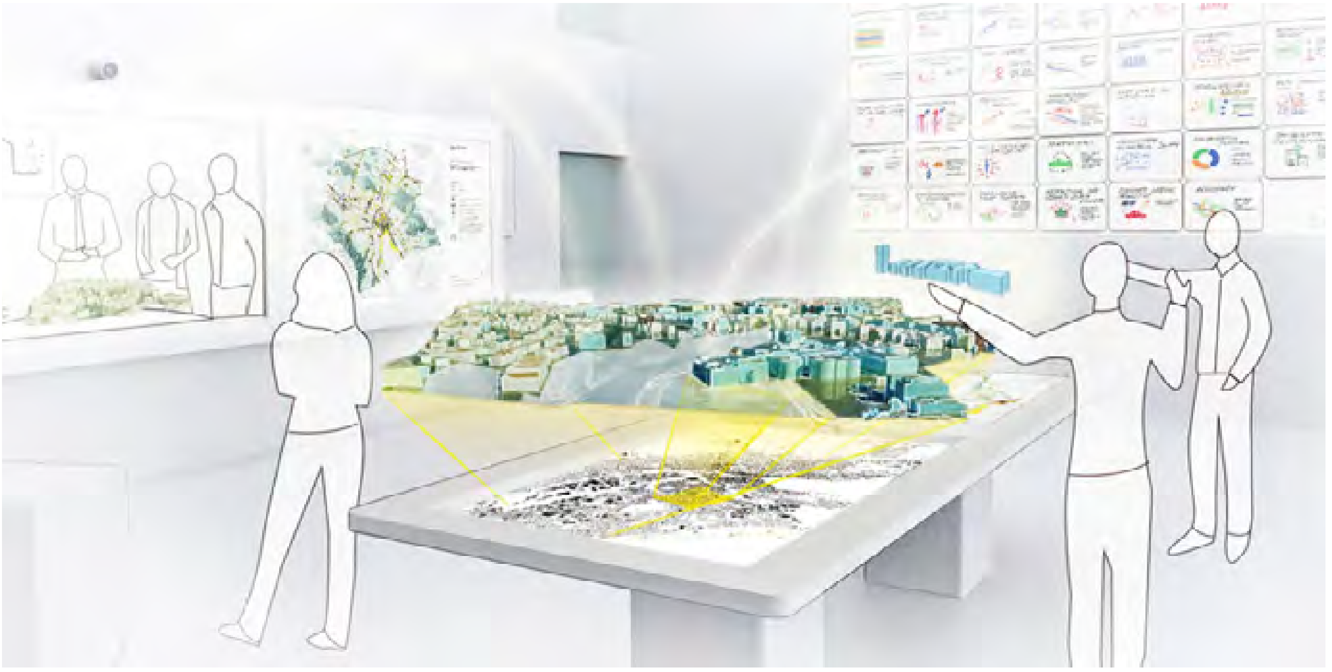
SCHUMACHER, Patrik. The Parametric City. Published in: Zaha Hadid – Recent Projects. Tokyo: A.D.A. Edita, 2010.

VEREBES, Tom. Masterplanning the Adaptive City: Computational Urbanism in the Twenty-first Century. New York: Routledge, Taylor & Francis, 2013.

Ocean CN, Parametric Pearl River Delta
(http://ocean-cn.org/project/yan-jiao-hua-run-4d-city-masterplan/)



Human - computer interaction concept
FCL Magazine Special Issue: Simulation Platform, Hightlights 2010-2015.



4. Design

4.1 Dynamic Urban Model (D.U.M.)

Addaptive, flexible and responsive urban model which can be further extended to more eligible spatial planning system which proceeds from actual requirements of urban population. From demands of inhabitants, residents, labourers and visitors of specific locality. All these individuals and groups leave every day, every hour and every second a virtual footprint through their behavior and acting in the urban environment. With the help of this proposed model – D.U.M. – it becomes possible to read this virtual breadcrumbs, understand behavior of urban populations and translate it to suitable virtual site speific design. The role of an architect-urban planner is then moved to more abstract and strategic level. His job is to understand the socio-economical relations, investigate urban population behaviour and set the correct connections among people-software-design.

This proposed model of urban evolution prediction is primary based on data inputs. These inputs represents social interactions with urban environment. How people behave, how they act, what are their requirements and intentions within the city. D.U.M. works with abstracted inputs, which are core for understanding of urban environment and relates them in complex way and as a result it tries to predict urban growth or decline. It also simulates a behavior of potential investors in the area through strategic multi-agent system. So the model is able to predict exact sites, where the development is going to happen. And on these sites it predicts a site specific uban form and also buildings themselves. The model gets more detailed qualitative data from inhabitants, labourers and visitors of the neighbourhood of specific site and through analysis of these big data D.U.M. is able to design a virtual buildings which are the most appropriate for specific locality. As people and their requirements change in time, so does the data which they are producing, and through this time-changing virtual footprint of people in neighborhood a design of buldings is dynamicly changing to meet people's demands.

The whole model is of course abstracted, as any model, so the software is enabled to work with data and interrelationships among them. It was a key task to choose which datasets are the most important to develop as precise model as possible. After several experiments three most important and relevant factors left. These are data-based factors represented as Connectivity, Developability and Intensity of urban environment. All these three factors are described more detailed further in the text. Through these three data-based factors a whole evolution of city is modelled. After the prediction of growing, stabilized and declining localities is done, the D.U.M. is adding other data inputs to make a prediction as precise as. These data are more related to how people percept the environment which is surrounding them. How do they (nejsem si jistá, ale podle mě je to správně bez do, je to oznamovací věta; a pokud tam chceš do, slovosed je how they do feel) feel in certain locality, what makes it attractive, how satisfied they are with physical conditions in it. All these data are more subjective, qualitative and more hard to be applied on a city as a whole. But they are telling us a very important information which we are able to use. These data are related to immediate surroundings of specific sites identified as developing by D.U.M. Intention of these inputs in D.U.M. is to know exactly what are the public demand and requirements of urban population on the smallest possible scale of building site neighborhood. This secures the suitability of potential future development. Another step in the model is a strategic multi-agent system. These kinds of systems are more detailed described in research chapter. In D.U.M. this system is representing the strategic behaviour of potential investors in the city. It can also be used to simulate a decisions only for a really specific type of investors. For example a developer searching for social housing development or large storage halls development, or small investors who want to run a certain type of services. Spatial conditions for such projects are of course very different. But in proposed D.U.M.´s the behaviour of such a specific investors is not simulated. The term „investor" is an abstracted element which wants

D.U.M.
Table scheme of ultimate data inputs and their correlations

Two examples are introduced - one current and one potential building site

Dynamic Urban Model (D.U.M.)
Data correlation scheme

	Identification data			Space syntax data								Exploitation of urban space	
			Current state	Connectivity (C)								Intensity (I)	
	Site ref. No.	Coordinates	Developed/Potential	Choice	(%)	Total connectivity	(%)	Total Depth	(%)	∑C	∑C(%)	Simulation of intensity based on urban data	∑I (%)
	Ref. No.	*x, y*	*Developed area/ Potential development*	*Syntax No.1*		*Syntax No.2*		*Syntax No.3*				*Geographical urban data (MA simulation - 3 to 1)*	
example_1	1370	115388, 654898	Developed	476,00	8,04	378,00	59,81	966,00	63,39	131,24	45,54	2	66,67
example_2	1773	565705, 228228	Potential	3699,00	62,47	630,00	99,68	1451,00	95,21	257,37	89,31	3	100,00

	Socio-economical data										Model results	
	Developability (D)										Result	
	Land use type	Price of lot (PoI)	Commercial building value (Cbv)	Economical rentability (Er)	Land use status (Lus)	Lifespan	Construction year	Building Age	Lifespan. - B.A.	∑D(%)	Absolute	Relative
	resideltial/ administration/ services etc.	*(%)*	*(%)*	*Price relation: ∑ Cbv / PoI*	*Er → used/ underused/ empty*	*Life expectacy according to -Land Use*	*Year*	*BA = (2016 - Construction year)*	*<-31; 69>*	*Lifespan - B.A. (%) calculation*	*∑C + ∑I + ∑D*	*(%)*
example_1	industrial	90	56	0,622	underused	40	1953	63	-21	90,00	202,21	68,08
example_2	-	-	-	-	empty	-	-	-	-	100,00	289,31	97,41

to develop his own intended project and tries to find a most appropriate site with the best rate of return of his investment. When calculation of Connectivity, Intensity and Developablity factors is completed, strategic multi-agent system representing potentional investors finds a specific developing sites, where additional data inputs are collected and most appropriate urban design is proposed.

The model is not just a simple simulation of investors‘ behaviour. In a way the model is also design, because it works with idealized scenario. In this scenario a most appropriate sites for development according to urban conditions and according to city population requirements are searched and then also developed. So the intensification, revitalization and reconstruction of the city is secured. We have to understand the requirements of urban population and the businesses, developers or comercial companies which are all responsible for ultimate spatial development. The D.U.M. is combining both these „types“ of requirements and tries to find the best solution and also urban design for them. So the urban environment stays really urban. Tendency of spreading of build-up area is therefore limited, infrastructures can be minimalized and free land can be preserved. More about this urbanistic and urban planning starting-points can be foud in the first chapter of research part of this thesis.

4.1.1. The Areas of Interest

For the first case study which tries to examine the possibilities of data driven modelling, planning and design the central part of Manhattan was chosen. In this diploma thesis the D.U.M. of Manhattan's´ quarter West Chelsea serves just as preparation for verifying all possibilities. The fully working and complete proposal of D.U.M. in this thesis is just second D.U.M. of The Isle of Dogs in London. But due to full understanding of my decision making process and designing process I am presenting also the partial results and findings of the preparation D.U.M. of West Chelsea in Manhattan, where all successive steps were tested. As a kind of guinea-pig all available urban data-sets were applied and studied until reasonable results were achieved. So already during work on D.U.M. of West Chelsea it became possible to settle three main factors - Connectivity, Developability and Intensity.

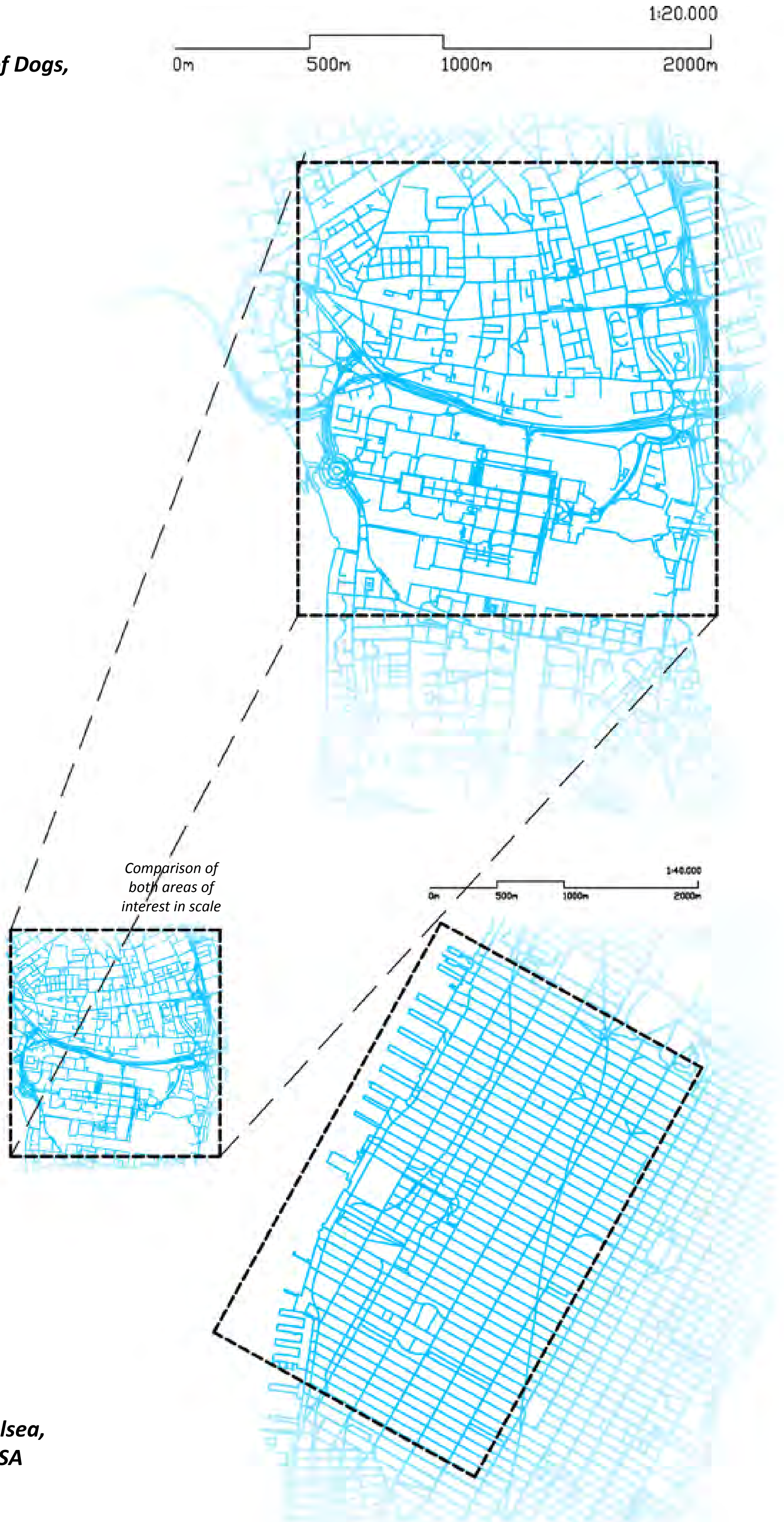
West Chelsea, Manhattan, NYC
The reasons why Manhattan has been chosen as a locality for pilot version of D.U.M. development are simple. It fulfils the general requirements on characteristics of area of interest: a part of city with high density, number of intended spatial investments, available urban data sets, broad spectrum of spaces and functions of urban environment. Since the government of the New York City tries to work, create strategies and plan the city development with the help of urban data and also makes a lot of them available for downloading or at least for looking through (as an example let me mention these sources: https://nycopendata.socrata.com/; http://maps.nyc.gov/doitt/nycitymap/template?applicationName=ZOLA, etc.) so the New York was a simple choice.

Another important and also kind of inspiring reason for Manhattan is that the local development policies are based on neighborhoods in almost every aspect of citylife. The local government realizes that the quality community life, accesibility to all required services, job accessibility and a positive image of neighborhoods are the key factors. Key from social, environmental and also economical point of view. The strategic document Resilient Neighborhoods devoted to all the neighborhoods in Manhattan is a general document addapted into other strategies of other departements incorporated in spatial development (flood protection, building regulations, zoning resolutions etc.). The specific main goals of Resilient Neighborhoods strategy for locality West Chelsea are following: reduce risks from natural hazards, foster economically and socially vibrant communities that are able to adapt to changing conditions, and coordinate land use planning with rebuilding activities and infrastructure investment (Department of City Planning, NYC, 2013). The Neighborhood-centered view has a long tradition in NYC and if one understands the challenges of modern cities and city planning, he realizes that this decentralized city management approach should be more and more reminded and applied.

Area of Interest
D.U.M. of The Isle of Dogs,
London, UK

Area: 2.95 km2

Area of interest of West Chelsea in Manhattan is approx. 2.6 times larger than area of interest of The Isle of Dogs in London. The reason for this is to test D.U.M. on different scales



Area of Interest
D.U.M. of West Chelsea,
Manhattan, NYC, USA

Area: 7.79 km2

Furthermore, Manhattan is for decades researched and investigated from the urbanism and urban planning point of view. From the time of masterplanning the world-known street grid of Manhattan, through era of Jane Jacobs and Robert Moses to Bloomberg's successful attempts to revitalize public spaces and make the city more livable. Moreover a huge amount of data is opened and available in NYC today, so it is possible to find enormous amount of reseaches or data vizualization projects which draw inspiration from virtual footprints of New Yorkers. It starts with transportation systems and traffic modes real-time analysis, data and information about consumption, environmental aspects of citylife or even criminality and safety, health care or life quality and economical description of neighborhoods and communities. On this account Manhattan is an unique phenomenon.

The Isle of Dogs, London

The north part of The Isle of Dogs forms a strategically significant part of London world city offer for financial, media and business services and is recognised as a part of the Central Activities Zone for office policy purposes, with Canary Wharf also functioning as a Major town centre for London workers and also local communities. The reasons for modelling urban evolution of this area are similar to Manhattan´s. In addition it is possible to find colourful mixture of functions and land uses, social mixture and fully developed and also vacant and abandoned sites, where new development projects are planned. All these aspects makes this area perfect for developing the D.U.M. and verifying its results.

This area of interest is going to undergo a new wave of development. Proposed transport investment including Crossrail will allow this locality to accommodate an additional 110,000 jobs by 2031. Improving public transport accessibility and capacity in and around Canary Wharf is one of the public investments priorities. Parts of the area have significant potential to accommodate new homes and there is a scope to convert surplus business capacity south of Canary Wharf to housing and support a wider mix of services for residents, workers and visitors. So the transformation of current built-up area is on the agenda Issue which is in detail solved in proposed D.U.M. Retail provision in Canary Wharf has the potential to develop and serve a wider catchment, complemented by a broader range of civic, leisure and other town centre facilities. In some parts of locality there is potential for less car dependent and more sustainable development form providing a wider range of uses and functions (Greater London Authority, 2011:267). According to London strategical documents in this area the Mayor will, and boroughs and other relevant agencies should develop sensitive mixed use policies to ensure that housing does not compromise strategic functions in the zone. Also work with social infrastructure providers to meet the needs of both local residents and that generated by the large numbers of visitors and workers (Greater London Authority, 2011:58-59).

Department of City Planning, NYC. NYC Planning, Resilient Neighborhoods – West Chelsea. New York: 2013. Available at: http://www.nyc.gov/

Greater London Authority. The London Plan: Spatial Development Strategy for Greater London. London: 2011. Available at: http://www.london.gov.uk/

4.1.2. Urban Data (Dynamics)

The behaviour of individuals and groups (in both private and commercial sector) can be observed through virtual footprint left by every day and in many cases real-time. One of the most difficult tasks during working on this thesis was to choose a proper data sets which enables to read the relation between people and environment they live in. First problem which was already mentioned is of course availability of data. Especially data gethered by commercial business. Such a data would make a great contribution to more accurate and more real-time data based on urban evolution models. For example communication services data, financial data, relevant real estate data or data from energy suppliers. Part of these data are also administred by public governments and their companies, but insignificant number has been opened yet. So one has to work with what is available. Data sets used for developing of D.U.M. can be subdivided into three main categories:

D.U.M.
Work-flow diagram of developed

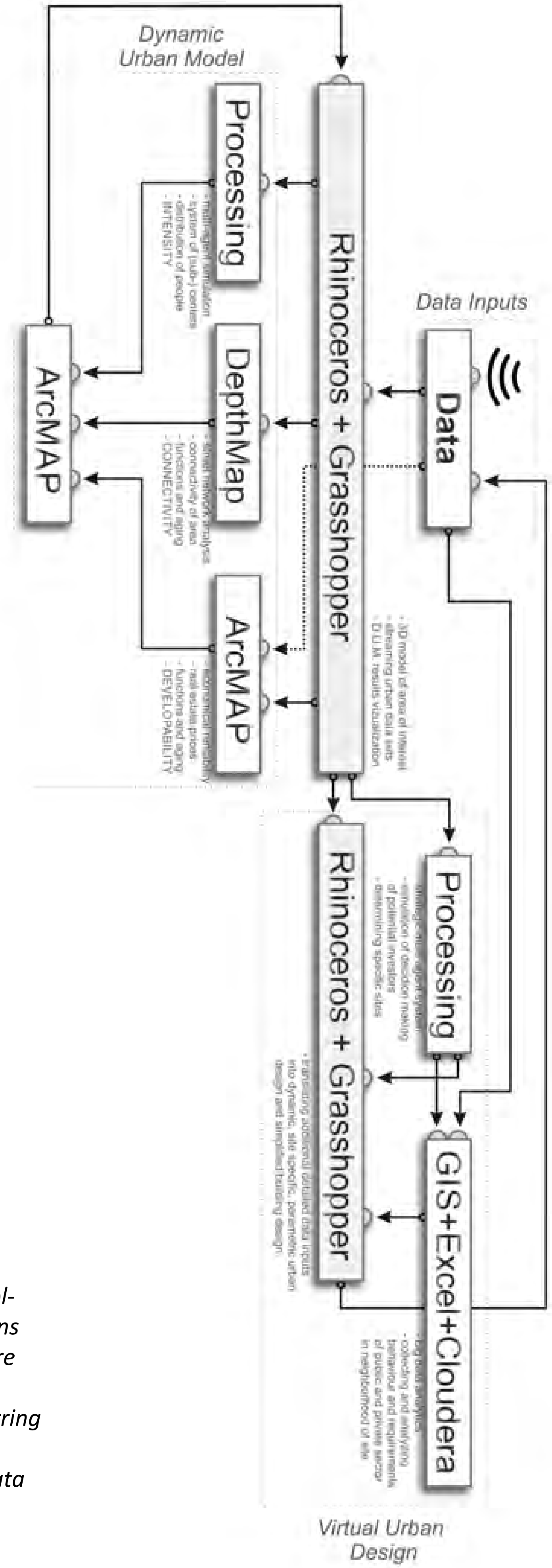
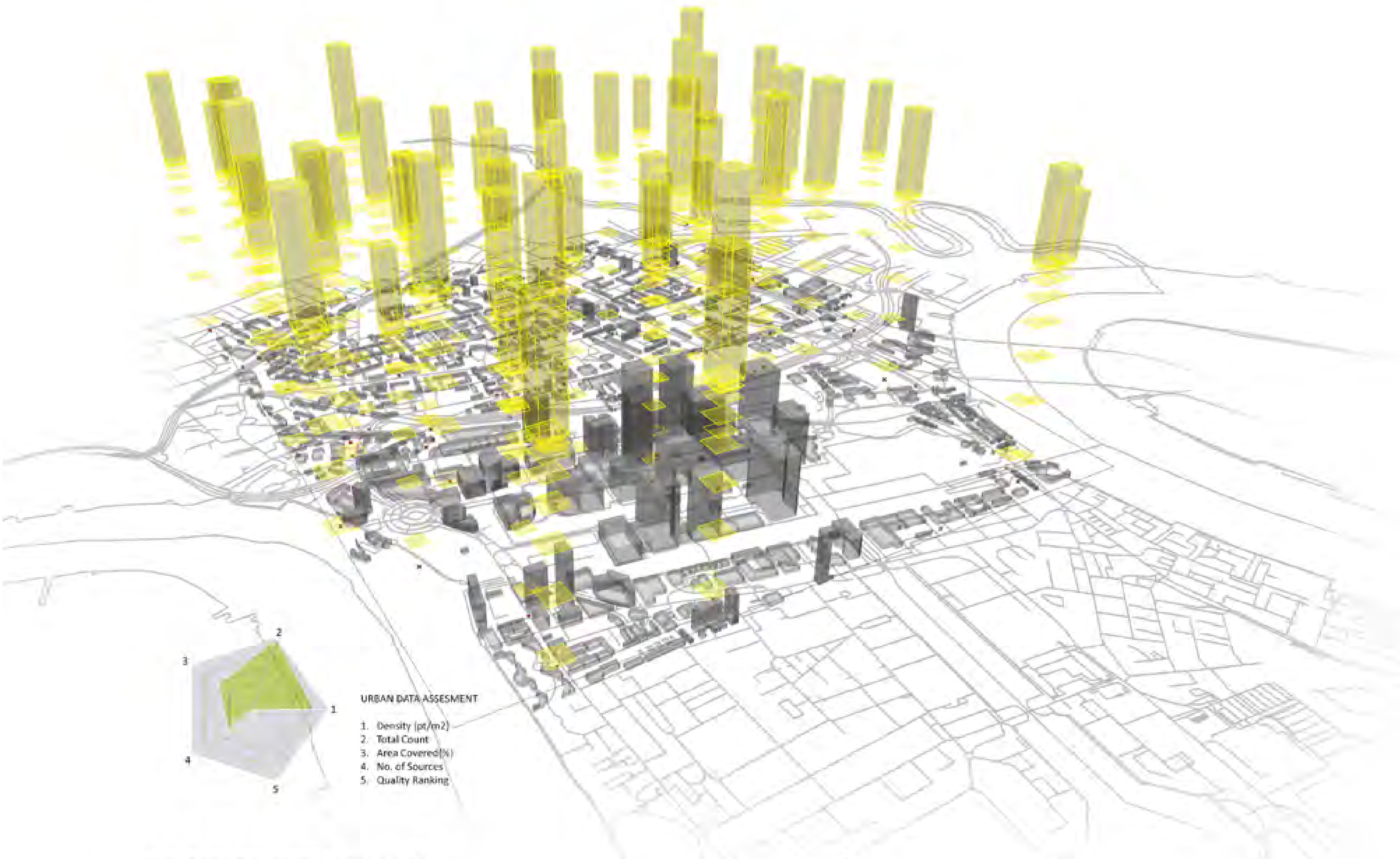


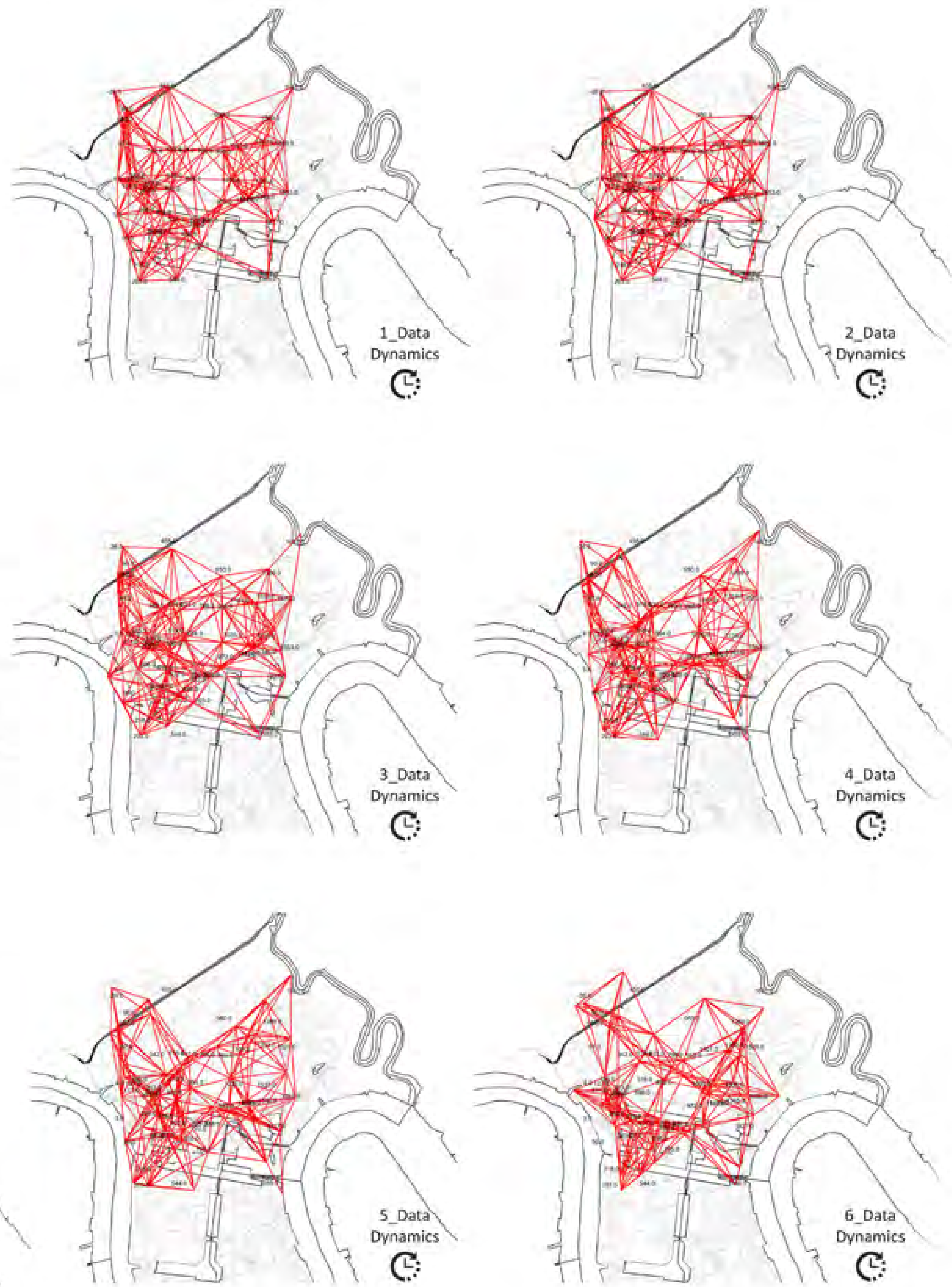
Diagram of D.U.M. toolset and interconnections among several software

Whole process is occurring in cycles and regularly repeated when new data inputs appears

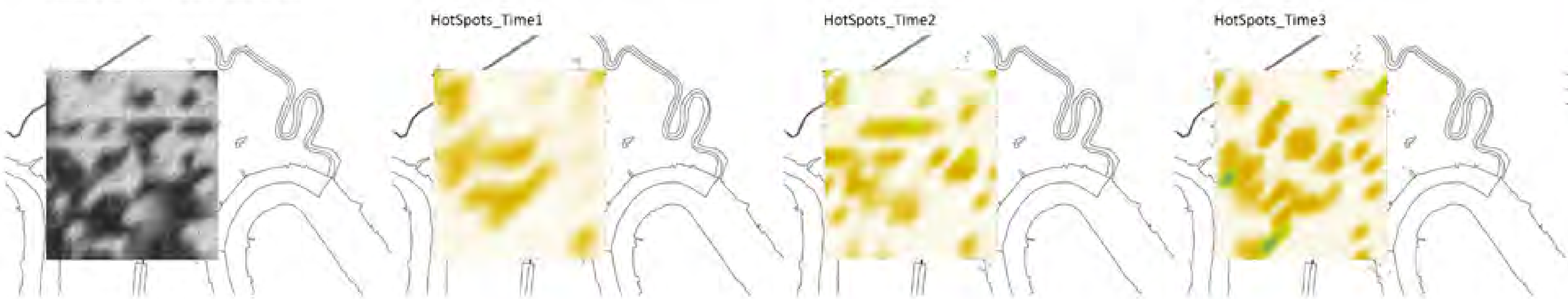
3D VISUALIZATION OF URBAN DATA
DATA-SETS FROM BIKING AND BIKE RENTAL APPLICATIONS



SIMULATION OF DYNAMICS OF URBAN DATA NETWORKS D.U.M. OF THE ISLE OF DOGS



HOT SPOTS IDENTIFIED BY URBAN DATA
AGGREGATE RESULT SCHEME



3D VISUALIZATION OF URBAN DATA

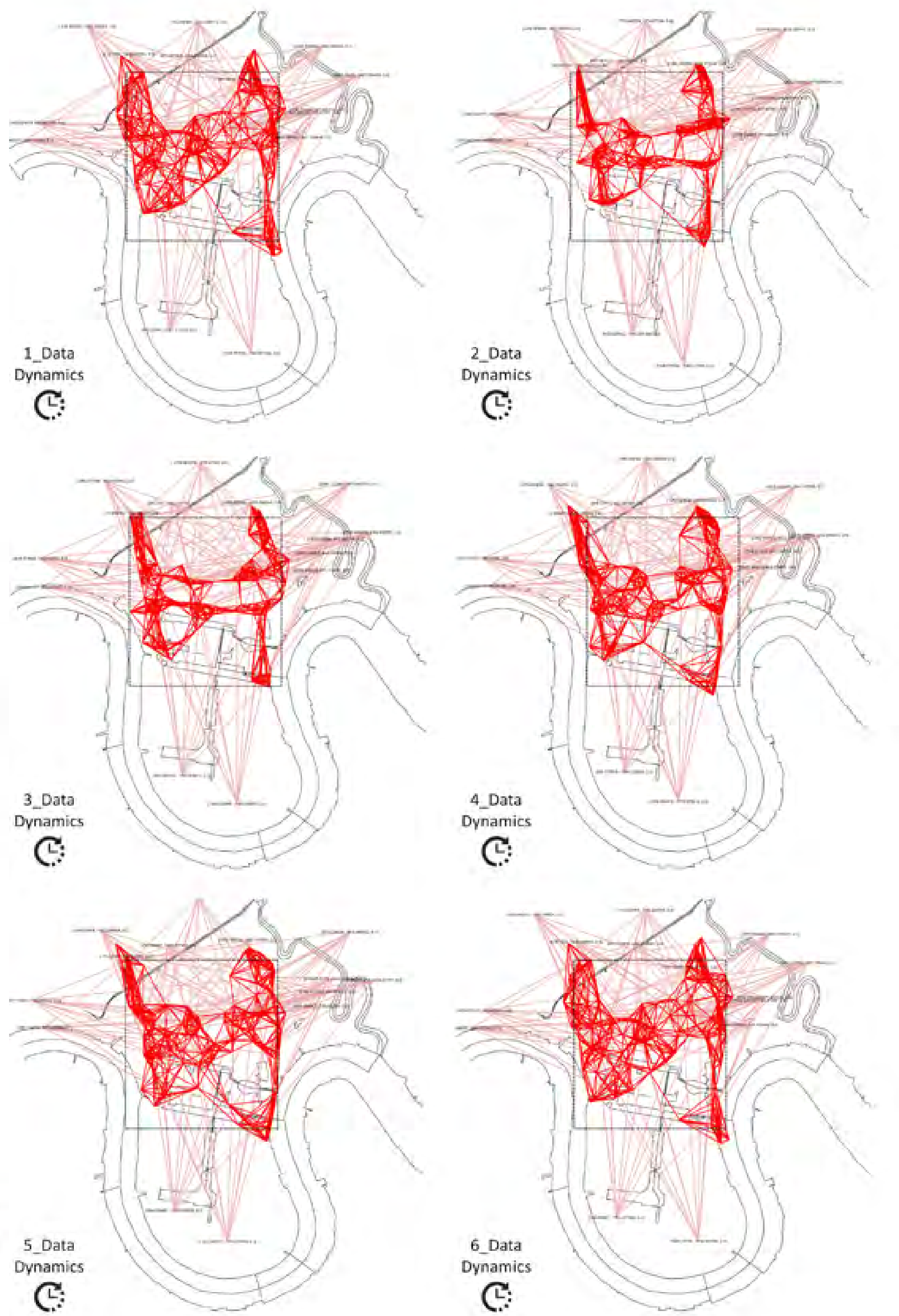
DATA-SETS FROM TAXI APPLICATIONS

HOT SPOTS INEDTIFIED BY URBAN DATA

AGGREGATE RESULT SCHEME

HotSpots_Time1 HotSpots_Time2 HotSpots_Time3

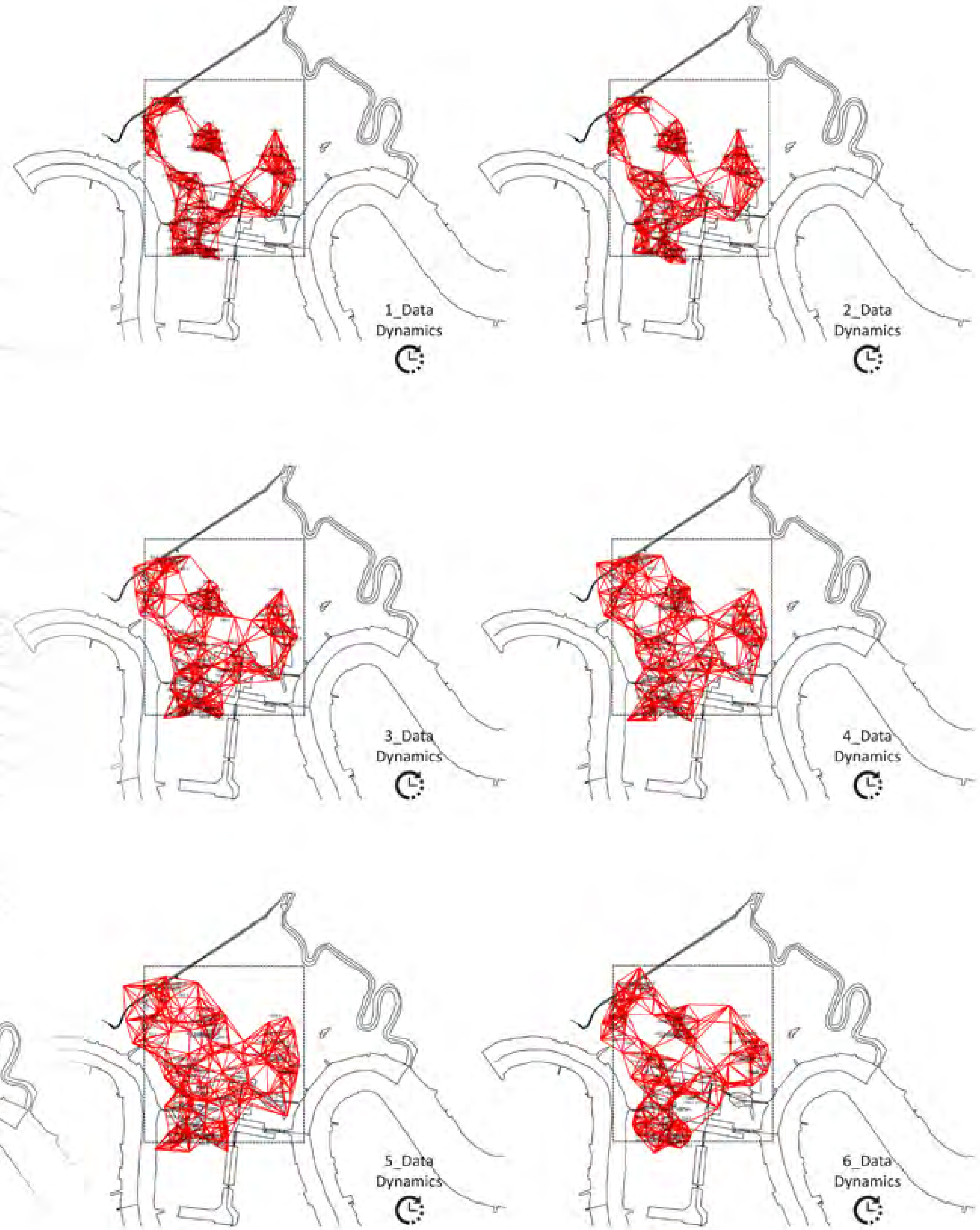
SIMULATION OF DYNAMICS OF URBAN DATA NETWORKS ***D.U.M. OF THE ISLE OF DOGS***



3D VISUALIZATION OF URBAN DATA

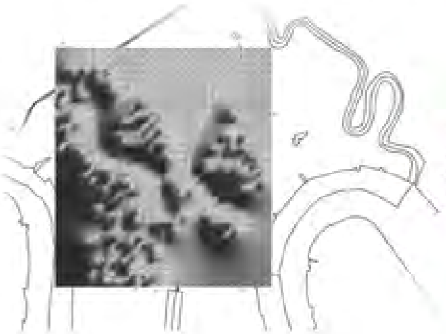
DATA-SETS FROM SEVERAL SOCIAL NETWORK APPLICATIONS

SIMULATION OF DYNAMICS OF URBAN DATA NETWORKS ***D.U.M. OF THE ISLE OF DOGS***

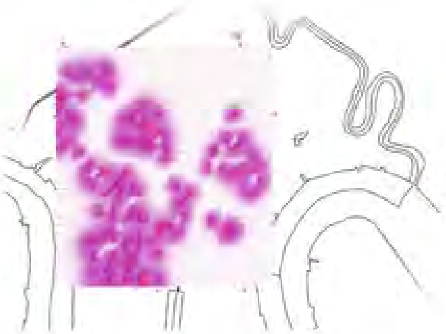


HOT SPOTS IDENTIFIED BY URBAN DATA

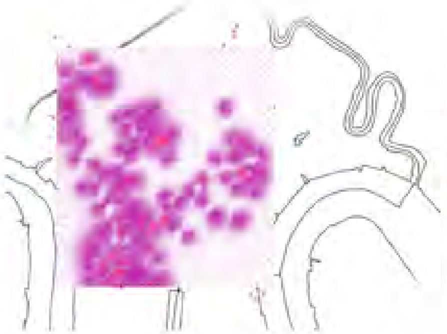
AGGREGATE RESULT SCHEME



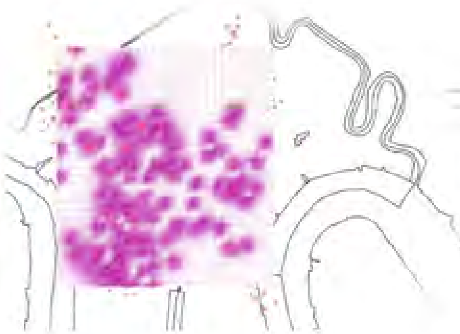
HotSpots_Time1



HotSpots_Time2



HotSpots_Time3



- Urban Data 1 – Quantitative geographical data (for determining centers / subcenters)
- Urban Data 2 – Socio-economical data (for determining economical rentability, de mographical situation and its change etc.)
- Urban Data 3 – Detailed urban popula tion data (for detailed understanding of urban population requirements for development of specific sites)

Urban Data 1 – Quantitative geographical data
Regarding the first category of quantitative geographical data, when I was going through available data in several cities, I realized that the level of openness and the type of data, which are left opened in specific city, are the first indicators of how the real citylife looks here and there. For example you can find a lot of data sets regarding biking, bike sharing and bike-intended applications producing streaming data in Copenhagen or Amsterdam. In New York, which was the first case study of D.U.M., there are similar opened data, applications and data vizualization projects related to taxi driving. Or there are a lot of walkability data sets in Stockholm. And as a last example let me also mention criminality and safety regarded data sets, researches and released smart devices applications for Brooklyn in NYC. This gives you a first hunch which type of data you should use for modelling the specific city.

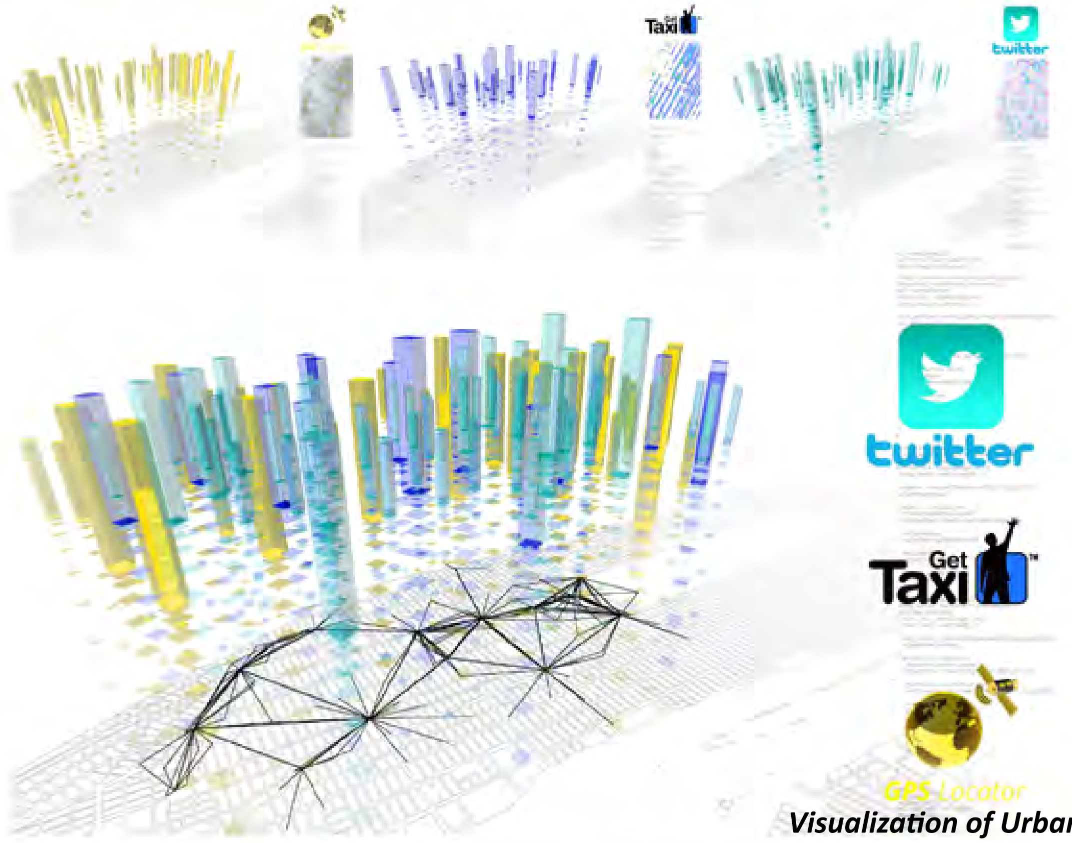
In general it is also possible to say that any kind of data which can be geographicaly projected can be used. Of course the important thing is to choose the data type which is the most representive for the modelled city. In D.U.M. case study Manhattan taxi data, geographical data from navigation applications and data from social network Twitter (this company is leading in data openning policy) were used. Among these the taxi data were the most detailed, as mentioned above. Also public transportation data was considered at first, but later on it shows that those data covered the same locations as other data sets and brought no use. So because of work flow public transportation data was later exluded. For D.U.M. of The Isle of Dogs as well as for West Chelsea´s D.U.M. Twitter and taxi data were analyzed. Also really relevant data related to biking, bike routes and bikesharing. Also UCL reseach which was analyzing and providing data from the other social networks all over the London were used. Then a several other data inputs were tested like online provided “smell map“ of London or data sets related to jogging.

Generating Centers – Subcenters Network
So these data sets were used to vizualize urban life of one Manhattan neighborhood – West Chelsea. They were also used to hierarchize the urban space to centers and subcenters. In the case of Chelsea it was easy to check if this hierarchization really corresponds to what one could have expected, because Manhattan is the city of neighborhoods and communities. So public buildings, main squares, parks and main streets can be used as a back check of data based urban hierarchization. And it was not a surprise that these two ways mostly correlated. But one can find several places which he would not expect to be important or centre-like. That is why examining and using urban data is important. Suddenly to more real image of urban network emerges. And what is really benefitial this images is evolving and changing as people are using the city and as the citylife is adapting to new effects

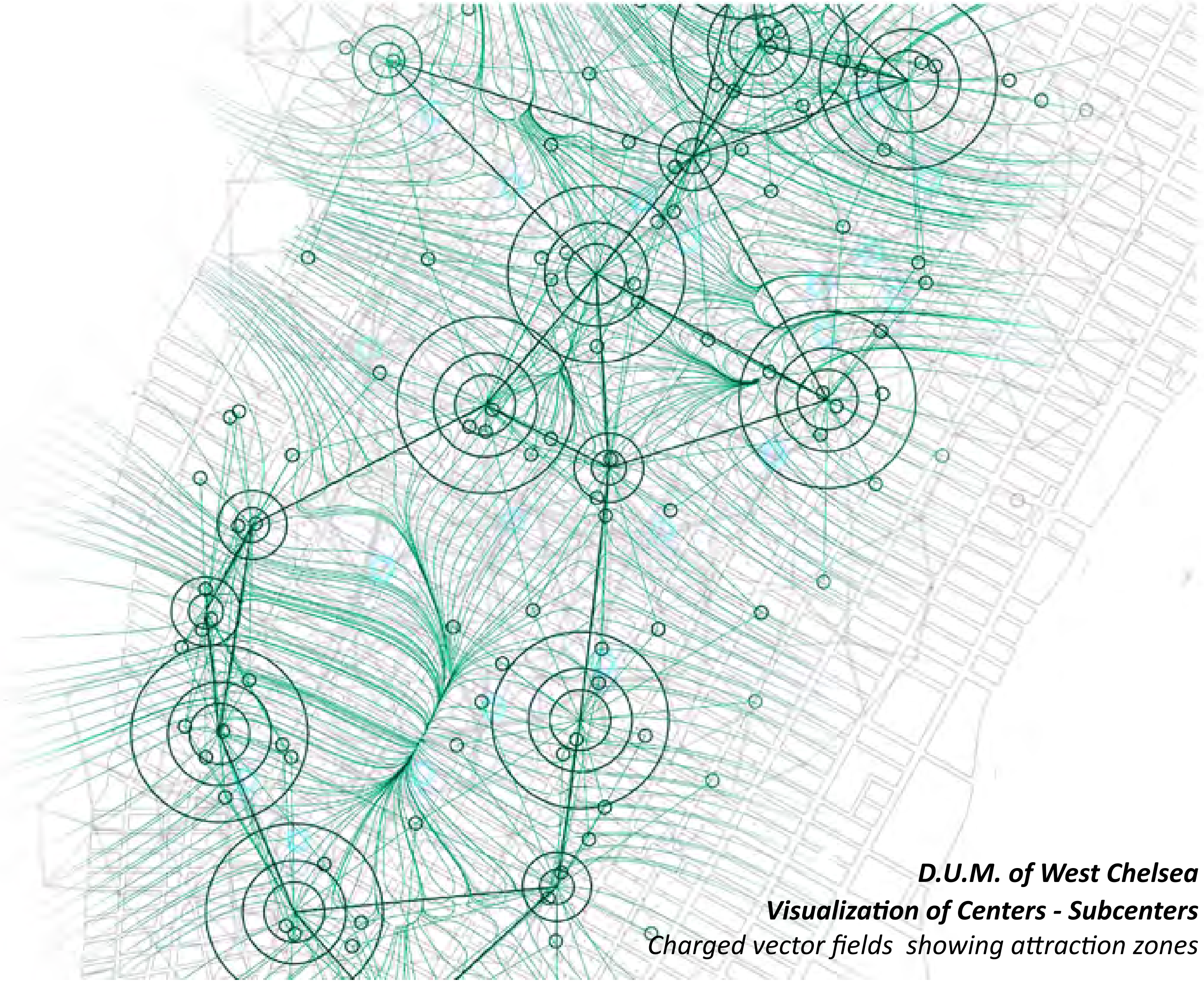
For visualizing of this centres – subcentres network in West Chelsea the Vector fields method was used. It is method conducted in Grasshopper which charges (similar to magnetic force) all the points which stand for urban data geographical projection to city map. So one gets a vector for every such a point. And now according to density of points and vector charging it is possible to determine areas with higher level of centrality. In both proposed D.U.M.s there were identified two levels of centrality - centres and subcentres. In the case of West Chelsea these centres were also connected according to distance which symbolizes walking distance among centres. This distance was up to 900 meters for main centres and 650 meters for subcentres. So the final diagram is showing vector charging of points, identified main centres and subcentres and connections among them.

Similar procedure applied in West Chelsea was used during developing the D.U.M. of The Isle of Dogs. More exactly its northern part, although Vector field method was dropped out because it was found as visualy confusing and not really expressing the intended picture of the area of interest. But the points that stand for urban data geographical projection to city map were generated as well as in the case of the first D.U.M. Then a script was designed to count the density of these points. So to do that a regular square grid was layed over the whole area and a number of these urban data points was counted in every grid cell. From this procedure the pixelated

D.U.M. of West Chelsea



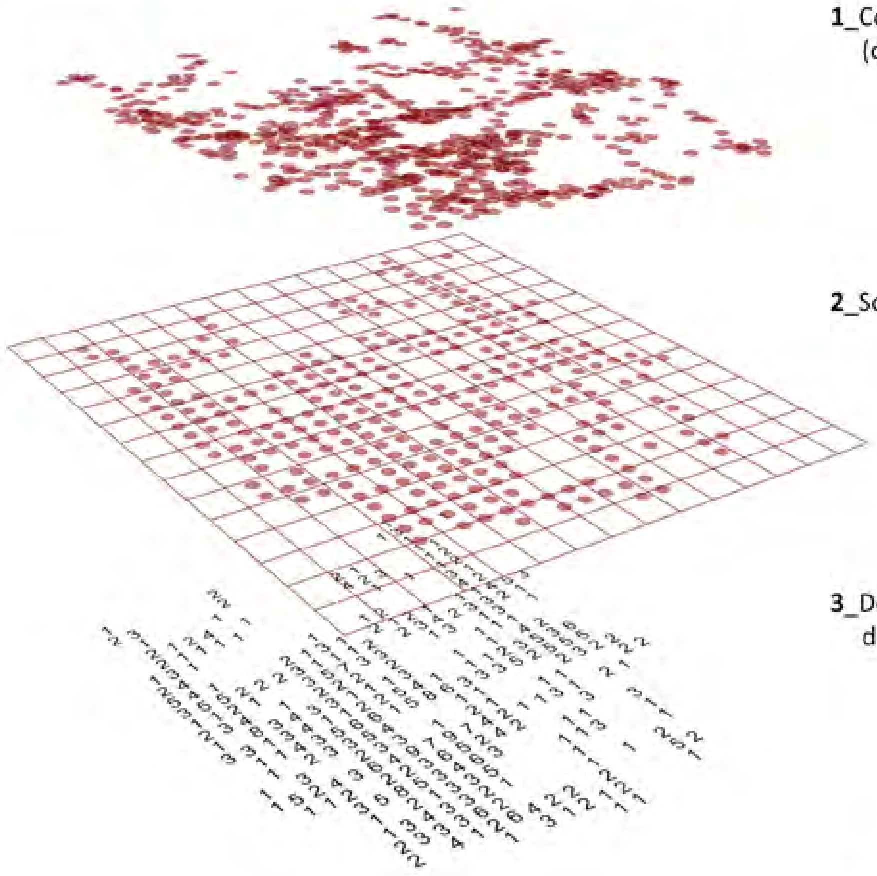
Visualization of Urban Data



D.U.M. of West Chelsea
Visualization of Centers - Subcenters
Charged vector fields showing attraction zones

DETERMINING CENTERS / SUBCENTERS

From Urban Data to Hierarchized Perception of City



1_Collecting urban data
(data dynamics)

2_Sorting data densities

3_Determining level of data
density in each grid cell

4_Pixelated hierarchization
of center localities in city

D.U.M. of The Isle of Dogs

Identification of main centers of area of interest.

It is not supsising these are related with main public spaces and transportation hubs.

5_ The modeled area of interest is divide into categories accorging to realtion to main centers or subcenters. This is further used as inputs for other procedures of D.U.M.

diagram of urban data density arised. Then proportionally the most dense was identified as main centres and the slightly less dense cells as subcentres. Because The Isle of Dogs area of interest of proposed D.U.M. is significantly smaller than in the case of West Chelsea it was not meaningful to specify the connections based on walking distances as in the case of the first D.U.M. Next step was simple - designing the series of metaballs curves over the identified network of centrality points. The bright and clear visualization of hierarchy of the localities within the area of interest emerged.

When researching and visualizing the geographical virtual footprint of urban population, it is possible to find and determine a unique and small positive deviations. Local events that makes a specific place attractive, not-planned public spaces which are strengthening community life, places in office areas where people meet for a lunch, coffee or cigarette. Places where people intentionally go and where they stay. Places where they are happy to be. Small streets, dead ends, vacant sites, terraces, rooftops. These are often places not intended by city planners to fulfil this purpose. These are spaces which emerges bottom-up. These are very important spaces for every city and you can see how these are emerging or disappearing through reading right data sets produced by urban population. And as a city planner you must not neglect these soft and delicate bottom-up exposures of urban population life.

Data used for these purposes can be found here:
http://mappinglondon.co.uk/2014/all-the-tweets/

http://twitter.mappinglondon.co.uk/

http://wearedata.watchdogs.com/start.php?locale=en-EN&city=london

http://labs.strava.com/heatmap/#7/-1.69739/52.00179/orange/bike

http://labs.strava.com/heatmap/2014-2015.html#14/-0.02747/51.50006/orange/bike

http://vartree.blogspot.cz/2014/04/i-know-where-you-were-last-summer.html

http://vartree.blogspot.cz/2014/03/london-maps-and-bike-rental-communities.html

Urban Data 2 – Socio-economical data
The second data category embraced in D.U.M. is socio-economical data. These are intended for determining economical rentability, demographical state and change and calculating economical indications of sites. These are especially used for calculation of Developability factor of D.U.M. And this factor is pretty complex to be calculated (see following chapter). In D.U.M. of West Chelsea the process of designing proper data and data operation was just in the beginning and it was not finalized. This had happened later during developing of D.U.M. The Isle of Dogs in London. Data-sets like land use category, year of construction of buildings, price of lots etc.

An other option how to implement these socio-economical data is adding them on in these particular localities of area of interest with a specific urban and social conditions. This was not done in proposed D.U.M.´s but it is a way how to improve the modelling accuracy of these models. For London these data can describe for example the deprivation of localities, social structure of urban population, prevailing nationality in neighborhoods, gross income classification etc. Of course there is a legitimate place for data inputs like these to D.U.M. In the further chapter Other possible factors these data are mentioned and as such these can be added to modelling process if necessary.

Data used for these purposes can be found here:
http://mappinglondon.co.uk/category/data/

http://maps.cdrc.ac.uk/#/metrics/dwellingage/default/BT-TTFTT/14/-0.0380/51.5103/

http://wearedata.watchdogs.com/start.php?locale=en-EN&city=london

http://www.centreforcities.org/data-tool/#graph=map&city=show-all&indicator=housing-stock\\actual\\2012--2014

http://luminocity3d.org/Economy.html#employment_density_change_2001-2011/11/51.5512/-0.1586

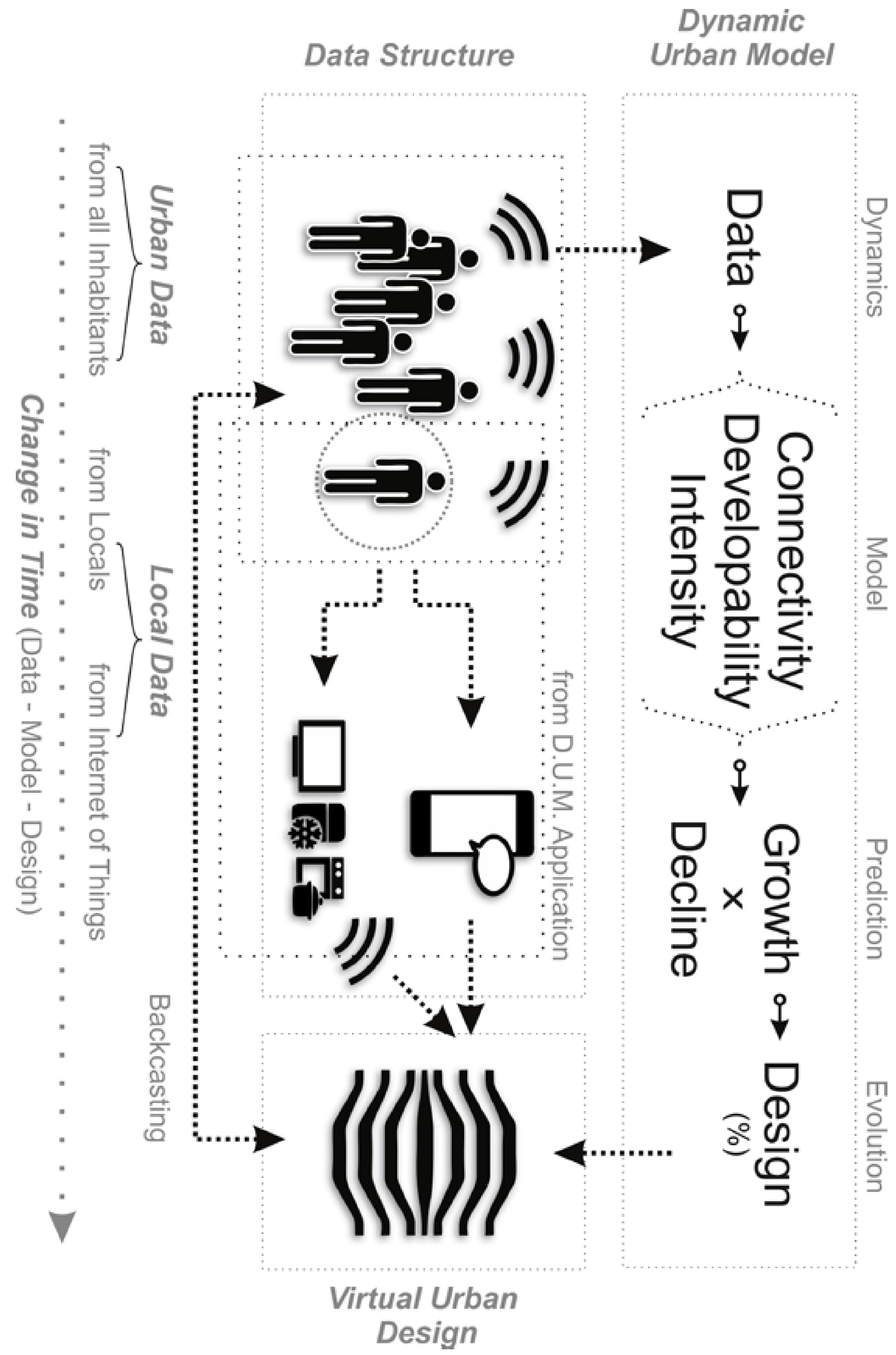
http://datashine.org.uk/#table=QS606EW&col=QS606EW0017&ramp=YlOrRd&layers=BTTT&zoom=14&lon=-0.0126&lat=51.4946

http://luminocity3d.org/Economy.html#employment_density_change_2001-2011/11/51.5512/-0.1586

http://vis.oobrien.com/booth/#

Urban Data 3 – Detailed urban population data
Urban population data for detailed understanding of public requirements for development of specific sites. These third category of data sets is a bit complicated. These data sets are exactly the ones most difficult (and in many cases impossible) to get. The research chapter Urban data is dedicated also to description of these detailed data sets. Through analytics of these data, city leaders, stakeholders and citizens can gain vital real-time insights from multiple data streams (traffic, social media, devices and sensors that are shaping the Internet of Things-IoT) to make more accurate decisions, achieve greater efficiencies, and respond faster in emergency situations.

D.U.M.
Scheme of data sources and interactions during process of dynamic urban modelling



These detailed data are used as inputs for site specific urban design or design of particular buildings. And since it is not possible to get these data sets it is necessary to generate them artificially with the help of Grasshopper scripting (manual engaging of input data and then random generation of their dynamics) and with the basic knowledge of trends and tendencies of demand of public and commercial sector. To get this knowledge documents, articles and materials (published both by local governments and media) referring to description of dynamics of this demand was studied

As an example of materials used for this purpose see the overview of information sources:

Data sources:

http://mappinglondon.co.uk/category/data/
http://www.bbc.com/news/magazine-29915801
https://gephi.org/

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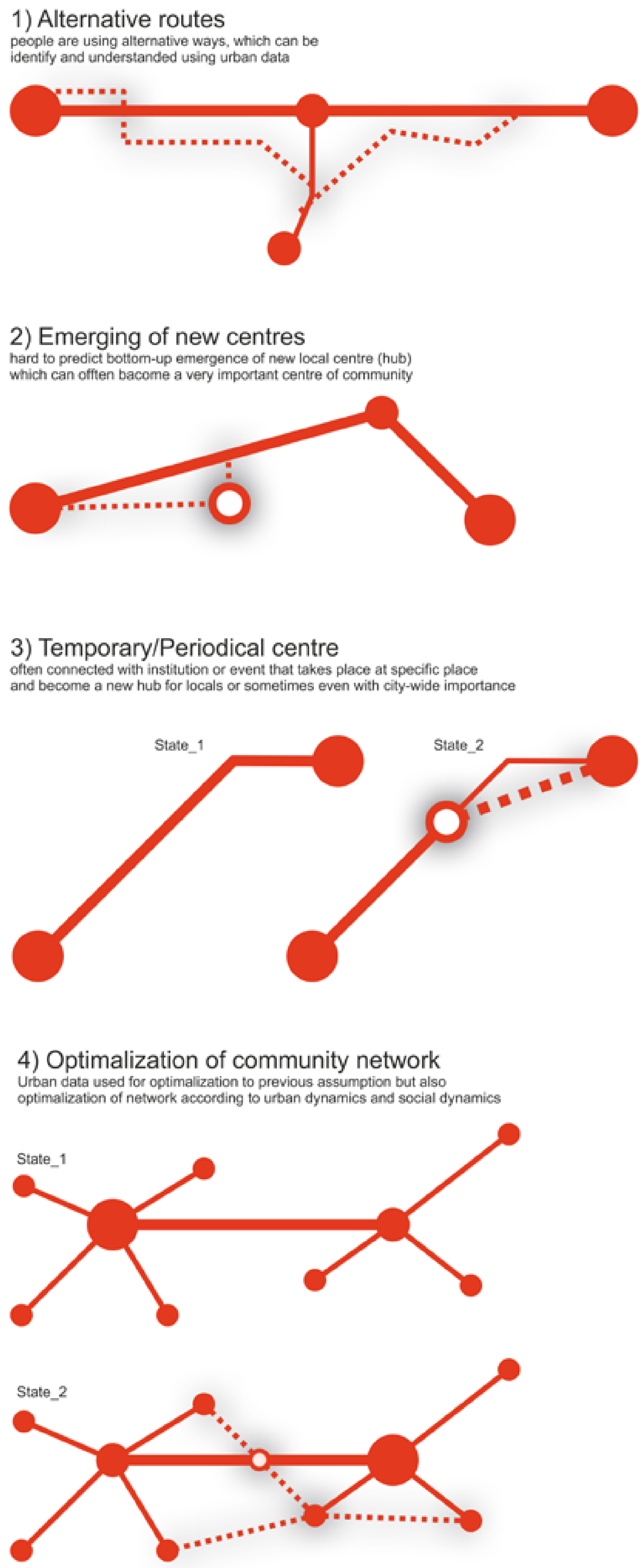
4.1.3. Urban Evolution Model

4.1.3.1 Connectivity

Regarding street network connectivity and accessibility of space, there have been serious researches proving its importance. Especially importance of pedestrian accessibility. Because it is really important to understand that it does not matter, which mean of transport is currently the most attractive, most lucrative, which transportation mode is currently mostly used, supported or advertised. People have and always will have pair of foots which can be used for walking. Thousand years back or thousand years in the future, people walk. And this fact has of course consequences in urban environment and in socio-economical processes in the cities. For example study of housing and office market in Stockholm shows that walkability basically explains the differences in prices and rents. So the specific monetary value of walking distances to shops, restaurants, culture, transit stops, street connectivity, parks or waterfronts can be defined. What is surprising in Stockholm research is that car accessibility did not have a significant effect on apartment prices or office rents. The authors of this study concluded that this property market is driven by suprasing. And the environmental and social benefits of this fact comes as a bonus. (Goodyear, 2015). And this can be also seen in behaviour and decision making of property developers, that connectivity is on of the important factors for allocation of their investments.

For the developing of D.U.M. Space Syntax analysis was used to evaluate the level of Connectivity of street network. The term Space Syntax embraces a set of theories and techniques for the analysis of spatial configurations. It was developed at The Bartlett, University College London in the late 1970s as a tool to help urban planners simulate the likely social effects of their designs. The general idea is that spaces can be divided down into components and segments, analysed as networks of choices, then represented as maps and graphs that describe the relative connectivity and integration of those spaces. The three most popular ways of analysing a street network are integration, choice and depth distance. While integration analysis provided similar results as the choice analysis during developing of D.U.M., it was replaced by connectivity analysis. All these particular analysis are described more detailed further in this chapter.

Urban Data_1
Schemes of connections possibilities of otherwise unpredictable outcomes



Softwares

There is a several software and methods how the Space Syntax analysis can be performed. Among others lets mention the Urban network analysis which is a plug-in toolbox for ArcGIS which is able to compute five types of network centrality measures on spatial networks: Reach; Gravity Index; Betweenness; Closeness; and Straightness. Though it was primarily developed for the analysis of urban street and building networks, the toolbox can be also used for other spatial networks, such as railway networks, highway networks, or utility networks. The plug-in is though not really user-friendly and the work is kind of difficult.

Other possibility is plug-ins for Grasshopper, which would be an ideal choice due to workflow of D.U.M., but unfortunately the quality and reliability of these plug-ins is really low. In this case DeCoding Spaces and Spider Web plug-ins are in mind. Although their results could be very useful if the procedure is working and finally comes to an end. The level of closeness, betweenness and connectivity can be measured through DeCoding Spaces components, and with the help of Spider Web one can see the accessibility of urban network from determined points.

So because of mentioned annoyances with described software the DepthMap toolbox developed at UCL was used for assessing the connectivity of street network of West Chelsea and The Isle of Dogs. DepthMap is a simple and user-friendly software which contains several possibilities how to conduct Space Syntax analysis and so called Axial analysis of network which can be easily imported in as a *.dxf file. It is also possible to edit the street network directly in DepthMap, which can be very useful for adjusting the network or designing a new one and see how it affects the rest of the network. For D.U.M. the global integration in Axial analysis, which shows how each street is connected to all others in a whole city in terms of the maximum possible direction changes, was after several tests eventually set on 10, meaning it shows how each street is connected to its vicinity in terms of ten times direction changes. This setting showed the reasonable differentiation of the particular streets. With the Axial analysis set there was a need to select measured factors for D.U.M. Connectivity. Among all analysis results the Choice, Total Connectivity and Total Depth results for each street was exported to the excel table sheet and than imported in ArcMAP, where all values (Connectivity, Developability and Intensity) are assembled and further interpreted.

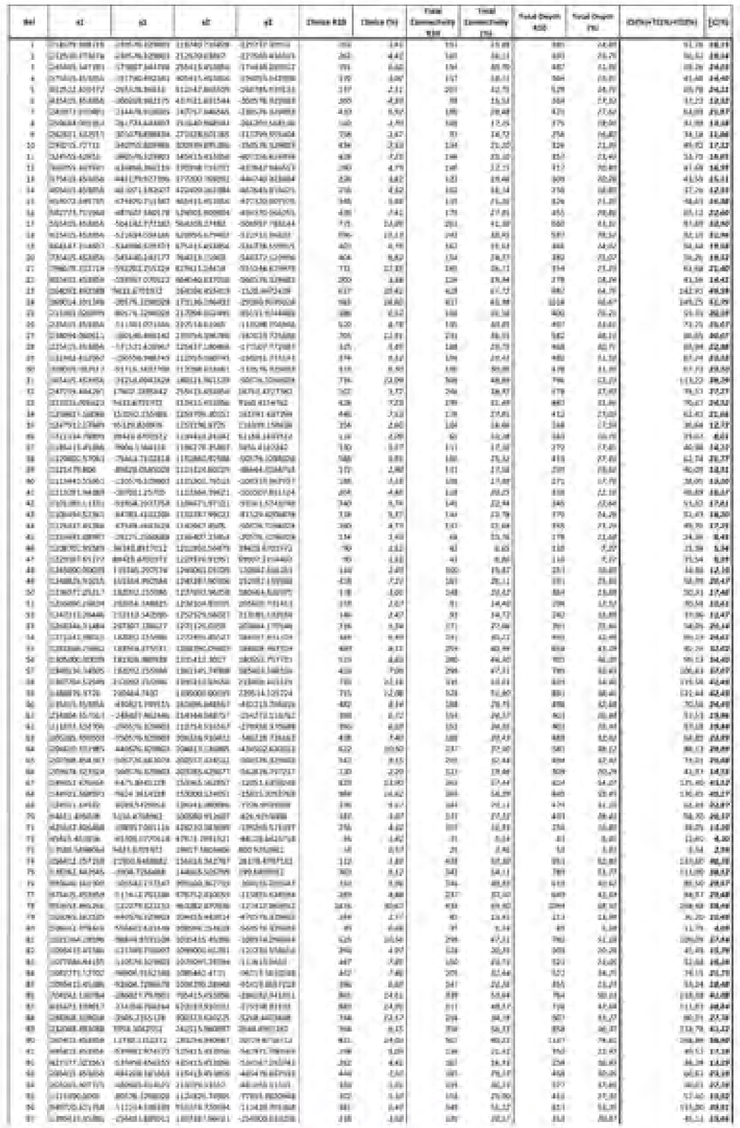
Choice, Total Connectivity and Total Depth

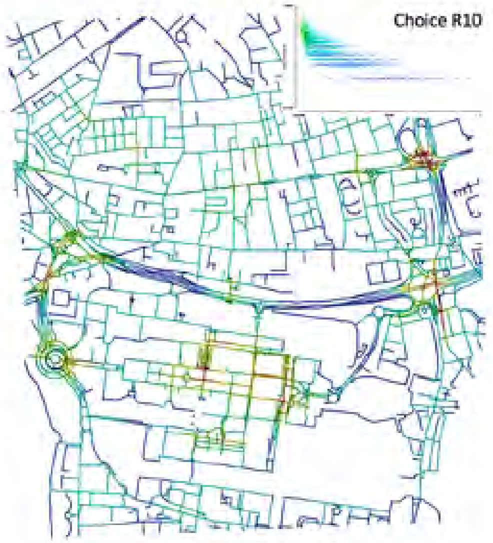
Now let´s briefly introduce individually each part of Space Syntax analysis results. For this introduction the UCL Space Syntax online glossary was used (UCL Space Syntax; 2016). The Choice measure is easiest to understand as a ‘water-flow’ in the street network. Imagine that each street segment is given an initial load of one unit of water, which then starts pours from the starting street segment to all segments that successively connect to it. Each time an intersection appears, the remaining value of flow is divided equally among the splitting streets, until all the other street segments in the graph are reached. For instance, at the first intersection with a single other street, the initial value of one is split into two remaining values of one half, and allocated to the two intersecting street segments. Moving further down, the remaining one half value is again split among the intersecting streets and so on. When the same procedure has been conducted using each segment as a starting point for the initial value of one, a graph of final values appears. The streets with the highest total values of accumulated flow are said to have the highest Total Choice values.

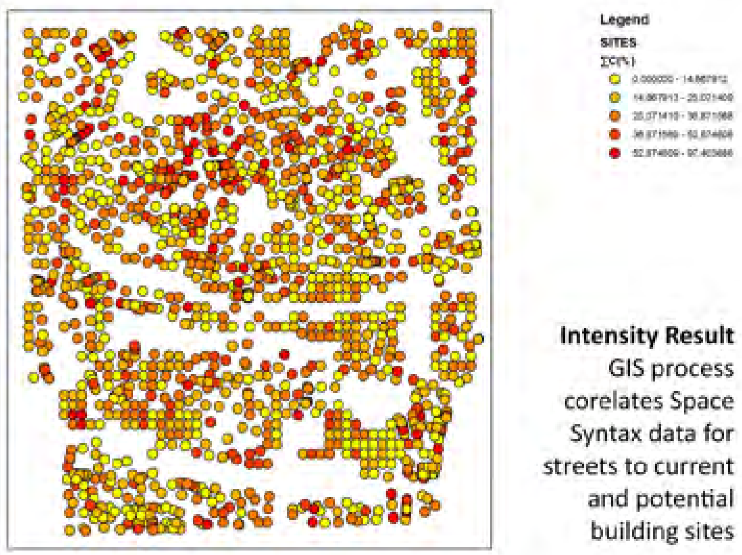
The Total Connectivity of segments of street network in the terminology of Space Syntax analysis methods is defined as the number of segments directly connecting a root segment. This is a static local measure. Every physical network in every city (or this method can be also used for analysing connections inside a buildings) is an interconnected whole in which each space has a different topological status. For instance, some of the spaces are well connected (with a high degree of connectivity), while others are less so. This is the fundamental principle of Space Syntax.

CONNECTIVITY

D.U.M. Input Based on Space Syntax Data







Intensity Result
GIS process corelates Space Syntax data for streets to current and potential building sites

Depth Distance is the most intuitive of the analysis methods. It explains the linear distance from the center point of each street segment to the center points of all the other segments. If every segment is successively chosen as a starting point, a graph of accumulative final values is achieved. The streets with lowest Depth Distance values are said to be nearest to all the other streets. Again, the search radius can be set and limited to any distance.

GOODYEAR, Sarah. How Stockholm Became the Ultimate Walkable City. CityLab. 2015. Available at: http://www.citylab.com/commute/2015/03/how-stockholm-became-the-ultimate-walkable-city/388433/

UCL Space Syntax (University College London). Glossary. UCL:2016. Available at:
http://otp.spacesyntax.net/glossary/

4.1.3.2 Developability

The Develpability factor stands for the economical rentability of potential development. The calculation of this factor is simplified compared with much detailed economical rentability analysis conducted by commercial and development companies. But in a simple way this factor tells us about this really important potential of each site. Because in the metropolitan cities modelled in this thesis (and for which the D.U.M. toolset is primarily developed) the commercial groups are still responsible for the most of spatial development and we need to understand the procedures of decision making to accurately predict the future evolution of urban environment and secure its quality outcome. But also what needs to be mentioned is that developers and local governments have to perceive the public demand for spatial development. That is why proposed D.U.M. is combining data inputs representing public demand and requirements and real estate market conditions represented by this Developability factor. And if these market conditions change or the architect or urban planner designing other D.U.M. determines different market conditions in other city, this Development factor calculation can be easily adjusted.

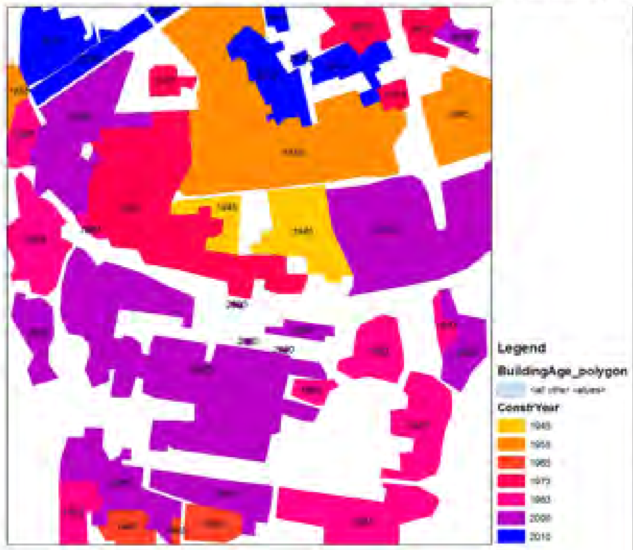
According to mindset of commercial companies involved in spatial development land is perceived as an economic good and the most important thing is that any land intended for development must be able to generate higher yields than what the costs are (Kohl, 2016). Also for the successful development investors have to be able to estimate what people want and what they can afford. And if the ultimate development meets the demand of people (and term „people“ does not mean just potential customers) and creates high quality space the general perception of commercial development and perception of new buildings and spaces can be very good. The neglection of public demand during preparation of development projects is one of the things responsible for negative perception of new constructions. Another thing often mentioned is the lack of solid vision, strategy and pro-activity from municipalities.

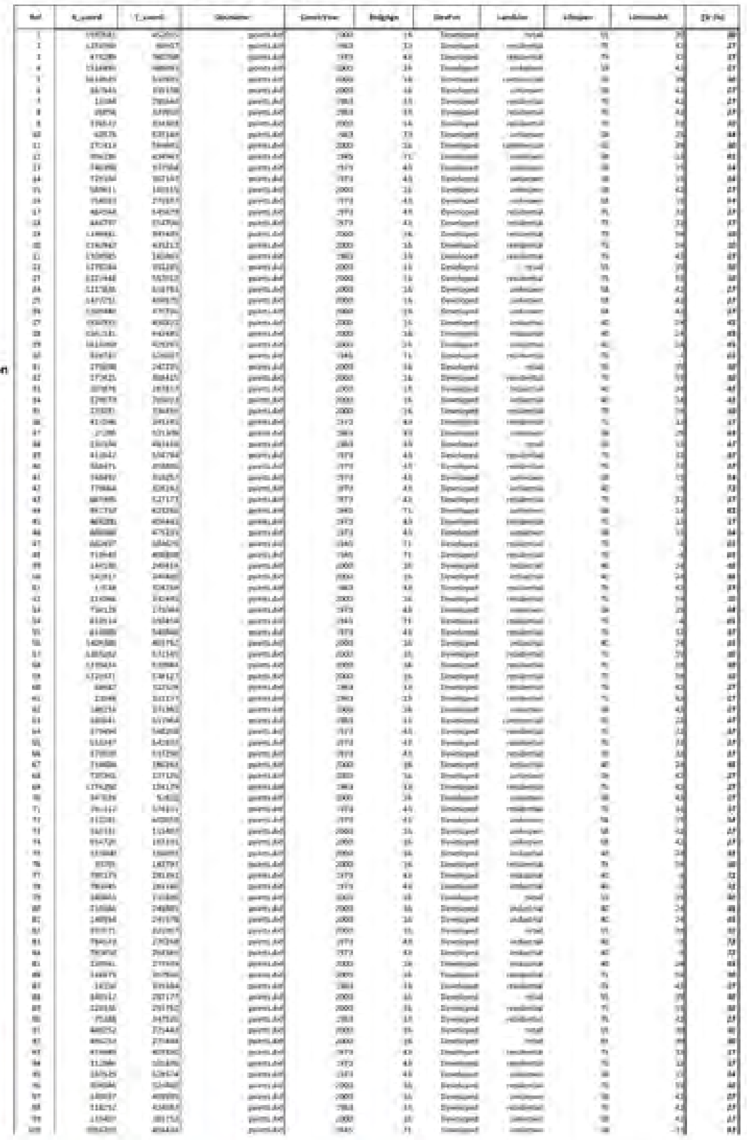
In D.U.M. several data are used for calculation of Developability factor. First let me mention that the setting of the process of calculation of this factor was changed several times during developing of D.U.M. of West Chelsea in Manhattan and the final calculation process described further was used just for D.U.M. of The Isle of Dogs in London. The input data for Developability are for all sites: land use category and price of lots. And for current building sites only: the volume of buildings and building age data are added. Fortunately all these data sets are available for London. But unfortunately all these data are only allowed for viewing, not downloading in some kind of data format. So these data had to be vectorized and shapefiles had to be created and than evaluated according to viewed data (mostly done in Grasshopper, partially in ArcMAP).

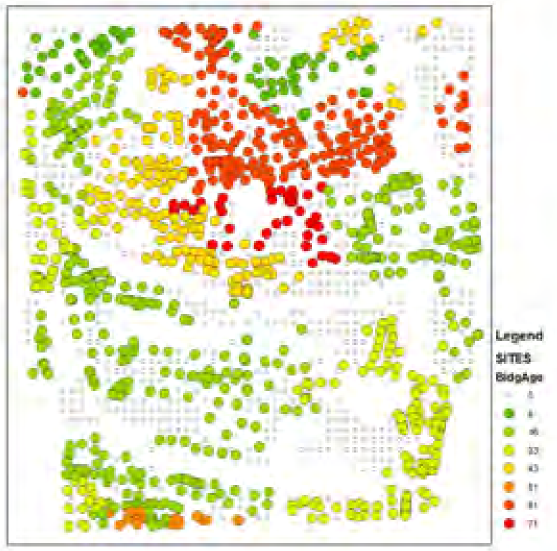
When we have these data ready, the laws of economics are applied to spatial development. When these are incorporated then the development is governed by general law of supply and demand and also by the law of diminishing returns. Meaning each territory is heading towards a state where it is exploited in economically optimal way. This process is also known as Bid Rent (Maier, Řezáč; 2016). This process is effected by several aspects like for example user preferences, attractivity of areas, value of buildings, market situation etc. All these aspects are dynamically evolving and permanently changing in time.

DEVELOPABILITY ***D.U.M. of The Isle of Dogs***

D.U.M. Input Based on Age of Buildings, Value of Sites and Land Use Categories







Developability Result

GIS process corelates age of buildings, value of sites and land use category (economical assesment) to current and potential building sites

To describe this process first gross commercial value of buildings (Cbv) is calculated based on land use of lot and volume of building on a lot (for better undersanding please see *Table scheme of ultimate data inputs and their correlations* in the beginning of chapter 4. Design). This gross commercial value is then related to price of lot (Pol) and from this economical rentability (Er) is calculated ($Er = \sum Cbv / Pol$) for each current built-up site. Now it is possible to determine land use status (Lus) of each site. If the economical rentability proportion is higher than 1 then land use status is marked as „used“. If it is precisely 1 or smaller then Lus is marked as „underused“. If there is no building on a site Lus = 0, then the land use status is marked as „empty“. and this state is, naturally, on all potential building sites. This calculation is mostly important for current built-up lots. And when marked as „underused“ there is a question of redesigning the building or change of land use category. To determine this the building age data comes into consideration. According to charts of economical rentability of construction (Maier, Řezáč; 2016) we can identify the time when the new building or a new function of building is relevant. The exact time depends on commercial value of building (Cbv) age of building (BA) and its function and correlation of this intermediate result to price of lots (Pol).

To simplify the calculations and the workflow of D.U.M. the age of buildings was transformed to life expectancy of building index according to current land use. This life expectancy is an tricky thing to assess because it depends on much more than just land use of lot and by its extension on function of building. It depends on type of construction, its quality, maintenance time, quality of technical infrastructure of the building etc. This aspect of D.U.M. should be better prepared but as mentioned due to workflow and a fact that this concerns just the part of assessed sites this simplified method was chosen. So the life expectancy of building according to land use was set as: residential = 75 years, commercial (office) buildings = 55 years, retail = 55 years, industrial constructions = 40 years, unknown type of building = 58 years (aggregated). This setting is based on several researches dealing with lifespans of buildings or durability and actual service lives of constructions. For example University College London sheet focusing on Lifespans of buildings and decision making processes (UCL Engineering, 2014).

So the final result of Developability factor counts with construction year data, which are available for each site, then calculates actual building age until current date and says how this stands related to life expectancy of building. And when the land use status (Lus) based on economical rentability of building (Er) is taken in an account the percentage rate of Developability of each site is done. This final result is in a form of data table sheet employed also with results of other two main factors (Connectivity and Intensity) to further modelling in D.U.M.

One final comment at the end of this chapter. One thing that is now not implemented in D.U.M. but it is envisaged to be in the future is the development of building technology and resulting life expectancy of buildings and constructions. Also currently tested more adaptive and flexible building technologies can completely change our view on land use of sites, economical rentability of buildings and in a first place on the dynamics of change of built-up environment. In the case of such a building technology development this Developability factor of D.U.M. has to be redesigned completely.

KOHL, Lukáš. In Bourání. Radio Wave. Prague:2016. Available at: http://www.rozhlas.cz/radiowave/bourani/_zprava/bourani-s-developerem-lukasem-kohlem-po-skole-toho-clovek-moc-neumi-ale-hodne-tusi--1596422

MAIER, Karel; ŘEZÁČ, Vít. Ekonomika v území: Urbanistická ekonomika a územní rozvoj. CTU: Prague. 2006.

UCL Engineering (University College London). Refurbishment & Demolition of Housing. Lifespans & Decisions: Factsheet. UCL. London: 2014. Available at:

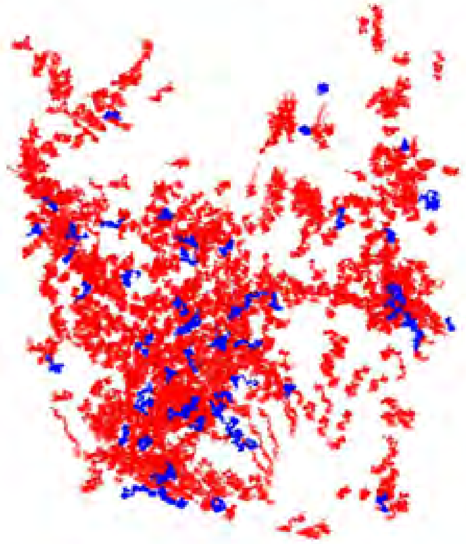
4.1.3.3. Intensity

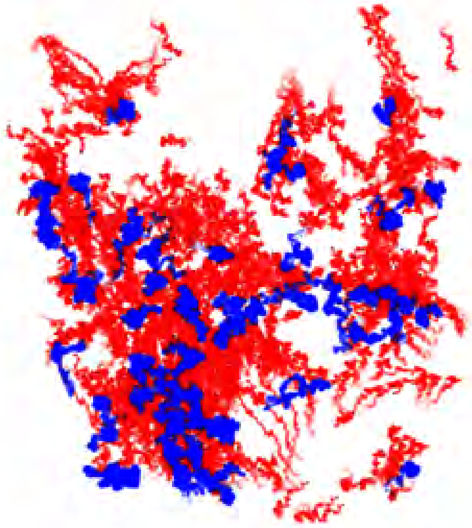
We can think about intensity as a geographical projection of position of each and every individual in urban space in real-time. This projection tells us where people stay, where they are heading and through which routes. What are sources and what are intended targets of their movement through city. These can show us an unpredictable alternative paths, areas of visit and stay, places where people like to stay, places people are seeking for. Such data provides us with informations about distribution of people within the city.

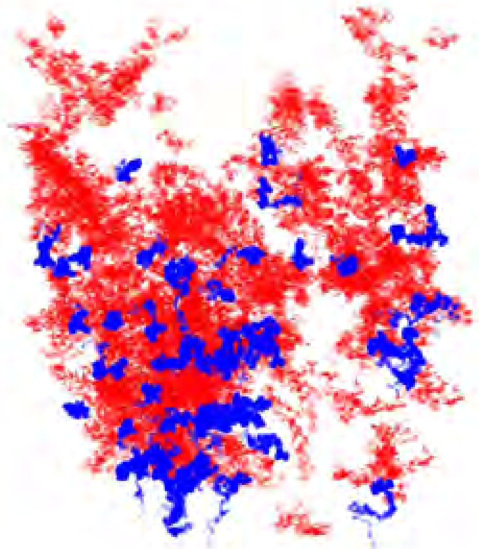
INTENSITY

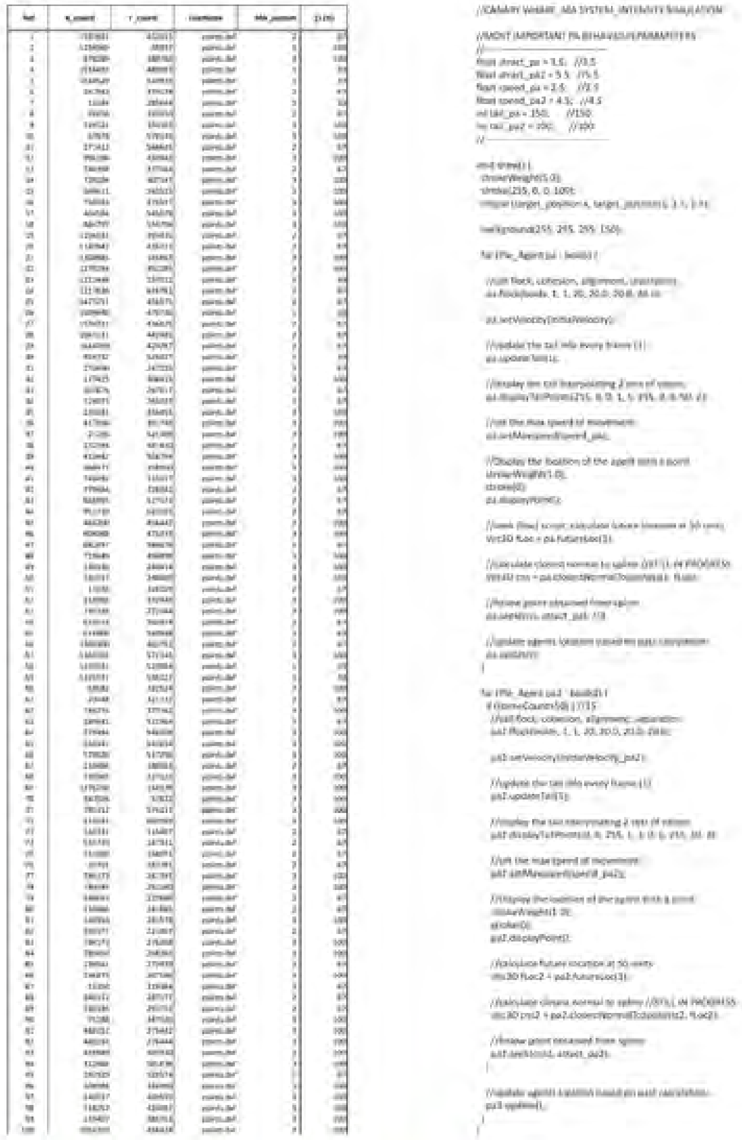
D.U.M. Input Based on Multi-Agent System Simulation

D.U.M. of The Isle of Dogs





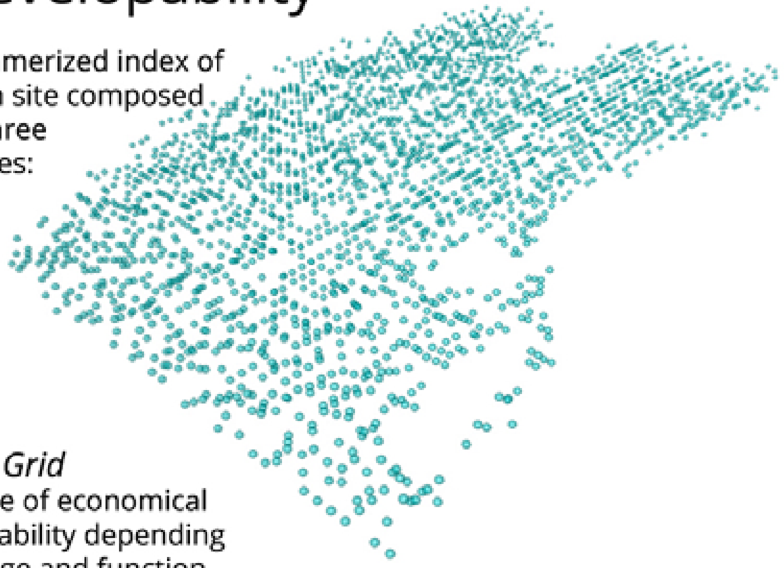




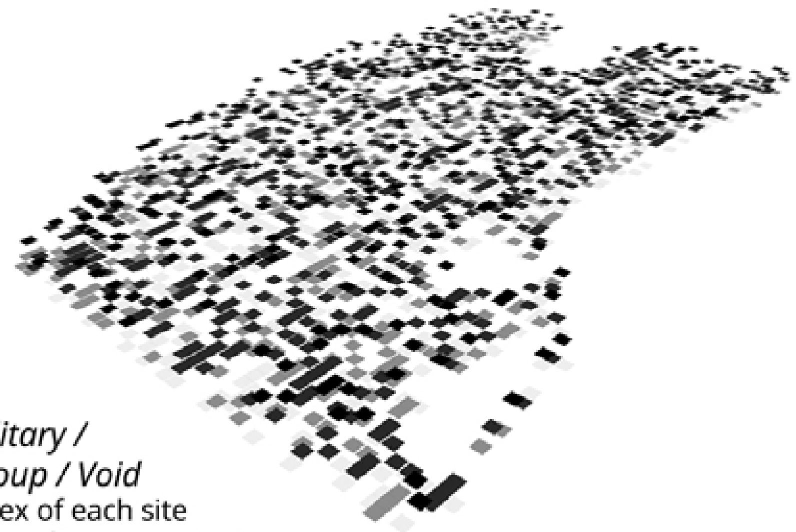
Intensity Result
GIS process corelates Multi Agent System Simulation of intensity of urban area use (scripted in Processing) to current and potential building sites

Developability

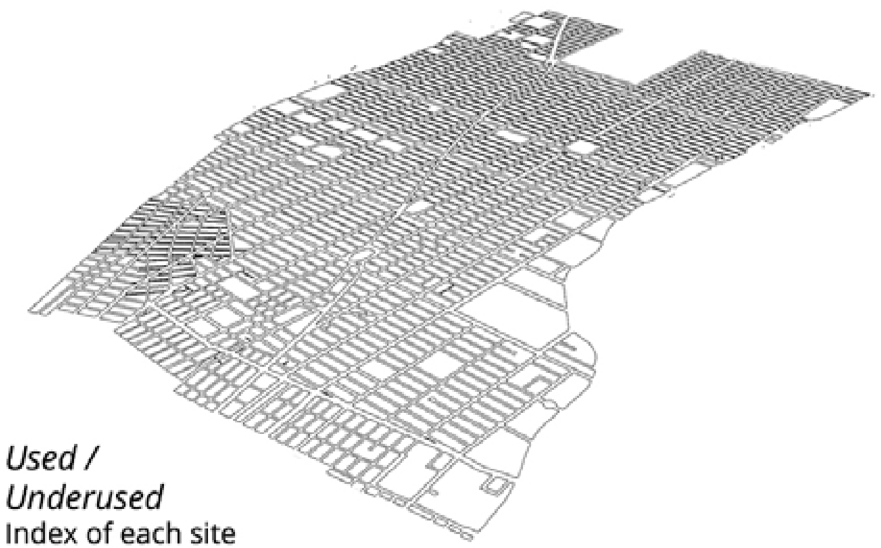
Summerized index of each site composed of three values:



Age Grid
Stage of economical rentability depending on age and function



Solitary / Group / Void
Index of each site depending on context

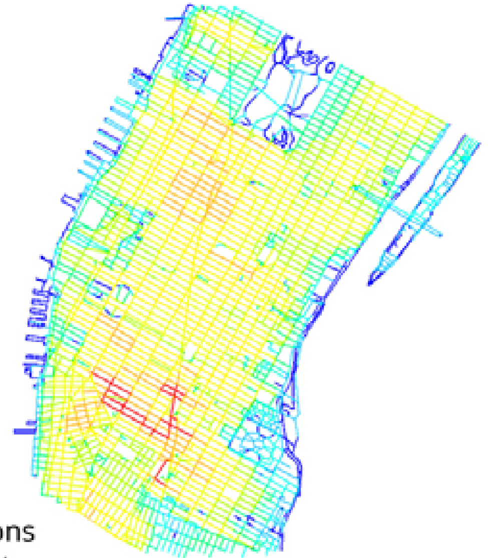


Used / Underused
Index of each site telling the level of usage

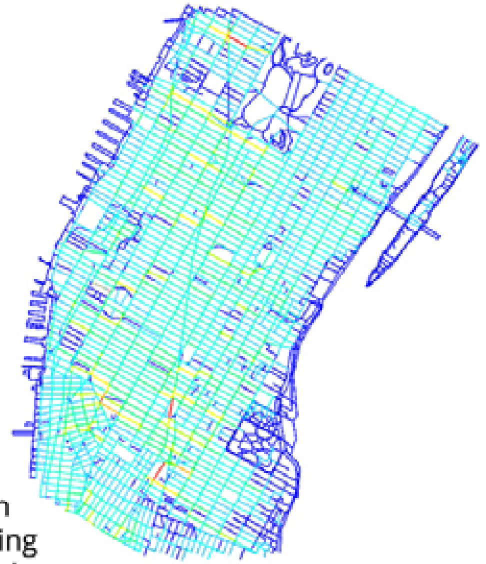
Connectivity

Summerized index of each street depending on its level of connection to enclosed streets. DepthMap soft-was used for this analysis:

Integration
Of each street in the whole analysed urban area



Connectivity
A n amount of direct connections from each street



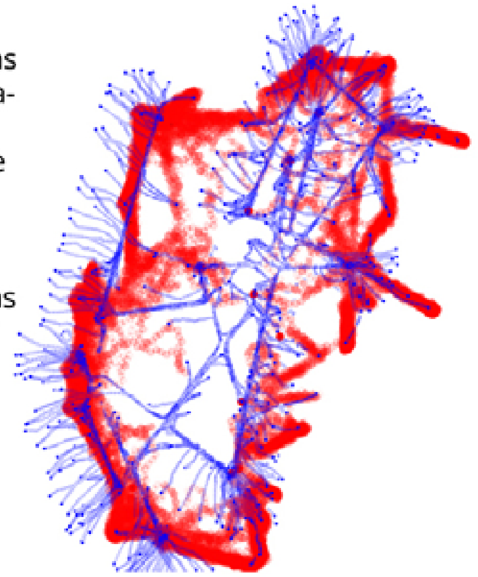
Choice
An index of eachstreet when pedestrianis wiling to turn max. 10 times

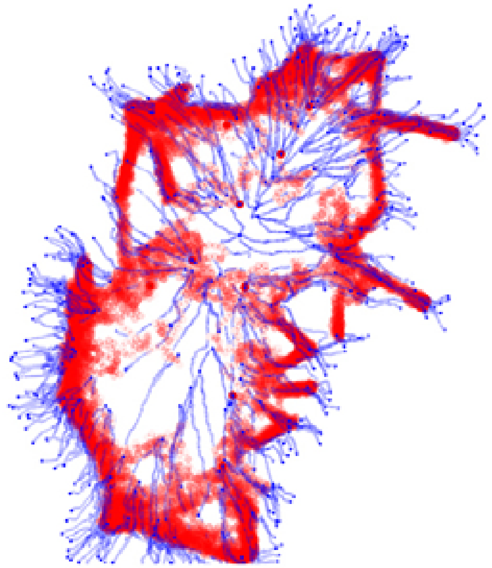
Intensity

Multi Agent systems are used for simula-tion of intensity of urban area. Theese routes are divided into two groups:

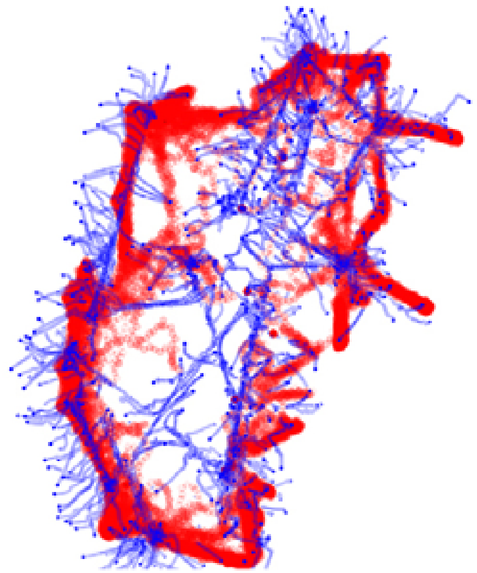
1) Main connections Blue Agents, which are staring from main hubs and centers and are seaching other main hubs

2) Yellow Agents which start from sub-centers and are attract to both main and sub centres





Main and Sub Centres
Are deffined by geographical and tima datas gained from people



Berhaviour
We can find see different results when setting differnt behaiour of Agents.

Key thing is to use the one which simulates best the intesity of using urban area.

The simulation of intensity of exploitation of urban space is performed by specific multi-agent system. This system is designed based on network of centers and subcenters of area of interest. This network of points works as a starting points for agents. Agents starting from subcenters are searching routes to main centers and vice versa.

In a certain way this Intensity simulation also substitutes the information from several transportation data inputs, because this is already incorporated in the centers and surcenters network as a position of points among which individual agents are moving. Also behaviour of simulation agents is imitating crowd behaviour and crowd intelligence. So the final result is not just a simulation of individual agents, but simulation of crowd of agents with inner interactions and communication (more in previous Research chapter - Multi-Agent Systems and Swarm Systems in Urbanism), which is much more than just total sum of separated individuals.

Intensity and Urban Development
The level of intensity of exploitation can be also seen as if every individual person in the city has a geographical sensor detecting his actual position all the time and everywhere. But as if it is not possible due to ethical reasons and right for ones private we have to find a way how to simulate this distribution and movement of urban population.

These information are one of the really key factors for potential spatial development of any kind. Underused or even vacant localities are often right on the edge of the overused ones, and if used properly, these can help to lower the intens exploitation a distribute it in a more appropriate way. Determining these and enabling the proper form of development for investors can also prevent the cities from further spatial growing and sprawling. Intensification of the city structure at the most appropriate sites should be one of the efforts of local governments all around the world. And in many cases why this is not happening is just the lack of informations about these sites. And what is resulting from this is wrong spatial and zoning regulations plus lack of coordination of particular intentions. D.U.M. is able to offer these informations and enable the authorities to set proper regulations and to coordinate better the numerous public and private development intentions.

Intensity in D.U.M.
As mentioned above the Intensity factor is simulated through multi-agent systems seeking centers and subcenters of the area of interest. This system has been scripted in Processing (Java scripting language). For easier manipulation with agents Plethora plug-in developed by José Sanchez was used. This plug-in focuses on multi-agent systems and tries to simplify the setting of their behaviour.

Determined network of points (centers and subcenters) designed in Grasshopper and based on Urban Data 1 – Quantitative geographical data, is streamed through data tables as a text file to Processing folder from where it is imported to Processing interface. Then the behaviour of agents in specific modelled city has been scripted and run several times. Because of internal behaviour among agents the result of Intensity simulation is always different. So the aggregation of many of these results was done (through overlapping of layers with different results) and the final *.jpg file of multi-agent intensity analysis was created. This image is then imported to ArcMAP for further work with data allocation to individual current and potential building sites (described further).

4.1.3.4. Other possible factors

Of course there is plenty of possibilities how to implement other important factors that influence spatial development in cities. How to use other data sets or how to choose additional data inputs for D.U.M. in a specific cases to improve even more the predictive strength or to create even more quality and appropriate urban design. Also we need to think about special conditions of each city, inimitable issues and problems and social characteristics which drives the spatial development of each city. And not just a cities as a whole but also their parts and quarters. As an example we can introduce the unique characteristics of long time neglected localities which suddenly became attractive. So called gentrification process (with its advantages and disadvantages) which can be measured by other entries than connectivity, developability and intensity used in D.U.M. of West Chelsea and The Isle of Dogs. So for such localities the suitable entry should be an other data based input like the Attractivity, which would measure the attractiveness of certain part of area of interest. Flow of people, their interest in local services and free-time activities, their activity on real estate market, bank mortgages for this locality etc.

Attractivity
And the urban modelling approach based on dynamic data inputs introduced in this thesis is not the first and unrealistic. In a part of London this approach which measures data from social networks and can predict a localities which potentially will undergo a rapid wave of gentrification was applied. The computer scientists found a way how to screen data from Twitter and Foursquare (internet social networks) and map the places visited by most socially diverse crowds (Collins, 2016). These scientists built a geographical network of restaurants, clubs, shops and apartments and then observed social networks data and connections among their users. Through linking of virtual social network and physical geographical network, the team was able to construct several measures of the social diversity and distinguish places that brings together friends versus strangers and find a places which brings together socially diverse crowds. Other measures reflected an account income, education level, environmental factors and others. The most important message is that the process of gentrification does not start when outsiders move in, it starts when outsiders come to visit.

So as you can see dynamic, real-time and detailed data, which of course have to be anonymous, are able to foretell the change in social and also physical structure of the urban environment. And that is the main advantage of data driven approaches in urban planning and urban design used for developing of D.U.M.

Data Sources
For the purposes of this data driven planning and design we could use also data sources which will certainly become more common soon. These data sources are basically very sensitive sensors which are screening surrounding environment and its conditions. These sensors can be part of monitoring systems like IoT, IoE, Swarms of flying mini-sensors etc. mentioned earlier in the research part dedicated to Urban data. These can give us informations about air quality, heat level, sound and smell environment, real-time but also long-term traffic situation, financial situation of inhabitants etc. Or we can go even further in our ideas and say, that these sensors will be able to say, whether people are happy, relaxed and satisfied and what are the reasons for this, when this is caused by urban space that surround them. These indexes of happiness based on biological factors are already known, but such a data are unfortunately not collected or opened for further use.

These sensors can be applied in a larger sphere of activity. They can also be part of systems which are not just monitoring the conditions in the cities, these sensors can be installed in systems which are creating the environment. Smart, educative, dynamic building systems which screens the lives of people and are able to adapt the surrounding environment to their unique needs. If Smart cites are mentioned in this thesis, we can also talk about smart buildings and in extension flexible adaptive buildings and spaces. There have already been developed several systems which are based on adaptiveness and responsiveness. Among others let me introduce HypeCell system designed by research team at Design Research Laboratory at the Architecture Association School of Architecture in London (AA DRL, 2015) or Swarm Robots proposed by Akira Mita. When we are talking about other possible factors of urban evolution in this chapter, the automatic intelligent systems are able to deliver these factors. The urban environment would be able to understand its inhabitants down to their emotional state (Mims, 2012). So the city, urban space and buildings would be interconnected living-like system monitoring and assessing conditions and based on this designing the most appropriate environment for its population. That would be the ultimate level of D.U.M.s

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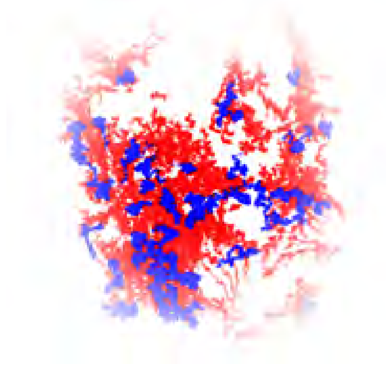
AA DRL, Design Research Laboratory. HyperCell. 2015. Available at: http://www.hypercell.co.uk/

COLLINS, Nathan. How to see Gentrification Coming. Pacific Standard. 2016. Available at: https://psmag.com/how-to-see-gentrification-coming-6adf-b582a0d#.7dkn4jdcv

MIMS, Christopher. Robot Swarms Aim to Bring Buildings to Life. BBC. 2012. Available at: http://www.bbc.com/future/story/20120717-bringing-buildings-to-life

```
// MULTI-AGENT SYSTEM SIMULATIN INTENSITY
// OF EXPLOITATION OF URBAN SPACE
// D.U.M. OF THE ISLE OF DOGS, LONDON
//© Pavel Paseka, 160322

import processing.opengl.*;
import plethora.core.*;
import toxi.geom.*;
import peasy.*;

ArrayList <Ple_Agent> boids;

//using peasycam
PeasyCam cam;

Spline3D st1;
Vec3D pointgrass = null;


//create a spline
Spline3D sp2;

float DIMX = 1000;
float DIMY = 1000;
float DIMZ = 1000;

int pop = 300; //150

void setup() {
 size(1200, 600, OPENGL);
 smooth();
 cam = new PeasyCam(this, 1000); //600

 //initialize the arrayList
 boids = new ArrayList <Ple_Agent>();

 //build the spline from values
 sp2 = new Spline3D();
 for (int i = 0; i < 20; i ++) {
  Vec3D v = new Vec3D(-600 + (1200/20*i), random(-50, 50), random(-50, 50)+100);
  sp2.add(v);
 }

 for (int i = 0; i < pop; i++) {

  //set the initial location as 0,0,0
  Vec3D v = new Vec3D (0, 0, 0);
  //create the plethora agents!
  Ple_Agent pa = new Ple_Agent(this, v);

  //generate a random initial velocity
  Vec3D initialVelocity = new Vec3D (random(-1, 1), random(-1, 1), 0);

  //set some initial values:
  //initial velocity
  pa.setVelocity(initialVelocity);

  //initialize the tail
  pa.initTail(200); //200

  //add the agents to the list
  boids.add(pa);
 }
}

void draw() {
 background(235);

 //import coordinates from grass (pointsgrass)
 String start[] = loadStrings("pointsgrass.txt");
 st1 = new Spline3D();
 for (int k =0; k < start.length; k++) {
  String row[] = split(start[k], ',');

  pointgrass = new Vec3D(float(row[0]), float(row[1]), float(row[2]));
  st1.add(pointgrass);

  strokeWeight(2.0);
  stroke(0);
  point(pointgrass.x, pointgrass.y, pointgrass.z);
  ellipse ( pointgrass.x, pointgrass.y, 1.5, 1.5);
 }

 //draw a rect as reference
 stroke(0, 90);
 strokeWeight(1);
 noFill();
 rect(-DIMX/2, -DIMY/2, DIMX, DIMY);

 //run all agents
 for (Ple_Agent pa : boids) {

  //call flock, cohesion, alignment, separation.
  //first define the population, then the distances for cohesion,alignment, separation
  //and then the scales in same order. Try playing with the scales and distances!
  pa.flock(boids, 1, 1, 20, 2.0, 2.0, 2.0);

  //update the tail info every frame (1)
  pa.updateTail(1);

  if (frameCount>300) {
   //display the tail interpolating 2 sets of values:
   //R,G,B,ALPHA,SIZE - R,G,B,ALPHA,SIZE
   pa.displayTailPoints(255, 0, 0, 30, 2, 255, 0, 0, 100, 5);
  }

  //set the max speed of movement:
  pa.setMaxspeed(3.7); //1.7
  //pa.setMaxforce(0.05);

  //if (frameCount>200) { //&& (frameCount<600))
  //  pa.dropTrail(5,100);
  //  strokeWeight(2.0); //1.0
  //  stroke(255, 0, 0);
  //  pa.drawTrail(20);
  //}

  //seek (line) script
  //calculate future location at 50 units
  Vec3D fLoc = pa.futureLoc(1);
  stroke(255, 0, 0, 90);

  //calculate closest normal to spline //STILL IN PROGRESS
  Vec3D cns = pa.closestNormalToSpline(st1, fLoc);
  stroke(255, 0, 0, 20);

  //follow point obtained from spline
  pa.seek(cns, 3.0); //2.5

  //update agents location based on past calculations
  pa.update();

  //Display the location of the agent with a point
  strokeWeight(2); //2
  stroke(0);
  pa.displayPoint();

  //Display the direction of the agent with a line
  strokeWeight(1);
  stroke(100, 90);
  pa.displayDir(pa.vel.magnitude()*3);
 }
 println (frameCount);
 //save JPGs for videos
}
```



D.U.M. of The Isle of Dogs
Processing Script_1 (Java Scripting)
multi-agent system simulating intensity
of exploitation of urban space

4.1.3.5. Urban Evolution Prediction

Sites Generating
First let me introduce the method of generating current and potential building sites (*scheme on right side*). Because to these sites all other modelling processes are related, all continuously gathered and assessed data are assigned, to these sites modelling of urban evolution and prediction of spatial development is connected.

Let´s start with the more complicated part of generating potential building sites. It is better not to burden the D.U.M. with the limitations of ownership or current division of lots. Because when you have a certain specific division of lots and their ownership (for example row houses which are very typical building form for cities in England) it implies again the same building form, same land use, same spatial development. And the possibility of merging the lots and transforming of the ownership structure is hard to cover in modelling process. So the other variant of generating potential building lots was applied. First the whole area of interest was covered by regular point grid dense enough to be compared the density of current building sites and their reference points. Than a not-builtable areas were subtracted from this grid. Meaning parks, expanse of water and main transportation roads and areas. Also main public spaces and squares were intended to subtract but it showed up that infrastructure of these public spaces, squares and plazas can also be transformed and adapted according to current needs of urban population and socio-economical changes. Many experts would not agree with this point, but not including main public space enables to model potential expansion of current building structures and its adaptation on evolution of urban society.

When we have generated potential building sites than current building sites have to be added of course. And that is an easy operation, because it is possible to get these data from OpenStreetMaps (importing to Grasshopper through Elk plug-in) or also local governments are releasing these data in a form of Web Map Services (just for viewing in GIS softwares) or even as a shapefiles (viewing and editing in GIS softwares). All these data sources were used for both developed D.U.M.´s. Although it is important to say that relevance of latest versions of these data is not very high, especially in the case of London. One can see this even if he will simple compare these data to Google Street View images. Nevertheless it at least enabled to compare results of D.U.M. with spatial development not integrated in used data but completed in reality. And it was a nice discovery that results of D.U.M. (growing, stabilized and declining localities – described more detailed in forthcoming chapters) match with actual new development. This has happened especially in case of D.U.M. of The Isle of Dogs, when D.U.M. results determined a huge development potentiality in one locality, which has according to Google images undergone big urban development in recent year. That was just a prove that selected factor assessed by D.U.M. were chosen and determined well. But that also proved the enormous dependence on data input quality.

D.U.M. results
The results of partial operations for assessing of Connectivity, Developability and Intensity have been gathered. Now these values needed to be assigned to sites (current and potential building sites). This is what is after all evaluated in D.U.M. – sites. So we have had a data for streets (shapefile type: lines), for clusters and neighborhoods (shapefile type: polygons) and now a procedure to allocate these data to the sites (shapefile type: point) which they pertain to had to be done. As the most convenient and appropriate way how to do this an importing all these data to GIS software was evaluated. So particular data results are assembled in ArcMAP in the form of data tables. And now the procedure of allocating data was performed. The data was selected and assigned based on geographical location. This can be done by Select by Location operation in ArcMAP. The ArchMAP lets you to select features from required data layer based on where they are located in relation to the features in another data layer regardless of data type (line, polygon, point). And next the operation intersects the data layers and one can work with the data from lines and polygons which geographical belong to the specific sites and assign the data values to the sites.

Each factor of D.U.M. (Connectivity, Developability and Intensity) now assigned to proper site is than recalculated as a proportional value. So we can get new data columns for Σ C (%), Σ D (%)and Σ I (%). This recalculation secures each D.U.M. factor has equal significance. This is of course for developed D.U.M. of West Chelsea in Manhattan and D.U.M. of The Isle of Dogs in London. But it is easy to imagine that for D.U.M.´s of other cities the measure of importance can vary for each factor. Of course there has to be a right reasons for these differences.

The recalculated values of each factor are that added up and again recalculated as a proportional value for each site. And this is what we can call as a one of result of D.U.M. The percentage value of each building site (current or potential). This value represents the level of potentiality for further development. These values can be interpreted and visualized as areas of potentional growth, stabilized areas or declining areas with low potential for undergoing any spatial development.

Strategic multi-agent system
Another step in the model is an application of strategic multi-agent system which was developed in Processing (*schemes and script on following pages*). These kinds of systems are more detailed described in Design Tools chapter. In D.U.M. this system is representing the strategic behaviour of potential investors in the city. When calculation of Connectivity, Intensity and Developablity factors is completed for every current and potential building site, these data are exported to Processing and strategic multi-agent system representing potential investors can find a specific developing sites. These marked developing sites are than exported back to Grasshopper, where additional data inputs are collected and most appropriate urban design is proposed on them.

Scripting of fully strategic behaviour of agents is though really complex and difficult task for advanced computer programmers. So in proposed D.U.M. just simple non-strategic behaviour is used. That is one of weaknesses of developed D.U.M., but it is also space for further improvement. As in other parts of this thesis the using of strategic multi-agent systems is rather showing the way of thinking about processes taking place in a cities.

Visualizing the D.U.M. results
To visualize D.U.M. results (proportional value for each site) a Medial axis method was used. That is a solution for describing the topology of a shape (in this case virtual shapes) through so called Medial axis, and using this description to create a form out of any closed shape or closed set of shapes. The logic of this script is using Voronoi cells to find the Medial axis.

D.U.M. of The Isle of Dogs
Generating current and potential sites

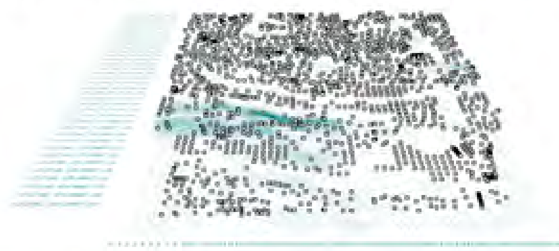

1_Potential Building Sites_ALL

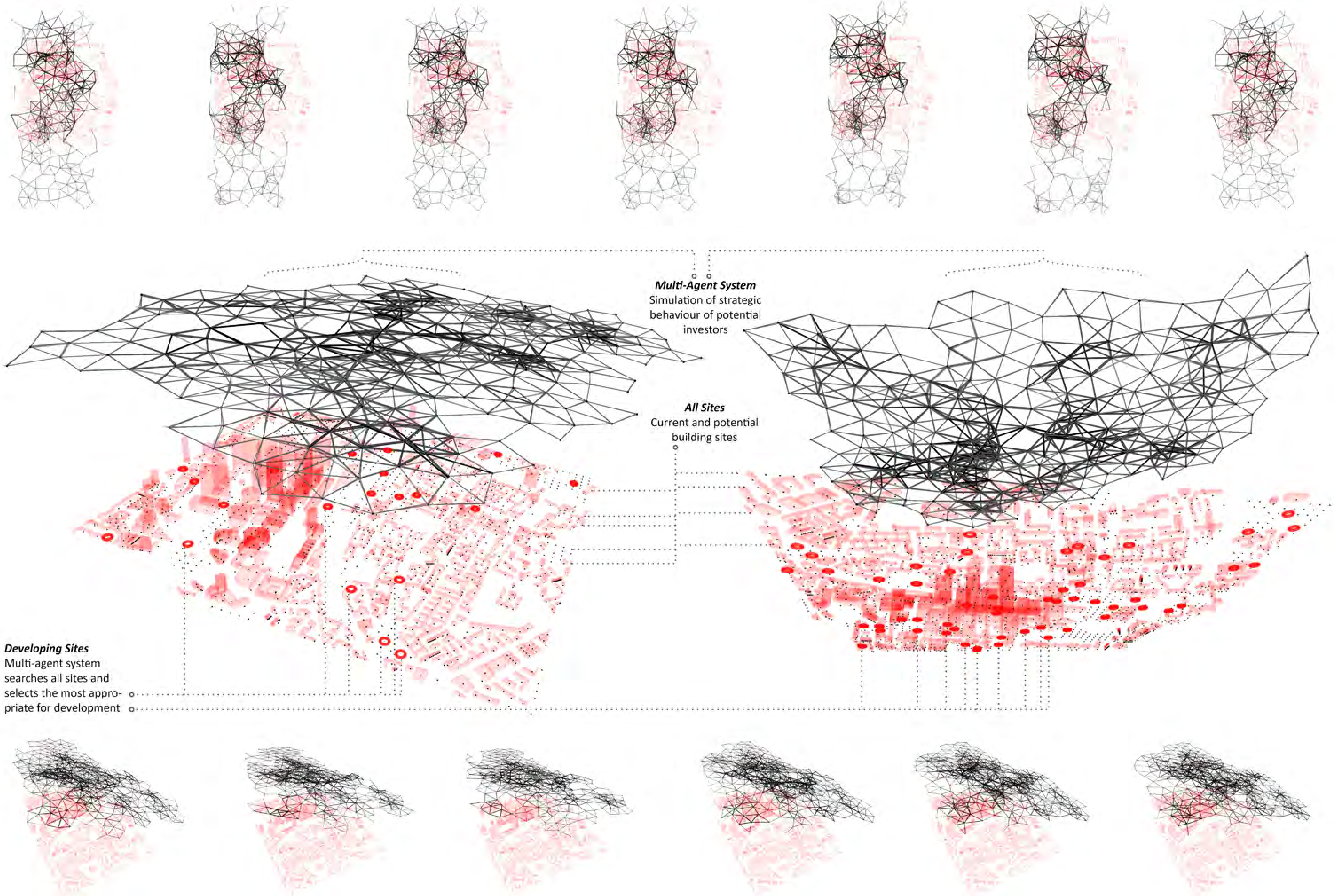

2_Not Buildable Areas_Parks, Water, Transportation etc.


3_Potential Building Sites_Difference_Not Buildable Areas


4_Current Buildings_ALL


5_Magneta = Current Buildings; White = Potential Building Sites


6_Result = Current Buildings + Potential Building Sites


Multi-Agent System
Simulation of strategic behaviour of potential investors
All Sites
Current and potential building sites
Developing Sites
Multi-agent system searches all sites and selects the most appropriate for development

```
// MULTI-AGENT SYSTEM SIMULATING STRATEGIC
// BEHAVIOUR OF POTENTIAL INVESTORS
// D.U.M. OF THE ISLE OF DOGS, LONDON
//© Pavel Paseka, 160420

import processing.opengl.*;
import plethora.core.*;
import toxi.geom.*;
import peasy.*;
import processing.pdf.*;

ArrayList <Ple_Agent> boids;

//using peasycam
PeasyCam cam;

//using plethora camera
//Ple_Camera pCam;

Vec3D start_position = null;
Vec3D buildingsites = null;
Vec3D buildingsites2 = null;
Vec3D agegrid = null;
Vec3D B  = null;
Vec3D A  = null;
Spline3D st5;
Spline3D st2;
Spline3D st1;

PShape s;

boolean record;

float D;
float D2;

float DIMX = 600;
float DIMY = 600;
float DIMZ = 600;

//float fromDist = 60;
//float toDist = 60;

int pop = 250; //300

//PrintWriter output2;

void setup() {
  size(1200, 700, OPENGL);
  smooth();

  cam = new PeasyCam(this, 40, 100, 0, 60);

 //initialize plethora camera (this,  x,y,z,  x,y,z);
 //pCam = new Ple_Camera(this,
 //17, 91, 100,
 //17, 91, 20);
 //64, 15, 70, // perspective view
 //20, 72, 20);

 // The file "*.obj" must be in the data folder of sketch
 s = loadShape("OBJ for processing.obj");
 s.setFill(color(255, 0, 0, 30));
 s.setStroke(color(0));
 s.setStrokeWeight(4);

 //initialize the arrayList
 boids = new ArrayList <Ple_Agent>();

 for (int i = 0; i < pop; i++) {

  Vec3D v = new Vec3D (random(40), random(150), 30);
  //create the plethora agents!
  Ple_Agent pa = new Ple_Agent(this, v);

  //generate a random initial velocity
  Vec3D initialVelocity = new Vec3D (1, 0, 0);

  //set some initial values:
  //initial velocity
  pa.setVelocity(initialVelocity);

  //add the agents to the list
  boids.add(pa);
 }
}

void draw() {

 if (record) {
  beginRaw(PDF, "output.pdf");
 }

 background(255, 255, 255);

 //Display Shapefiles
 shape(s, 0, 0);

 ////update camera Position
 //pCam.update();
 ////call come of the camera functionallity
 //pCam.moveStraightCamera(0, 0, 1);

 //import coordinates (Age Grid Points) from grass
String Age_Grid[] = loadStrings("agegrid.txt");
st5 = new Spline3D();
for (int m =0; m < Age_Grid.length; m++) {
  String row[] = split(Age_Grid[m], ',');

  agegrid = new Vec3D(float(row[0]), float(row[1]), float(row[2]));
  st5.add(agegrid);

  strokeWeight(0.5);
  stroke(0);
  ellipse (agegrid.x, agegrid.y, 0.1, 0.1);

  //point(agegrid.x, agegrid.y, 2);
}

for (Ple_Agent pa : boids) {

  //call flock, cohesion, alignment, separation.
  //the population, then the distances for cohesion,alignment,
  //separation and then the scales in same order.
  pa.flock(boids, 0.01, 1, 5, 1.0, 1.0, 1.0); //cohesion=0.001

  //update the tail info every frame (1)
  pa.updateTail(1);

  //Display the location of the agent with a point
  strokeWeight(2);
  stroke(0);
  pa.displayPoint();

  //Display the direction of the agent with a line
  strokeWeight(1);
  stroke(255, 0, 0, 90);
  pa.displayDir(pa.vel.magnitude()*3);

  //set the max speed of movement:
  pa.setMaxspeed(0.4);

  //import coordinates (Building Sites) from grass
  String  Building[] = loadStrings("buildingsites.txt");
  st1 = new Spline3D();
  for (int m =0; m < Building.length; m++) {
   String row[] = split(Building[m], ',');

   buildingsites = new Vec3D(float(row[0]), float(row[1]), float(row[2]));
   st1.add(buildingsites);

   //strokeWeight(1);
   //stroke(0);
   //ellipse ( buildingsites.x, buildingsites.y, 1.5, 1.5);

   float D=dist(pa.loc.x, pa.loc.y, buildingsites.x, buildingsites.y);

   //println (D);

   if ((frameCount>250) && (D<0.1)) {
    pa.setMaxspeed(0.000);

    strokeWeight(3);
    stroke(255, 0, 0, 100);
    ellipse ( buildingsites.x, buildingsites.y, 1.2, 1.2);
   }

   //draw a line between the agents in the distance specified.
   if (D<1.0) {
    strokeWeight(2.5); //3.0
    stroke(0, 0, 0, 100);
    pa.drawLinesInRange(boids, 1, 5); //5; fromDist, toDist);
   } else if (D<3.0) {
    strokeWeight(1.3); //1.8
    stroke(0, 0, 0, 100); //(0, 0, 0, 100);
    pa.drawLinesInRange(boids, 1, 8); //5; fromDist, toDist);
   } else {
    strokeWeight(0.5);
    stroke(100, 100, 100, 100); //(100, 100, 100, 100);
    pa.drawLinesInRange(boids, 1, 7); //5; fromDist, toDist);
   }
  }

  //seek (line) script
  //calculate future location at 50 units
  Vec3D fLoc = pa.futureLoc(1);

  //calculate closest normal to spline //STILL IN PROGRESS
  Vec3D cns = pa.closestNormalToSpline(st1, fLoc);

  //follow point obtained from spline
  pa.seek(cns, 0.5); //0.3

  pa.update();
 }

 if (record) {
  endRaw();
  record = false;
 }

 println (frameCount);

 //save JPGs for videos
 saveFrame("images/random-####.jpg");
}
```

D.U.M. of The Isle of Dogs
Processing Script_2 (Java Scripting)
multi-agent system simulating strategic
beheviour of potential investors

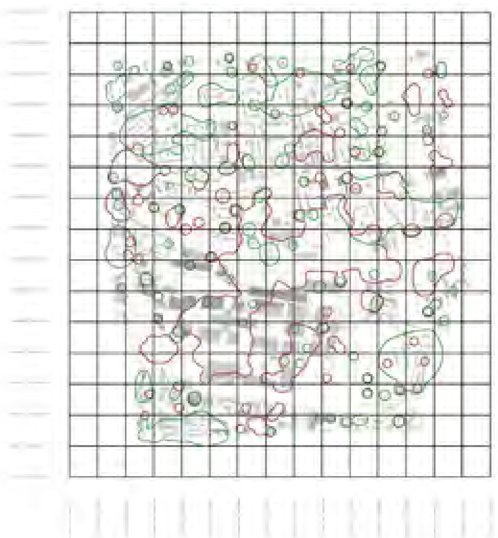
These curves are divided into a regular number of points, and these division points in turn are used to create a Voronoi diagram. The boundary between the cells corresponds closely to the elements that can be described as the "Ridge" and "Hips" of our form. Finally, we use the "Trim Region" command to trim the Voronoi cells, and we will only go forward with the pieces of geometry that are inside required region curves which are basically edges of potentially growing and declining areas. Boundaries of these areas are generated by metaball geometry and than only significantly large areas of metaballs are selected to show only relevant growing and declining areas, not the negligible ones.

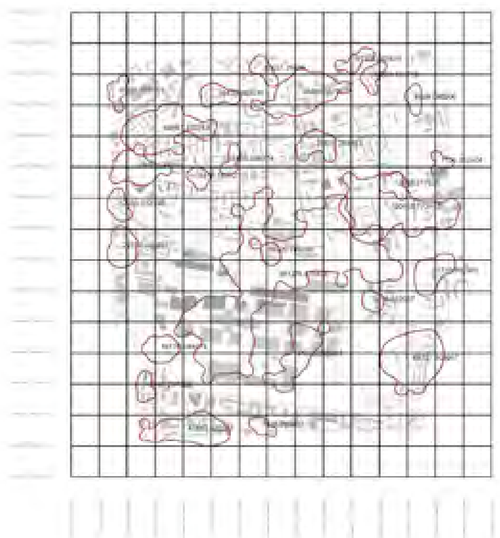
When the trimmed Medial axis are generated the endpoints of each piece of geometry are extracted, and then moved vertically based on their distance from the edge curve. The amount of movement is scalable based on the desired overall slope. Once these points are moved, the lines are be redrawn. This happens when input data changes and D.U.M. is still generating actual areas of growth (endpoints move „up") or decline (endpoints move „down"). In the next step the mesh are designed from points on guiding curves and than contour lines are generated an coloured into gradient colour for better visualization.

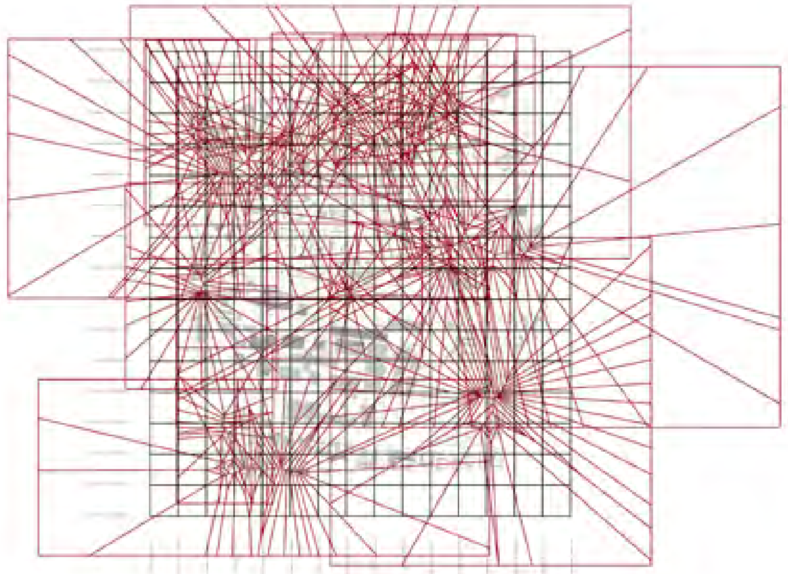
The so called stabilized areas was not described yet. These areas are supplement to growing and declining ones an no contours are displayed above them. These areas of the city are the ones with stabilized results of relation among economical utility, average connectivity of street network and with middle or high level of intensity of exploitation of urban space.

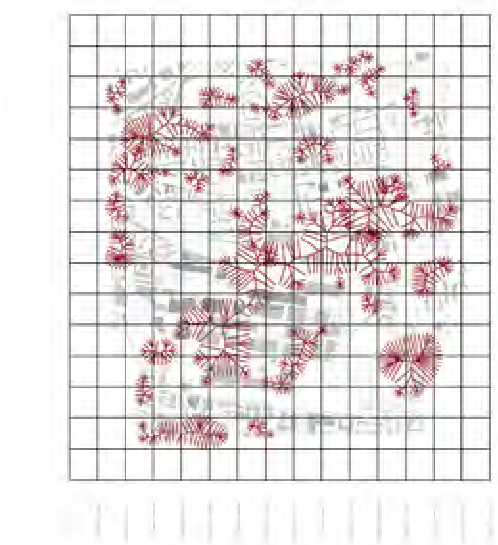
As the urban population using of urban environment is changing and evolving, the data inputs are dynamically changing as well, so D.U.M. factors of Connectivity, Developability and Intensity are recalculated and the results for every current and potential building site are still in progress. In this thesis it is not possible go gather and stream all those data inputs, so the random generation of change of input data is used. So the prediction showed when D.U.M. starts to collect the input data and displays model of the potential evolution is based on random numbers generated in unique Grasshopper component. So the latter modelled prediction is not based on real data. But in the initial stages of D.U.M. the input data are really describing the behaviour of people in modelled city so the results of the model are relevant.

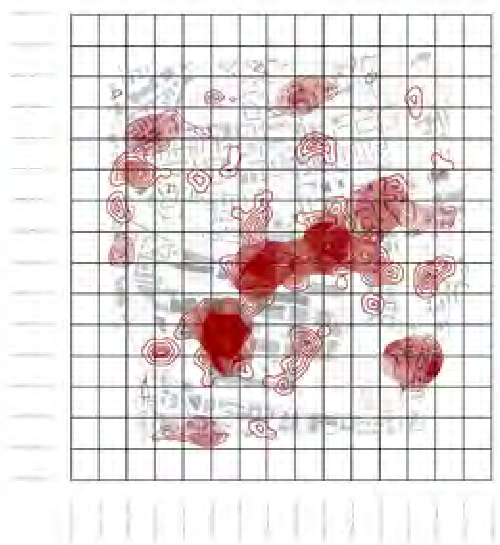

1_Potential growing and declining sites

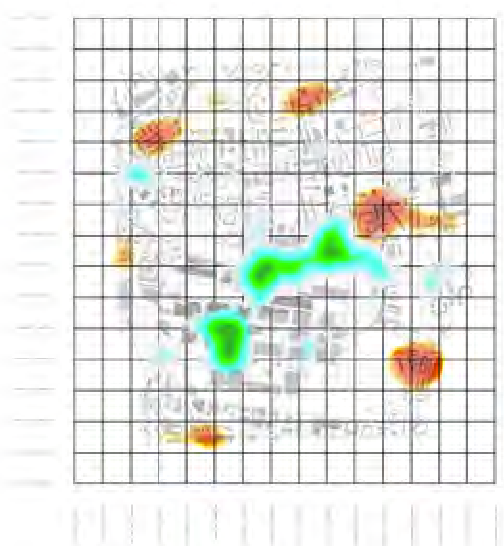

2_2D Metaball curves

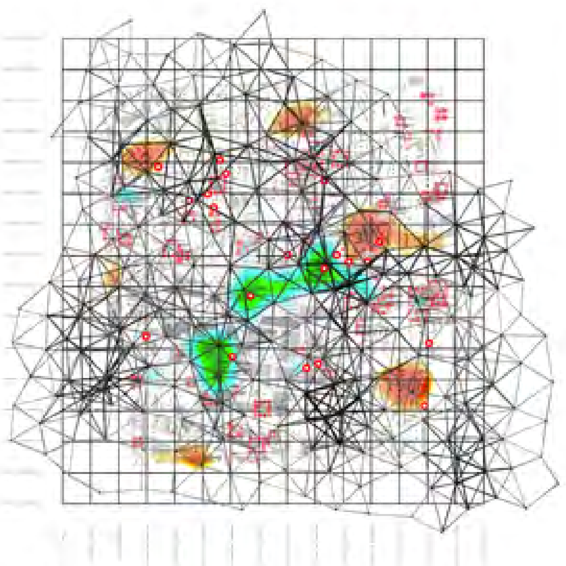

3_Selecting large metaballs

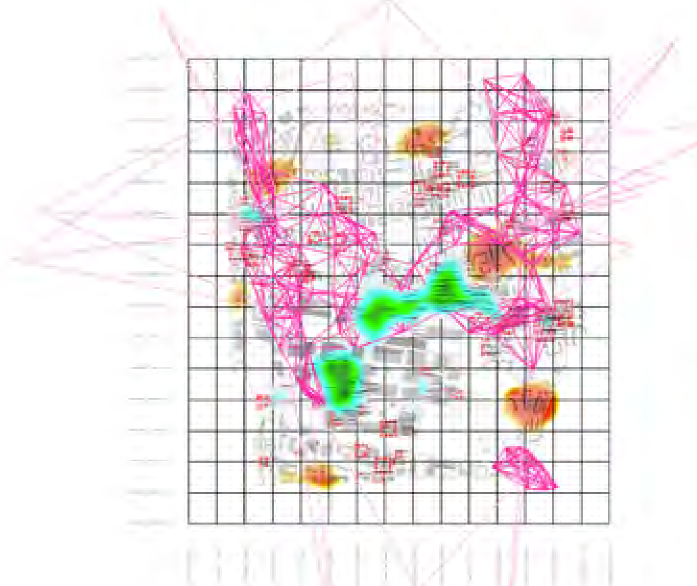

4_Voronoi diagram


5_Medial axis

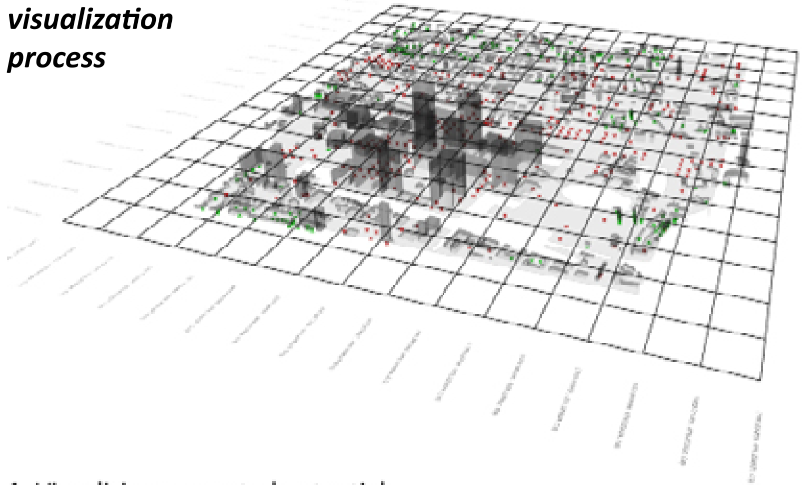

6_Meshes and contours


7_Colour gradient (growing vs. declining)

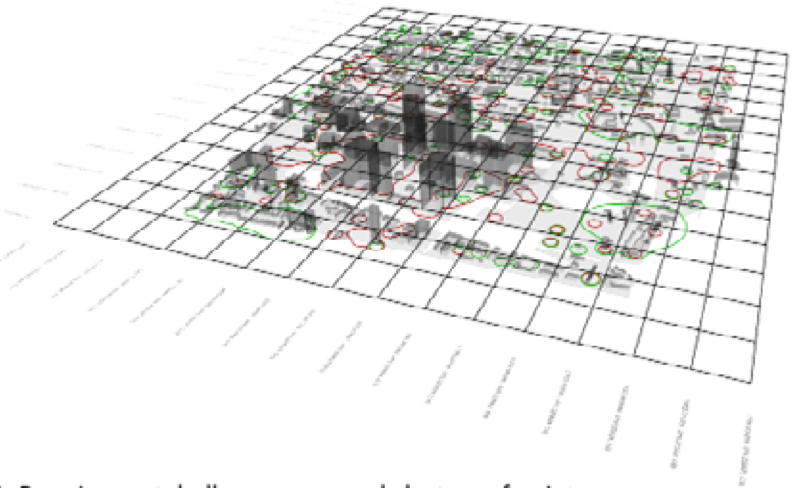

8_Strategic multi-agent system - virtual buildings


9_Visualizing data inputs

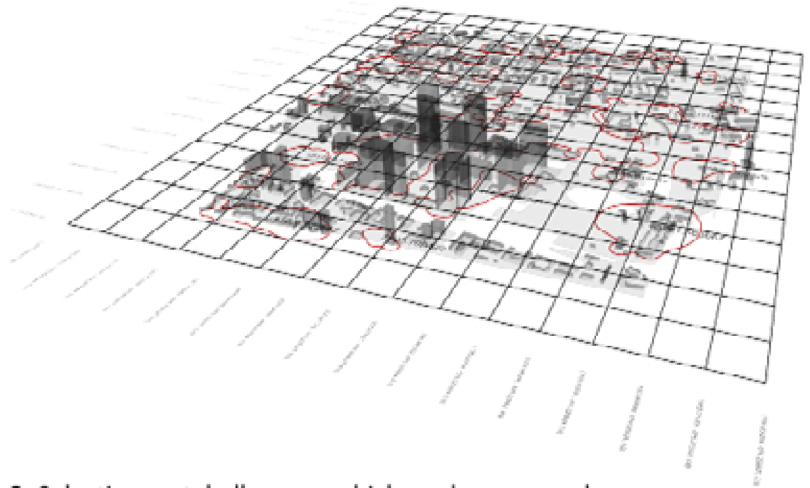
D.U.M. of The Isle of Dogs
D.U.M. results
visualization
process



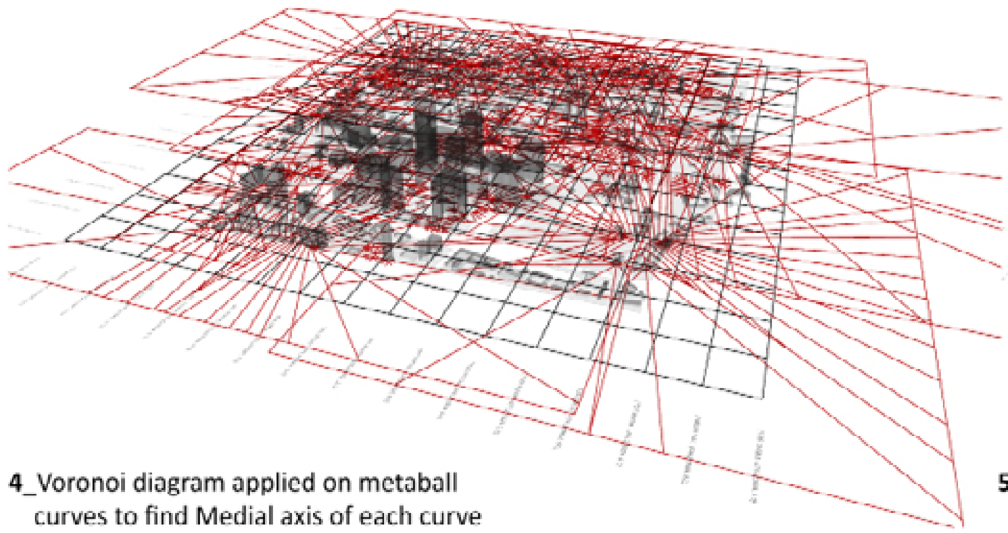
1_Visualizing generated potential
growing and declining sites (reference points)



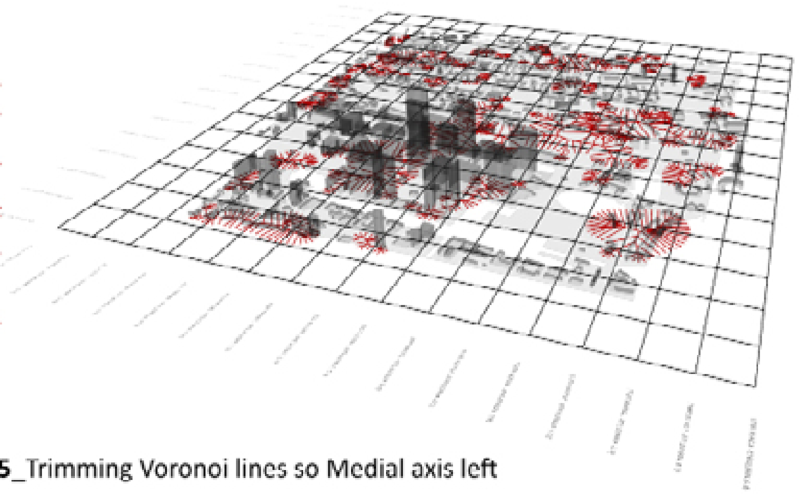
2_Drawing metaball curves around clusters of points



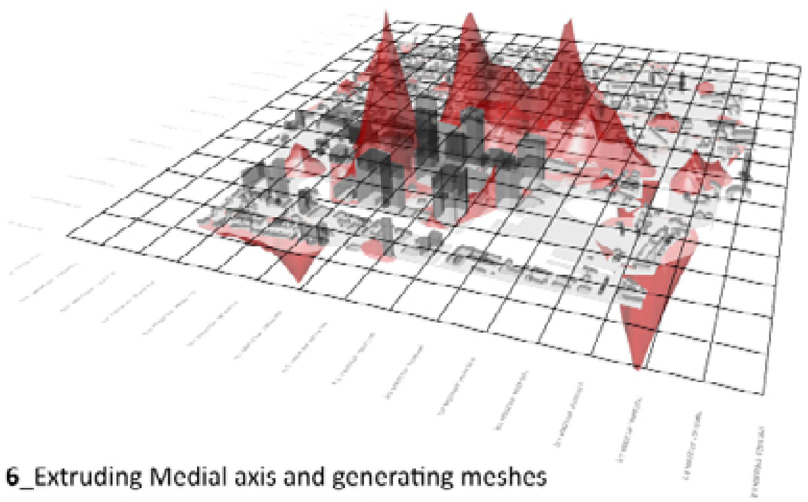
3_Selecting metaball curves which are large enough
to visualize areas with strong growth/decay potential



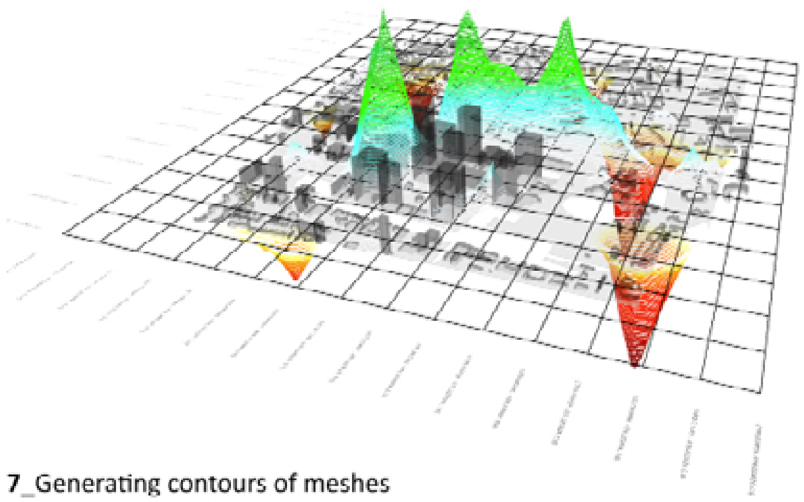
4_Voronoi diagram applied on metaball
curves to find Medial axis of each curve



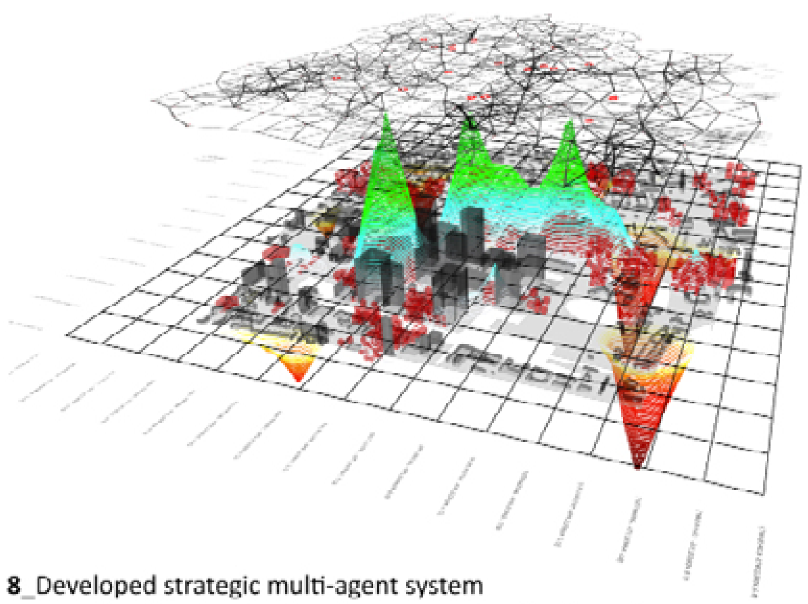
5_Trimming Voronoi lines so Medial axis left



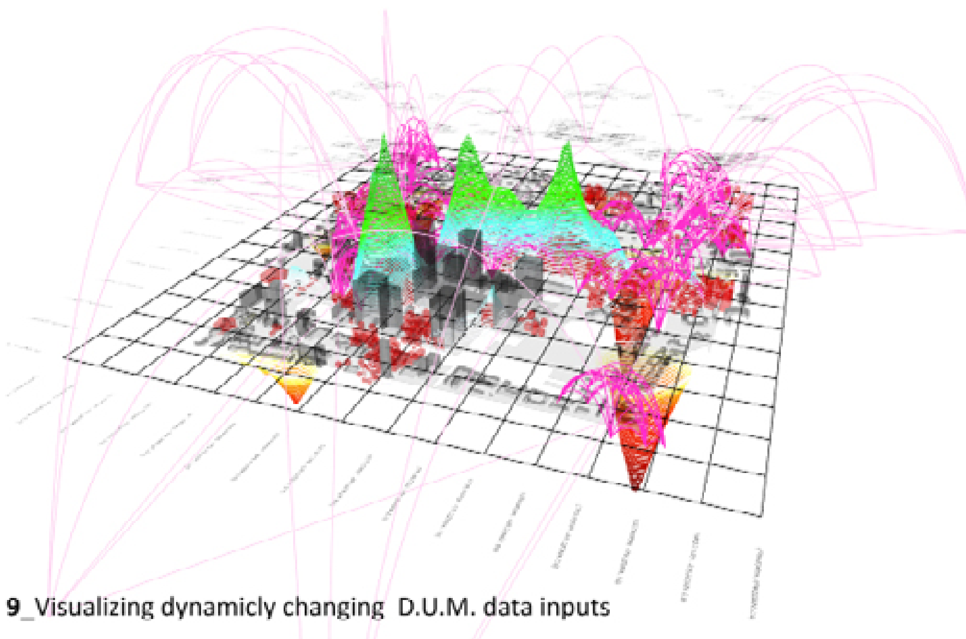
6_Extruding Medial axis and generating meshes



7_Generating contours of meshes
and colouring them according to their height



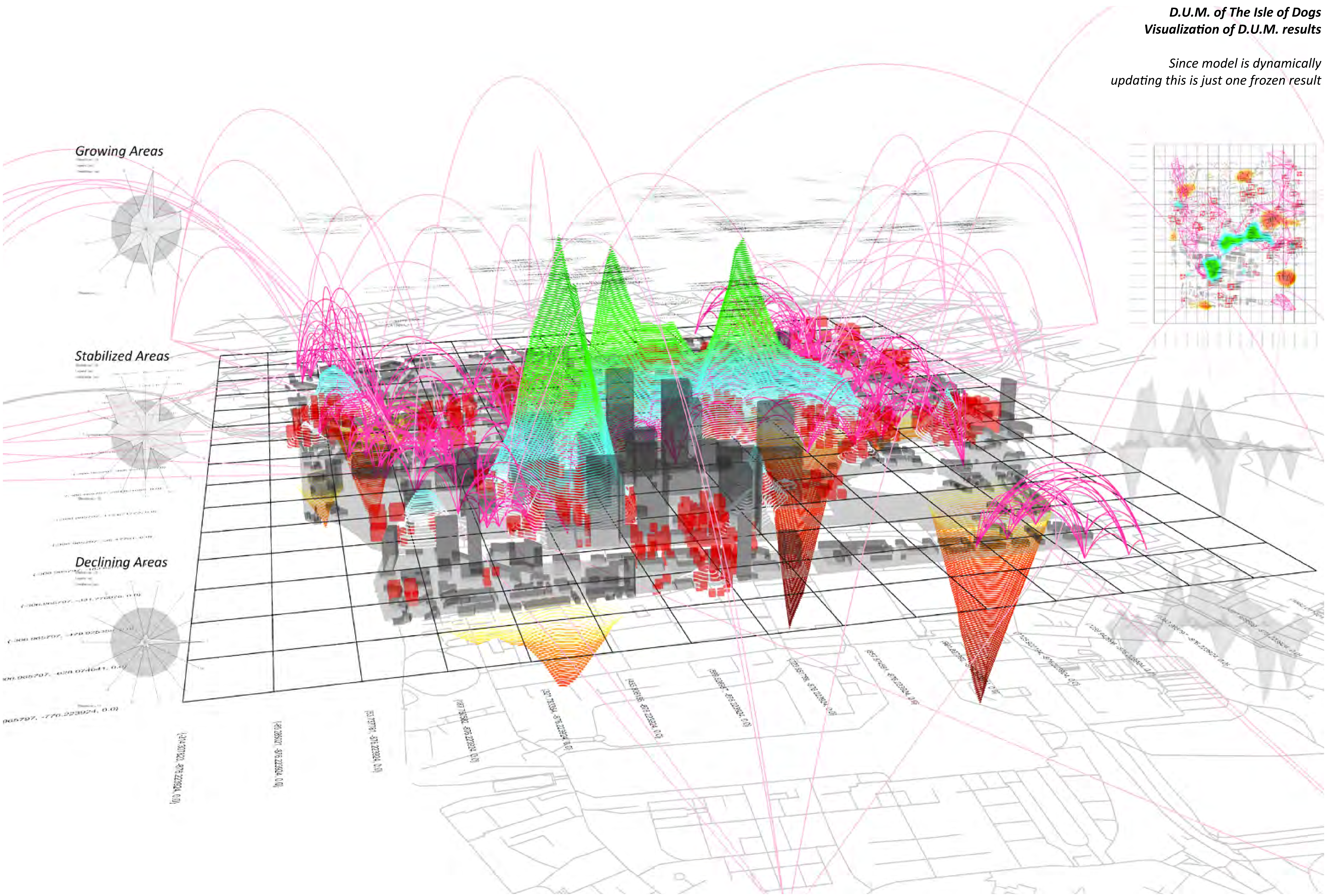
8_Developed strategic multi-agent system
searching for developing sites - generating built-up structures



9_Visualizing dynamicly changing D.U.M. data inputs

D.U.M. of The Isle of Dogs
Visualization of D.U.M. results

Since model is dynamically updating this is just one frozen result



4.2. Site-Specific Urban Design

From the very beginning of the idea of modelling and predicting urban evolution by computational and data analytics methods it was my intention to drive the whole modelling process through city scale up to site and building scale. When it is possible to model evolution of city, why not to model the resulting construction development? The question was how to translate the data describing requirements of urban population to actual buildings.

When one is interested in computational design, responsive and adaptive urban planning or parametric urbanism he can identify two main routes how to achieve this goal. First is to design a set of building forms, building typologies, which are often proceeding from current forms in a specific city. This approach is used for example in the Tom Verebes´ project of adaptive urbanism of Pearl River Delta (Verebes, 2009). This designed library of building structures can be of course adaptive in the terms of floor levels, dimensions in all a directions, number of rooms etc. But ultimately what you get is pre-set catalogue of building forms however adaptable they are.

Second approach how to translate the data sets representing public demand for spatial development in the cities is to design more abstract, non-typological, virtual design which on the other hand goes deeper into smaller scale of interior spaces or even rooms. This approach is often applied when the architect is working with emergent evolutionary algorithms like cellular automata, fractal division like L-systems or other types of growth simulation. As an example can be mentioned the project like Metabolism and Culture or Edible Infrastructures from students of Architectural Association, EmTech, (AA Emtech, 2016).

In such a design process, described more detailed further in the text, it is possible to set required spaces, their function and dimensions, interconnections among them and also their relation to position in the whole building geometry, connections to public spaces or sun exposure relation. This process is more complicated regarding development of such a proper complex Grasshopper script but it enables to verify, design and visualize a new forms not burden by current building typologies which may not be satisfactory anymore. For the purpose of this virtual building design the Grasshopper script developed by Martin Žatečka, my fellow student in FLOW design studio, for project Floor Plan Generator was used and transformed.

AA EmTech, Emergent Technologies and Design: Emergence, 2016, Available at:
http://emtech.aaschool.ac.uk/emergence/

VEREBES, Tom. Ocean CN Consultacy Network: Parametric Pearl River Delta. 2009. Available at: http://ocean-cn.org/project/parametric-pearl-river-delta/

ŽATEČKA, Martin. Studio Florian: Floor Plan Generator. 2016. Available at:
http://www.studioflorian.com/projekty/317-martin-zatecka-floor-plan-generator

4.2.1. Additional Data Inputs

As additional data inputs urban population data for detailed understanding of public requirements for development of specific sites are meant. This category of data sets is as already mentioned most difficult an in many cases impossible to get. But through analytics of these data and incorporating these to D.U.M. one gets insights from multiple data streams (traffic, social media, smart devices and sensors that are shaping the Internet of Things-IoT, internet of everything-IoE) to make more accurate decisions, achieve greater efficiency, and respond faster in emergency situations. These additional data inputs comes in a form of big data (described in Research chapter) and are used for exploring the hidden connections among the multitude of complex, non-linear and interconnected systems which surround us basally everywhere.

And analytics of these additional big data is used for detailed site specific urban design or design of particular buildings. And since it is not possible to get these data sets it is necessary to generate them artificially with the help of Grasshopper scripting (manual engaging of input data and than random generation of their dynamics) and with the basic knowledge of trends and tendencies of demand of public and commercial sector. From this process the data in table sheet form are generated and use as inputs for further Grasshopper

From continuously gathered and analysed data it is possible to design virtual buildings

This virtual city is accessible for any user through interface of D.U.M. application scripting operations which translate these table sheet data form to virtual urban design and buildings design. These operations are described in following chapter.

For better understanding of artificial generating of these big data results and simulating data sources like already mentioned social media, smart devices and sensors that are shaping the Internet of Things-IoT etc. we can take everyday life of an any individual in a city and imagine his needs according to what services he seeks after and how available these are, what he needs to buy and what places he has to visit for, where he works, where he relaxes, where he spent his free-time and how he gets to these places and if these places are in satisfactory condition and so on and on. And similar process and way of thinking is used for imagining behaviour of potential investors in the locality. And it does not matter if it is private individual entrepreneur or big international corporation. Everyone leaves a virtual footprint behind his acting in urban space. Of course artificial simulation of these data sets is very abstracted and detached from reality. But the intention of these big data analytics inputs in this thesis is not to show the precise results, but rather show how the general thinking about real-time virtual processes in urban space and their affection of physical urban environment can also looks like. And by my opinion how it should looks like.

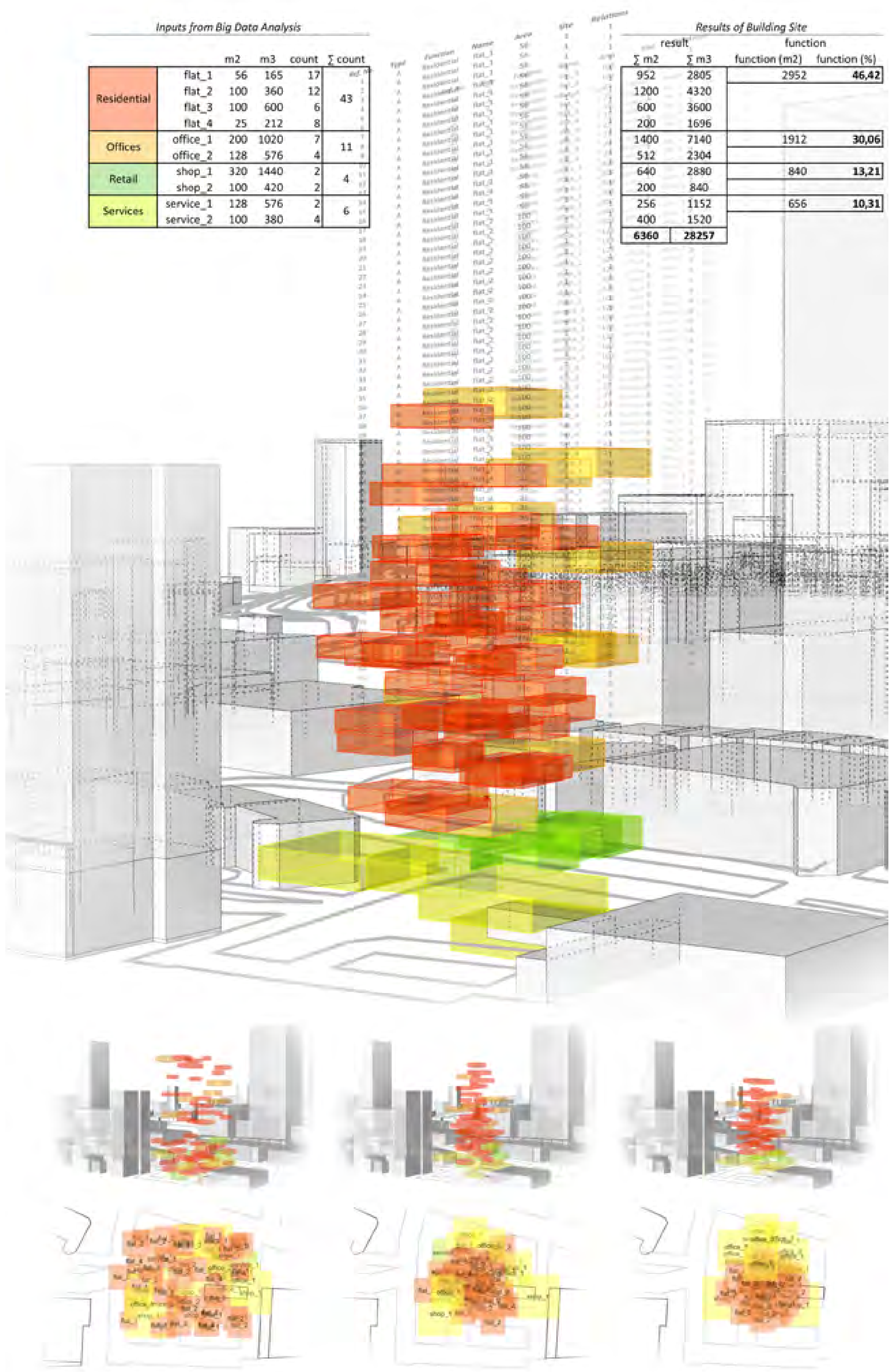
So when the time comes and these data will be opened up, all security and privacy policy issues will be settled, there will be no obstacles to using analytics of these big data for modelling, planning and designing better cities more suitable for their urban populations.

4.2.2. Data to Design

As mentioned above in D.U.M. the approach of virtual non-typology design of buildings was chosen. The whole process is guided by unique Grasshopper script. What is necessary is an Excel sheet - data input with required description of spaces. For the purposes of D.U.M. these spaces represents apartments, office spaces, retail spaces etc. So the more detailed division into particular rooms disposition was not embedded because of not enough number of relevant input data and also overall workflow of this designing part of D.U.M. In this input Excel sheet each column is representing a certain information about ultimate design. We can see reference number of each space, identification of building (A), function of space (residential, services, office etc.), more detailed description and division of each function according to its dimensions (flat_1, flat_2, flat_3 etc.), overall demanded floor area of each space (height of space is set further in Grasshopper script), and than indices representing connections among all the spaces (grouping of office spaces etc.), which are imported in and worked further with during scripting process.

This connections among spaces are amended also with their relations to position in the whole building geometry (luxury apartments position on the top of building etc.), connections to public spaces (services and retail connected to main public spaces etc.) or sun exposure relation (residential spaces on southern side, office spaces on northern etc.). One can easily add many other connections and relations among spaces. This secures that the ultimate virtual building design is not just a assemblage of geometrical spaces but it can also reflect the demand on how people want to use the spaces, how the whole design will be perceived, what impressions and feelings are required from the environment on the specific site. All the soft demands can be translated into set of algorithm which ultimately designs a building. And as everything in D.U.M. when these demands evolve and are changed so does through the developed script the resulting design. This ensures dynamic, adaptive and responsive building design required on the very beginning of D.U.M. idea.

The Grasshopper script itself stands vitally on Kangaroo plug-in, which a toolset working with gravity of geometries. Since the intention is not to design solid final construction but rather abstract virtual building design, Kangaroo can work with „floating" spaces and coordinate them according to set interconnections and relations. So after selecting proper building site (boundary curve) and importing guiding data (Excel sheet – functions, areas, interconnections) the script assign hight to each space as necessary and starts to organize them around central gravity point. Also central geometry (piped line) is guiding the height of whole virtual building and also the width dimensions. In the designed script it is possible to adjust force of gravity to all settings of interconnection and interrelations. For example if it is more important to group all not residential spaces together from some reason than their assigning to not sunlit parts of building, the force of grouping gravity can be easily set higher than the sun exposure gravity force.



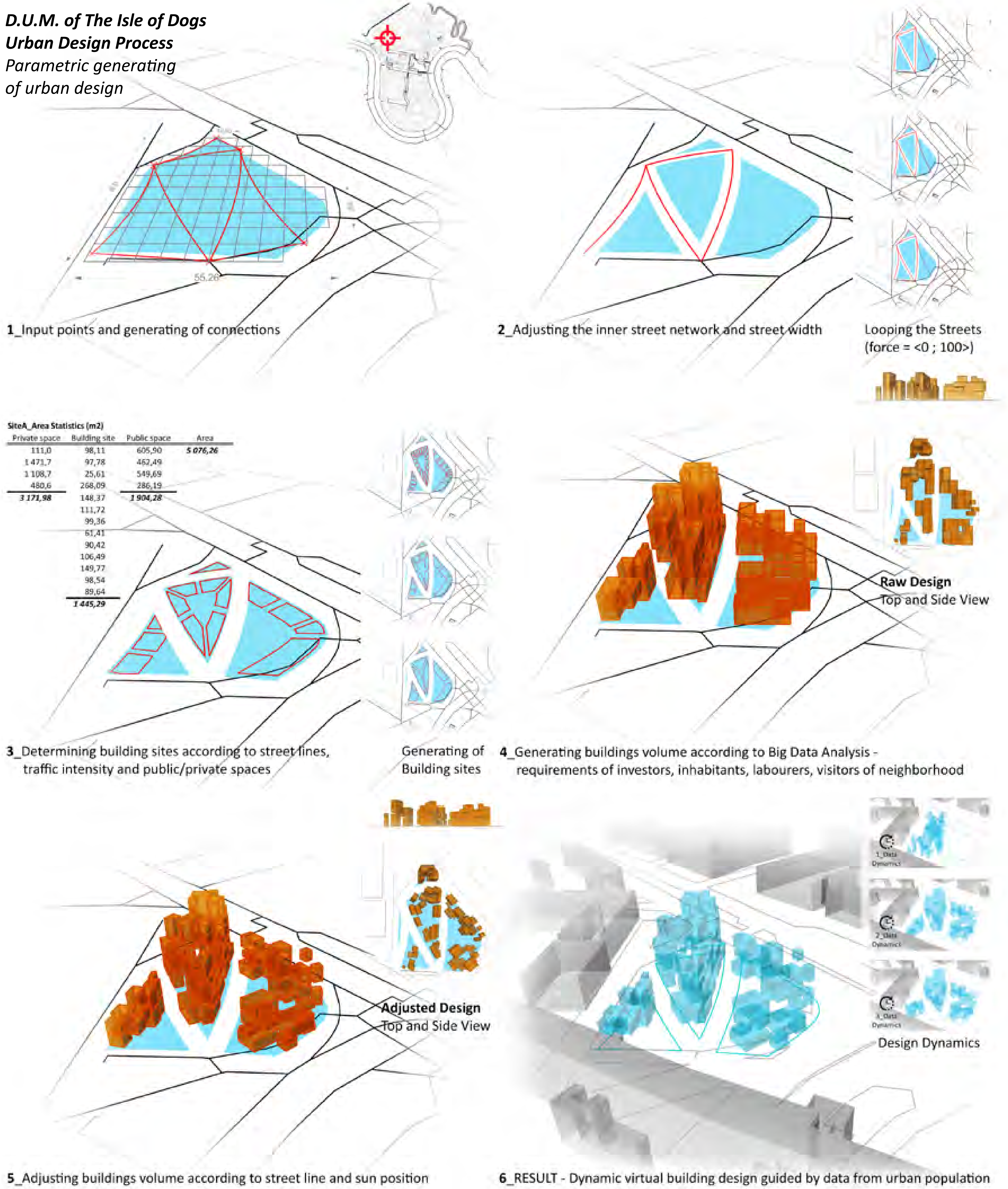
4.2.3. Urban Design

The specific case is when D.U.M. identifies as developing the whole set of sites. This can happen on the localities on the edge of built-up areas, on the large vacant localities inside the city, or on the large sites marked as brownfields. In such a cases the abstracted building design described in previous chapter is not enough. The more contextual urban design thinking is necessary. This task was completed with the help of parametric urban design tools conducted in Grasshopper.

The parametric urbanism is an adaptive approach enabling embedded constant change in final urban structure, which makes this approach well suitable for D.U.M. purposes (described in chapter Complex Urban Design and Parametric Urbanism). In D.U.M. the parametric urban design basically incorporates abstracted building design to wider spatial conditions of specific site to secure linkage to surrounding buildings and street and public spaces network. Also it enables to incorporates public demand for public spaces design in a similar way how the design of interior spaces of building is described in previous chapter.

Again this parametric urban design is driven by developed Grasshopper script. When large building site (or a composition of several smaller building sites) is selected as developing, first the input point based on physical connections are generated. These input points are interconnected into a form of internal network and adjusted (internal streets are looped according to natural directions of movement and their street dimension is setted – usually between 3-8 meters). When internal streets are adjusted and subtracted from the area of selected site, we get slighter site division. An according to public demand and assumed development these slighter sites can be divided further to actual building sites. In this step also requirements for public / semi-public / private open spaces are incorporated.

So the script has now generated where actual buildings should be. Now there are no restrains for using abstracted building design script described in previous chapter. This procedure gives us „the floating-boxes-like“ design. But since the curvature of internal and outer streets does not correlate with perpendicular geometry of boxes, these boxes are adjusted according to main streets curves. This procedure finalizes the whole process of parametric generating of urban design.



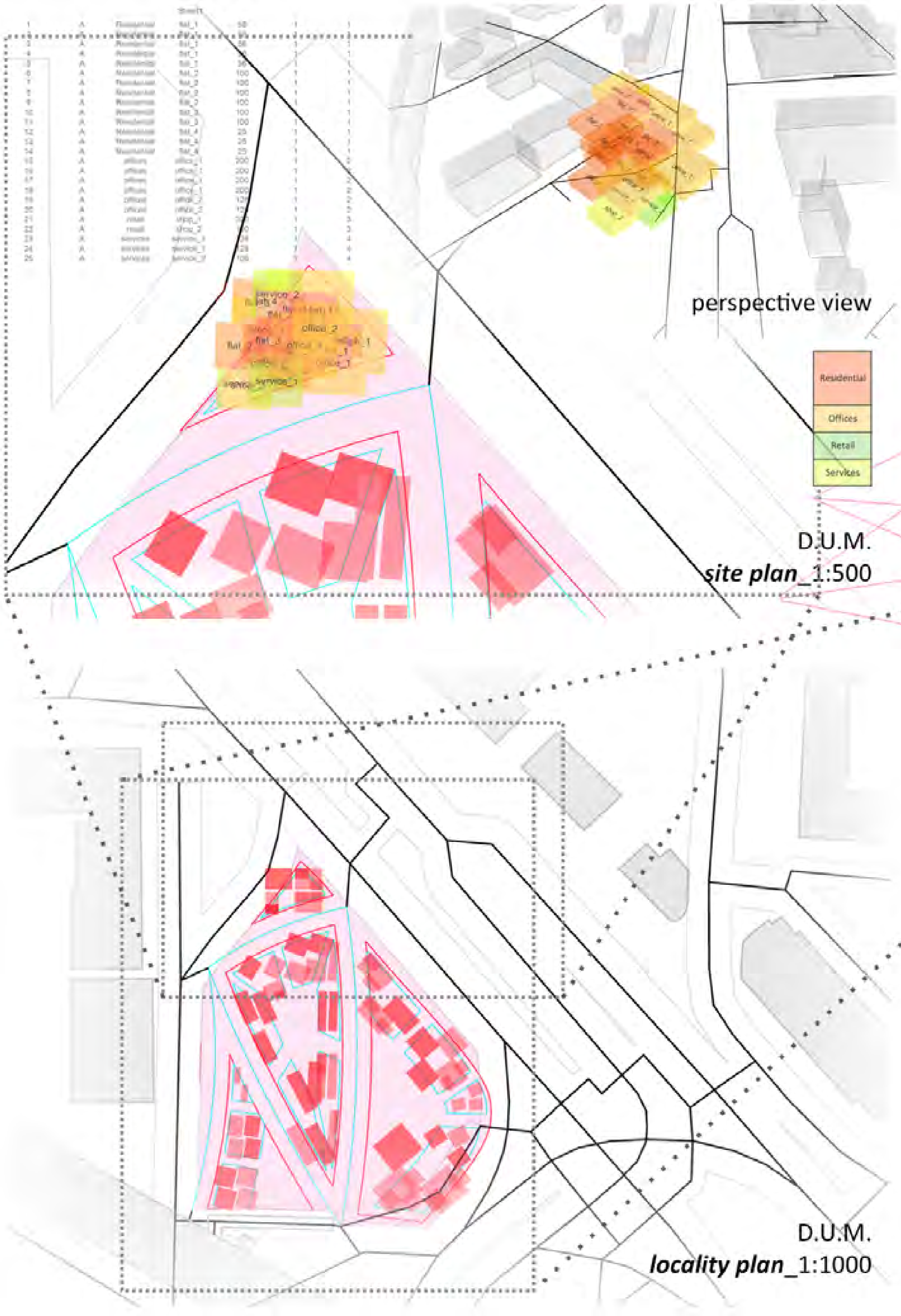
SiteA_Area Statistics (m2)

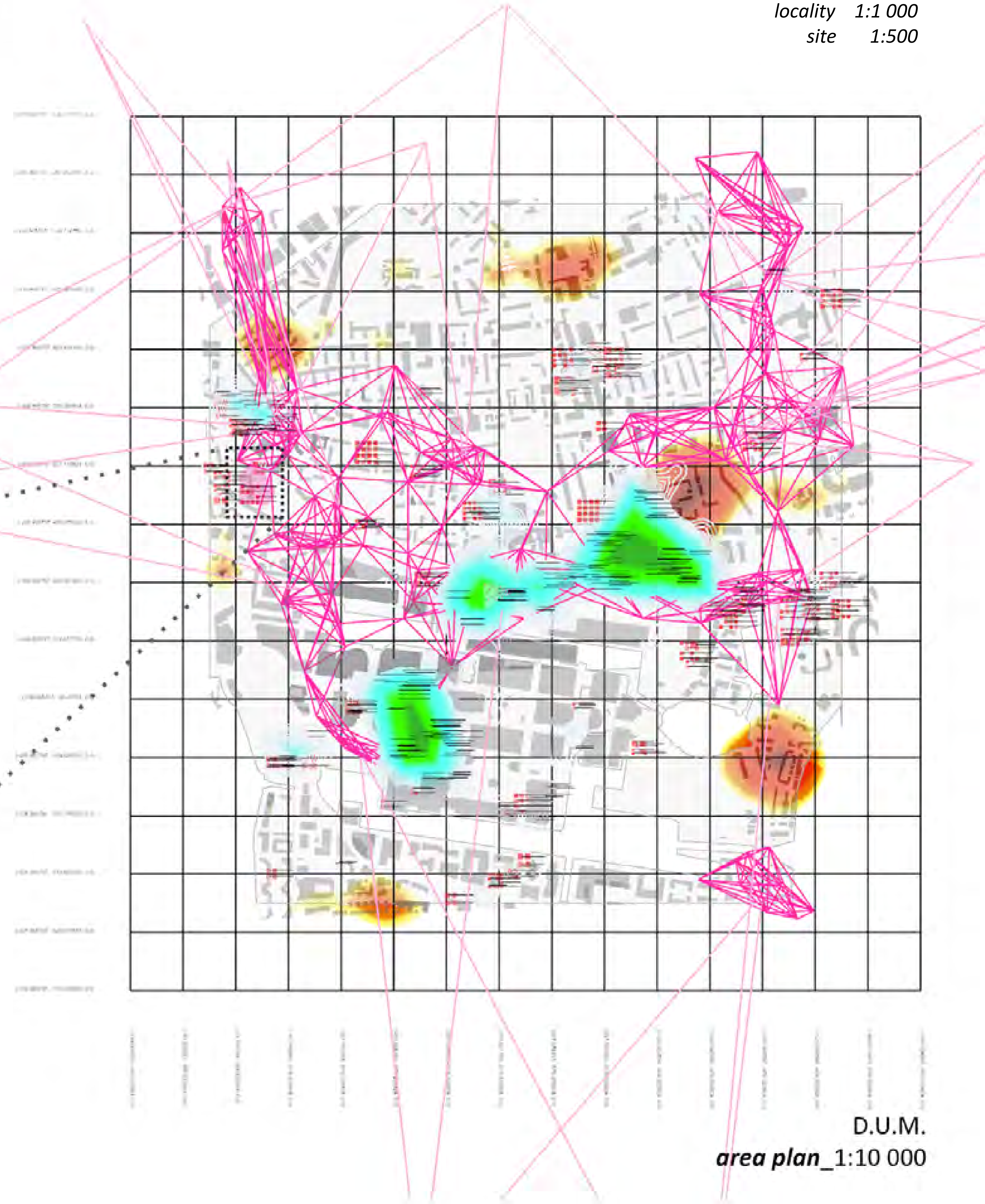
Private space	Building site	Public space	Area
111,0	98,11	605,90	***5 076,26***
1 471,7	97,78	462,49	
1 108,7	25,61	549,69	
480,6	268,09	286,19	
3 171,98	148,37	***1 904,28***	
	111,72		
	99,36		
	61,41		
	90,42		
	106,49		
	149,77		
	98,54		
	89,64		
	1 445,29		


J.P.Morgan
BRITANNIA HOTELS
THE INTERNATIONAL
Dynamics
Model
Data
Connectivity
Developability
Intensity

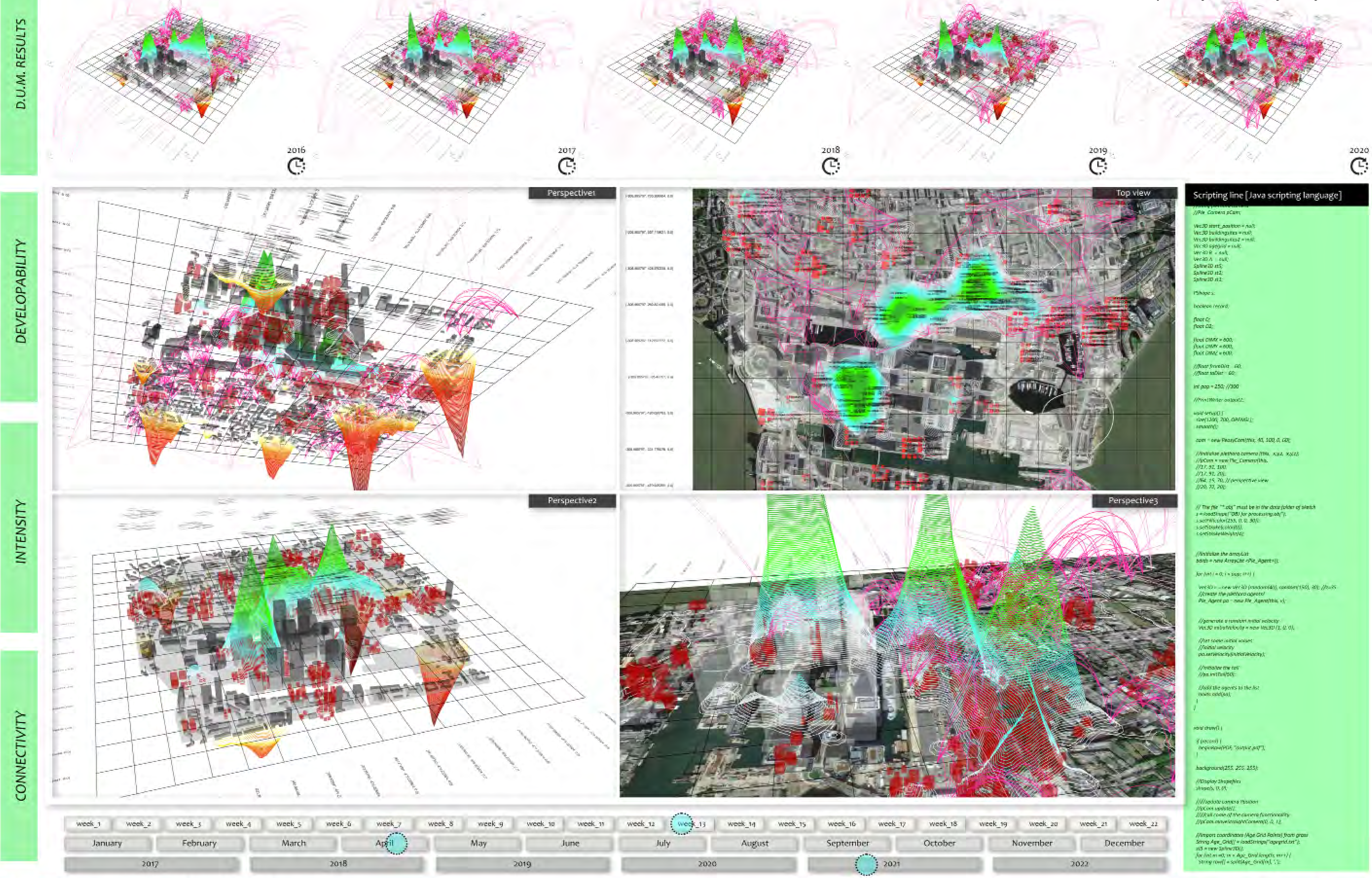
D.U.M. of The Isle of Dogs
Plan showing design in all scales

area 1:10 000
locality 1:1 000
site 1:500





D.U.M. of The Isle of Dogs
Proposal of users interface of toolset



D.U.M. DYNAMIC URBAN MODEL
DATA-BASED URBAN EVOLUTION PREDICTION TOOLSET

DESIGN STUDIO FLOW_CTU FA_2016

5. Conclusion

An initial intention and also motivation for this work was to try to find an adequate means, toolset or system how to understand, predict and also design modern cities. How to coordinate partiality interests in a flexible and adaptive way, because by my opinion that is what is urban planning about. Although in current cities there is a huge amount of interactions, individual and public interest, so much relations in physical, social and economical dimension of urban environment, that the whole design process had to incorporate much more knowledge and variables than it was expected.

The whole process of developing D.U.M. took almost a year. At first one gets a bit lost when he starts to get deeper and deeper in the issue of complexity, theories of social networks or emergent systems and their application in urbanism. But when you orient yourself, you just understand, that first thing you have to do is to abstract whole complex issues to the crucial and measurable variables. Than you have to determine how to measure them. And after many and many test when you do so, you just have to find correlation among all variables. And now there are no restrain to start modelling. This is looking pretty simple. But each an every step bring new questions and challenges, especially when you tries to develop general system.

Let me first describe the achievements of my work on diploma thesis. During developing D.U.M. I had to determine most crucial factor to have some inputs to algorithm operation. And since I wanted to have a urban model, which really focuses on actual life of actual people, these crucial determined factors had to be built on their demand – in the case of D.U.M. on analysis of data produced by urban population. Determining Connectivity, Intensity and Developability of urban environment as these crucial factors is one of the biggest success of this thesis. Understanding of cities through these factors is a fundamental for whole proposed system. Although D.U.M. is designed for simple addition of other inputs, these three are the most appropriate for current cities.

Another accomplished goal required on the very beginning is an adaptiveness and responsiveness of proposed D.U.M. We can notice calling for urban planing system which involves concepts of bottom-up development, crowd-sourced self-organization, flexibility of planning and not designing restrictive and rigid plans, although certain guarantees and common public interest have to be secured. And I think I fulfilled these expectations in D.U.M.

And last thing to mention is complex applicability of D.U.M. system on a city as a whole. From metropolitan scale down through investigated areas and localities up to the specific land and sites. Data based virtual planing and designing of urban structures and building. There is just one step missing and that is actual physical buildings. And if it would be necessary and possible, this extension of D.U.M. as a software guide for self-assebbling robotic construction system would not be hard to develop.

D.U.M. is able to analyse social interactions and behaviour of individuals and translate these into a prediction of evolution of city. Further more assembling of detailed data enables D.U.M. to create virtual site-specific urban design

Now to my initial plans which I failed to meet. First thing is a intention to develop a piece of software. Computer app which would integrate all the operation and processes described in this thesis. Although I was not able to connect all used software properly (Grasshopper + Processing + ArcMAP etc.).

Another kind of failure is partial deceptive application of certain operations in D.U.M. Meaning my inability to develop strategic behaviour of multi-agent system, so the non-strategic had to be used. Or that I was not able to get any real detailed data describing everyday lives of urban population in area of interest. So eventually I had to simulate these data. But despite of these weaknesses the proposed modelling and designing system is at least showing a clear course of spatial planning of cities as I see it and as I think it should looks like.

Buldings designed by D.U.M. and their variations in time as data inputs are changing

Standard building design
difficult to adjust both design
and physical structure

Parametric building design
simple to adjust the design
difficult to adjust physical structure

Self-assembling constructions
designing continuosly according to D.U.M.
and so is adjusting of physical structure

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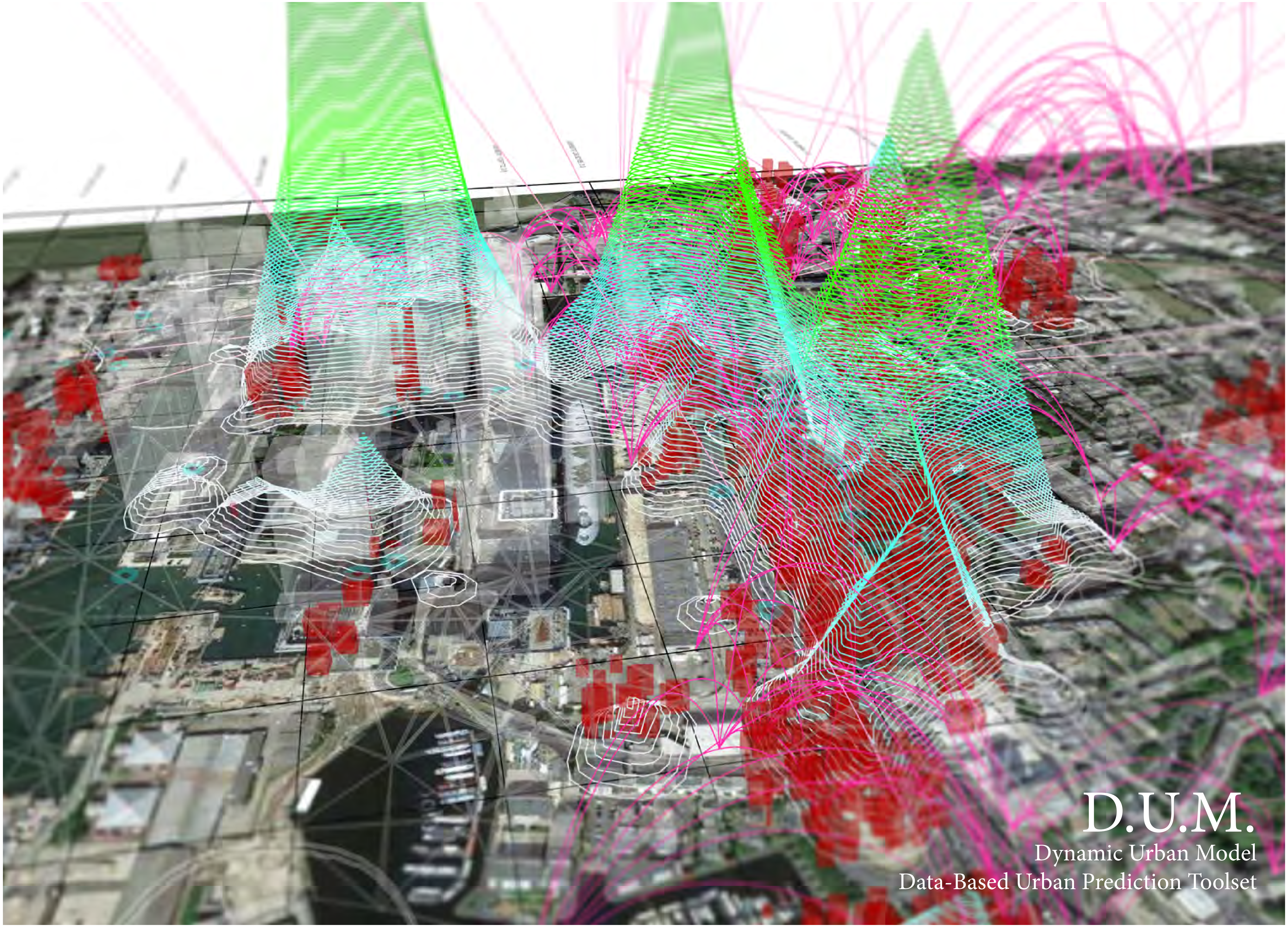
D.U.M.
Dynamic Urban Model
Data-Based Urban Prediction Toolset