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Title: Does top-down and bottom-up city morphology influence street integration?

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Does top-down and bottom-up city morphology influence street integration?

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Summary

“Le linee diritte appartengono agli uomini, le linee curve appartengono a Dio.”
(“Straight lines belong to men; curve lines belong to God”)

(Antoni Gaudi, 1852-1926)

This thesis presents an urban morphology study which examines the spatial configuration of 68 cities around the world, classified according to the circumstances under which they originated, planned or unplanned. The objective is to explain using Space syntax method, which urban morphology, top-down or bottom-up, has more influence on street integration level.

An initial analysis indicates that cities belonging to the same type have similar street pattern, but at the same time they can be distinguished from one another according to the network shapes as a consequence of their different topological conditions and development.

From ancient times, cities have been classified into those which grow organically and those which are planned. The distinction between these types is complex and blurred, and of course, most towns today are being formed from elements of both, bottom-up and top-down. The key difference involves the speed at which cities change, and the scale at which they develop.

The differences between BU (bottom-up) and TD (top-down) cities strike at the very fundamentals of the way cities develop. Since the form of the city is in direct relation with its street network pattern, and street network pattern presents the basis for the analysis, the street integration is the main metric of this study. This study does not analyse the factors which contribute to the city shape development (street pattern shape) such as social factors, culture, land use, terrain form, climate conditions etc. This study concentrates on the pure geometry of the city, keeping in mind the difference in the way they originated: unplanned or planned.

The measurement and the analysis of the spatial integration are conducted using the approach and the methods of Space syntax (Hillier, 1996). Integration is used as a measure which describes street accessibility or how easy it is to get to one street from all other streets (Hillier, 2009). Furthermore, integration explains how close each street is to all others, also known as closeness or “to-movement” (Hillier, 1996).

The results obtained following this study indicate that top-down cities have higher levels of street integration compared with bottom-up cities. Significant syntactic differences appeared while analysing cities with grid street pattern, which obtained the highest level of integration overall. The most segregated results are reflected in organic-like and cul-de-sac street patterns since they consist of many dead-end streets within their network. It is also concluded that SS (Space syntax) method can efficiently quantify precise spatial configurations of the large sample, and thus, compare urban street networks from the integration point of view.

By calculating integrated and segregated parts of the city, it is possible to know whether a proposed design fits into the existing structure of an area. It is also possible to create a new perspective in understanding street patterns and learn from mistakes when the integration is weak and should have been higher for the existing scenario (Hillier & Hanson, 1984). Calculating integration levels within urban areas can even help in regulating human movement, predicting crime, adapting traffic and solving commuting issues, connecting distant city centres in more efficient ways, creating social hubs or on the other hand planning safe neighbourhoods. Future study can go a step further analysing social aspects and liveability by studying human behaviour within integrated and segregated cities. The research would certainly benefit from such an effort as it would go beyond the rather clinical analysis of Space syntax and street integration level.

Keywords

Urban morphology; Top-down; Bottom-up; Street pattern; Street integration; Space syntax

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Abbreviations

IHS	Institute for Housing and Urban Development
SS	Space syntax
HH	Street integration
TD	Top-down
BU	Bottom-up
GIS	Geographic Information System
DV	Dependent variable
IV	Independent variable
LA	Land area

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1. Introduction

1.1 Background

This is a study about urban morphology and Space syntax theory. The research analysis examines the physical structure of urban street networks (street patterns) and the impact it has on street integration level.

For the purpose of this research categorisation of city forms is made as following: cities are observed from the perspective of how they originated, either planned or as unplanned, meaning that they are either top-down or bottom-up. Spiro Kostof (Kostof, 1991) recognises the difference between the two and mentions that there is no point in noticing the formal similarities between Washington (TD) and Valencia (BU), or Siena (BU) and Boston (TD). Additionally, Kevin Lynch (Lynch, 1981) while elaborating on urban form classification, introduces cosmic (TD), practical and organic models (BU) of the cities and ads to literature concepts of the normative model. The above mentioned two views served highly inspirational for this research. The aim of this research is to analyse and explain the influence of bottom-up and top-down urban morphologies on street integration level by using Space syntax theory. This research determines how sensitive the Space syntax method is, especially when conducted on two equally powerful but diametrically and ideologically opposite visions of urban morphology and street pattern: top-down and bottom-up.

Even though many top-down cities are older than the first historical official certification regarding their origin, they mostly developed in the first half of the twentieth century, particularly in Europe, and are associated with centralised planning. Staring from the 1990's, this planning trend originating from Europe, became an important urbanisation strategy in contemporary Asia (famous Chinese ghost towns), United Arab Emirates (Masdar, Dubai) and in the United States (so-called dormitory-cities). Opposite to the randomness (spontaneity) of bottom-up spatial development, geometrical structures of planned cities are equally supported in history by Le Corbusier' and Oscar Niemeyer' ideas, as they are today mirrored in Foster and Partners' Masdar city. However, bottom-up cities emerge highly decentralised, i.e. without a central control, but as a sum of small individual and across time actions. Michael Batty argues that cities in particular and urban form, in general, emerge from the bottom-up per se and that the spatial order we see in patterns can be explained only in this way (Batty, 2005).

Cities from different countries, eras, with different development history, have countless pattern shapes. The development of urban form is affected by various factors, such as geographical location, history, colonialism, religion, war etc. They are shaped by all sorts of people, initiated and destroyed for various reasons and correspondingly are categorised in many different ways. Cities are developing uneven through space and time, but one obvious feature they all have in common is the physical build (Morris, 1994). It remains with remarkable persistence, conserving evidence of past urban culture for present and future generations. Cities are almost never single-minded. Regardless how their initial shape is, they are never complete, never at rest and classifying them truly is a challenge. Categorisation of urban form is elaborated in Theory review chapter further on in this research.

Urban morphology study keeps its origins in the science of geography and it is used to distinguish, characterise and describe urban landscapes. Geographer Otto Schlüter was arguably alleged as the father of urban morphology (Whitehand, 2007). Additionally, in urban form analysis, there are two mainstream schools led by M. R. G. Conzen and G. Caniggia. The former defines how the integration of landscapes affects the early development of urban morphology (Whitehand, 2007), while the latter is primarily focused on town plans as a source for the historical study of urban morphology (Sima, Zhang, 2009).

This research will not use mentioned traditional morphological perspectives. The focus is on the physical built - urban street patterns, the way they evolve (planned or unplanned) and on their spatial analysis, more precisely their integration level (i.e. interconnection).

Integration is used as a measure which describes street accessibility or how easy it is to get to one street from all other streets (Hillier, 2009). Furthermore, integration explains how close each street is to all others under different types of distance and at different scale, also known as closeness or "to-movement" (Hillier, 1996).

Box 1 – Integration definition

Streets are the basis and heart of a city and are important for human activities (Jacobs, 1961). The degree of integration is a core characteristic of the street. The street network can be ranked from the most integrated to the most segregated. In grid street patterns (TD mainly) the encounter rate of people's movement mostly has a high correlation to integration; i. e. integration is a good predictor of pedestrian flow. In general, it is claimed for example that shops locate to streets with high encounter rate or they locate there where the plan designers can foresee a high rate (Klarqvist, 2000). This is only one of the benefits urban morphology study has.

Then:
Form precedes function!
(Louis Sullivan, The Tall Office Building Artistically Considered, 1896)

And now, after a century:
Space precedes function!
(Björn Klarqvist, A Space Syntax Glossary, 1993)

It is argued that the place is shaped according to the function that particular place takes. On a location where people usually prefer to meet, a public square emerge. On a location where people often trade, markets and piazzas appear. This thought is helpful in process of understanding how bottom-up cities develop. Today's place-making is mostly planned, designed and calculated in advance. A new square may become a preferred meeting place. Even on a simple example (Figure 1) one can see by every day walking through the city how difficult it is to predict a successfully and integrated city street plans:

Figure 1 – A failure of a pedestrian path plan
SOURCE https://ericdux.files.wordpress.com/2014/09/design_dev.jpg

Streets with high integration are able to attract more traffic flow, more pedestrians and even to increase the density of surrounding areas. Nevertheless, cities with street connectivity higher than others are expected to be more vibrant by people's activity, and to provide more accessible path selection choices for its inhabitants (Long, Baran, Moore, 2007). Furthermore, the movement flows are largely determined by the spatial configuration of urban street networks (Hillier, Iida, 2005).

In the late twentieth century, a new field known as Space syntax (SS) emerged. Theories and techniques within this field are applicable for the quantitative analysis of spatial configuration and they provide scientific precision for the study of urban morphology (Sima, Zhang, 2009). Space syntax theory (Hillier, Hanson, 1984) provides a computational method for describing urban structures (Jiang, Claramunt, Klarqvist, 2000) and further, provides a better understanding of the relationships between social and spatial attributes (Figueiredo, Amorim, 2005). In Space syntax methodology, the identification and description of a city's spatial form originate from a topological analysis[1] of axial maps (Hillier, Hanson, 1984). This research, in particular, uses axial lines and axial maps which have been already successfully used in the analysis of space configuration (Turner, Penn, Hillier, 2005), and are objective and significant for urban morphology studies (Jiang, Liu, 2010). The definition of the axial line is explained further in the Theory Review chapter. Furthermore, the study of the spatial phenomenon is done using the Geographic Information System (GIS) which provides the platform to make a spatial demonstration, and model the spatial features (Oliveira, Pinho, 2009). As Jiang (Jiang, Liu, 2010) notes, modern GIS system accurately performs computations of urban patterns.

1.2 SS criticism

Even though axial lines have precise and successful usage in the analysis of space configuration, there are critics arguing otherwise. Pereira (Pereira, et al, 2012) explores the potentials of applying Space syntax on transport performance analysis in the case study of the urban road system in Brazil. He investigates the impact of urban configuration, which have different integration degrees, on the average time spent on commuting. Findings imply that top/geometric measures show much better results, while the regular topological measures produce low regressions. He argues that two roads with same topological integration may exhibit completely different average vehicle speed. This is due to the fact that three-dimensional information, such as relief, variations in topography, obstacles on the roads and roads characteristics are disregarded when integration is calculated. Additionally, Pereira observes that axial lines do not consider the geometric aspects of reality (Figure 6) and that a topological analysis of urban configuration is clearly a one-dimensional approach to the road system. Aspects such as topology are not taken into consideration for the SS analysis. Finally, disregarding the geometrical properties of the roads (Figure 2) such as length, size, and number of streets, it is also valuable to mention that SS ignores the global extension of the road system as a whole, which does not show the accurate integration levels (Pereira, et al, 2012).

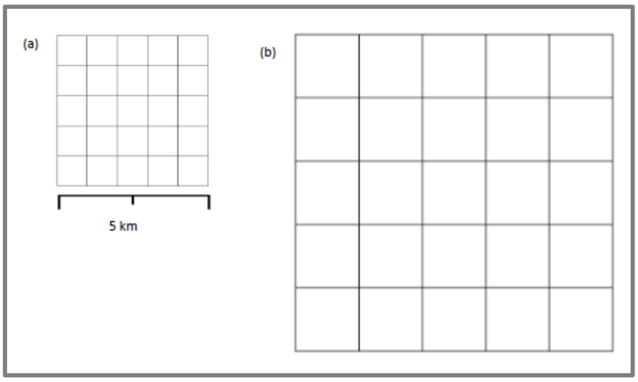


Figure 2 – Two road grids with the same level of integration but different commuting time
SOURCE: http://www.sss8.cl/media/upload/paginas/seccion/8214_2.pdf

[1] Topological distance is a generic form of describing a system of points and relationships between points; topology is about defining what space really means and relationships between subspaces or points in space, defined using mathematical structures. Topological distance is a distance measured in units, it quantifies the extent of topological differences between points, while the Euclidean distance is the "ordinary" (i.e. straight-line) distance between two points. Euclidean distance generalizes the notion of physical distance in two- or three-dimensional space to multidimensional space.

Building upon this fact, that the SS ignores the geometrical properties in different urban configurations is a limiting factor for its application to transportation studies.

Furthermore, Netto (Netto, 2011) points that the city deals with morphogenesis, structuration, and transformation as expressions of the social, economic and material forces, with circular effects. On the other hand, the SS deals with the bi-dimensional genesis and structuring of the cities, throwing light on material properties and functional processes focusing on spatial patterns. He criticises the SS for providing insufficient explanations of the city and for not taking social processes, the experience of urban space and meaning into account. Alan Penn (Penn, 2001) states that it seems possible to explain how people move but not why they move in that particular way, using SS analysis.

Criticised propositions of Space syntax also come from Hillier (Hillier et al, 1993, p.31) and Ratti (Ratti, 2004, p.6):

> "[…] in urban systems configuration is the primary generator of pedestrian movement patterns, and, in general, attractors are either equalisable or work as multipliers on the basic pattern established by configuration."
>
> "[Attractors] are a mere consequence of configuration [...] The tallest buildings appear in the most integrated parts of town."

Ratti (Ratti, 2004) argues that the grid urban texture (e. g. Manhattan) reveals the difficulty of accepting the claim that SS allows the modelling of pedestrian choice making. He also reflects on a difficulty of SS to take into account building height and land use, and its sensitivity to boundary conditions. Ratti claims that: "[…] the topological representation of cities, on which Space syntax is based, discards precious metric information and its rather limiting." Additionally, he suggests that with current increase in computational power new algorithms might allow a deeper understanding of urban texture and that this would contribute to answering the question which SS helped to frame: "[…] what is the influence of urban configuration on social life?", creating space for valuable future works. As Sara Westin (Westin, 2015) said:

> "Space syntax graphic axial and segment maps can be interpreted as rhetorical tools, which allow us to – figuratively speaking – go below the surface of the city and discover the underlying principles behind its organisation."

The possibility of combining SS among planned and unplanned city patterns has been discussed for some time now (Ye; van Nes, 2013). In his research, Jones uses topological analysis to predict crime manifestation in urban areas (Jones; Fanek, 1997).

"There are almost as many approaches to understanding cities as there are commentators trying to make sense of their complexity."

(Michael Batty, The new science of cities, 2013)

1.2 Problem Statement

What are the spatial differences between top-down and bottom-up city patterns? To what extent do the various spatial features trigger the different street integration level? This study does not analyse the factors which contribute to the shape of the city (street pattern shape) such as social factors, culture, land use, terrain, climate conditions etc. This study concentrates on the pure geometry of the city, keeping in mind the difference in the way they originated: unplanned or planned.

The first challenge of this research is to identify cities around the world and divide them into two different morphology categories, according to the way they evolved: top-down or bottom-up. The second challenge is to choose appropriate city pairs (consisting of one bottom-up and one top-down), which are comparable by land area size (km^2) and shape.

The idea is to compare cities within pairs by focusing on the differences provided by the way they originated (planned or unplanned) by eliminating biases regarding potential effects of shape and land area size on street integration level. However, the effect of land area size and street integration is analysed disregarding urban morphology, with the purpose of confirming if there is a significant relationship or not.

For example, the city form and urban street network of completely planned, renaissance city of Palmanova, Italy is compared with medieval bottom-up old city town of Tallinn, Estonia, as shown in figures 3, 4 and 5. Respectively, this procedure is repeated 33 more times during the research data collection process. It is important to bear in mind that cities within the different pairs may be interchanged and thus may give different results in street integration level due to different street pattern configuration or different morphology subtype (medieval, grid, Greek etc.). In order to increase the validity of the research, in addition to pair comparison, a multi-regression is conducted, based on the entire sample.

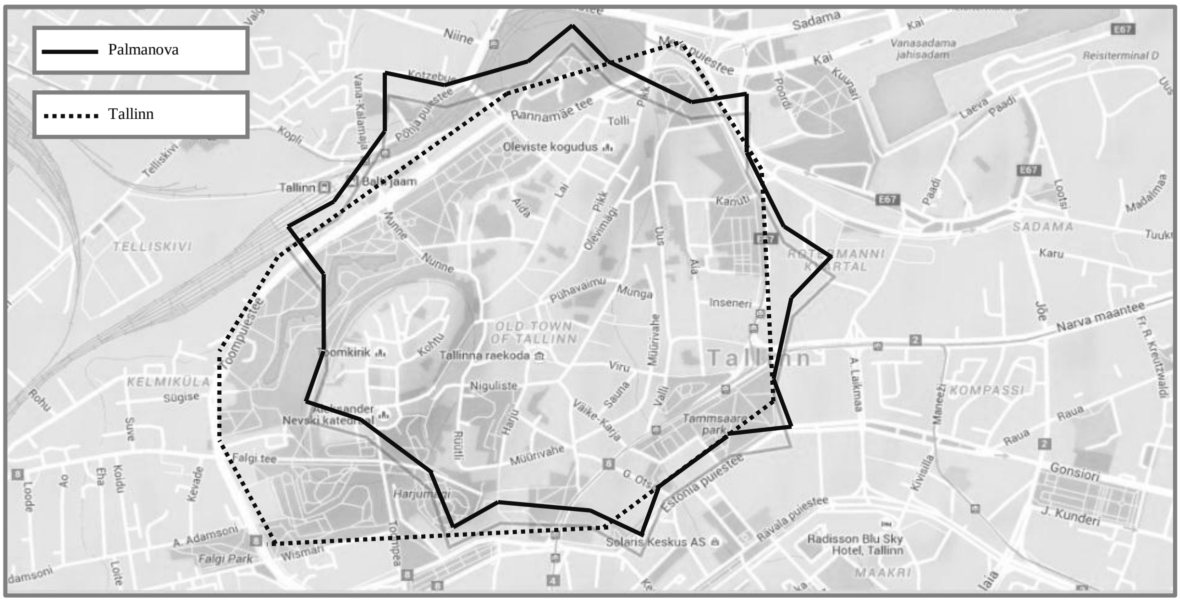


Figure 3 – An overlap of Palmanova city outline over the Tallinn city map (conducted on www.mapfrappe.com)

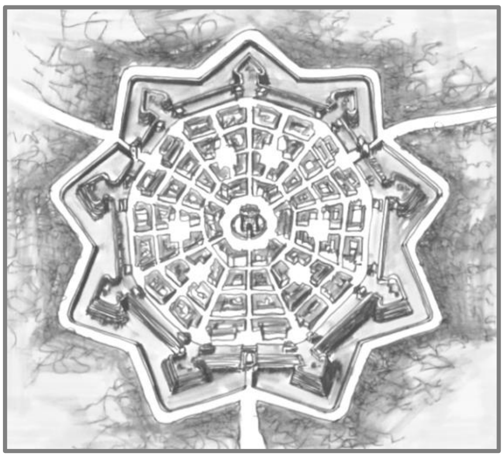


Figure 4 - Palmanova, Italy, 1598, LA: 1.1km²

Figure 5 – Tallinn, Estonia, 13th c, LA: 1.5km²

Furthermore, another research challenge is reflected in street data collection process originating from the MapFrappe (www.mapfrappe.com) online platform, GIS and SS's DepthMap tool. The MapFrappe tool provides cartographic overlapping of outlines as shown in Figure 3, for easier form and size comparison. GIS is used for the generation of axial maps. Space syntax theory and DepthMap software analysis are used to calculate the integration levels, i. e. how each street line is topologically connected with other lines within a certain range and it illustrates the degree of connectivity based on the geometry of these lines (Hillier, Iida, 2005). The research methodology is explained in detail in the 3rd chapter of this thesis.

A Student t-test and regression analysis method is used. The results are observed in order to provide a better understanding of spatial integration differences between the two analysed morphological types. It is reasonable to assume that cul-de-sac (dead-end street) street design, for example, contribute to poor spatial integration. But, which urban morphology causes more deprived performance of spatial integration: top-down or bottom-up?

1.3 Research Objective

The main objective of this research is:

A. To analyse and explain the influence of bottom-up and top-down urban morphologies on street integration level *by* using Space syntax theory.

Therefore, the specific objectives are:

1) To identify and analyse cities with bottom-up and top-down city morphology pattern groups;
2) To pair cities from the sample by land area size and shape, with one belonging to TD and the other belonging to BU city group;
3) To analyse and explain the relation between BU/TD city morphology and street integration using a Student t-test and regression analysis.

Lastly, as Space Syntax provides precise measures of spatial integration and it is applied to study urban morphology from a new and different perspective than in the traditional way, this study also tests the possibilities of this method and give recommendations for future studies.

1.4 Research Questions

Central question of this research is:
"Which city morphology indicates a higher level of street integration: bottom-up or top-down?"

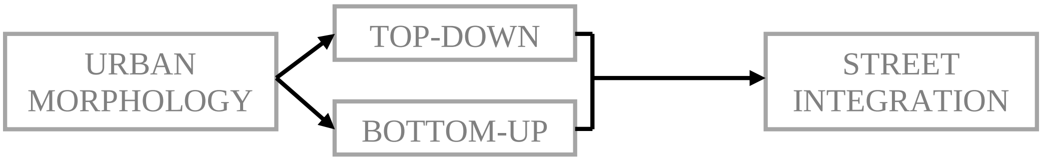
Box 2 – Main research question

Independent variable is *city morphology*, and thus, in the context of this study it represents a phenomenon that occurs in two different shapes:

- Top-down,
- Bottom-up.

Dependent variable represents the level of street network interconnectivity and it is termed *street integration*.

The relationship between ID and DV is a causal relationship with direct effect where IV influences DV:



Graph 1 - A Conceptual model with a direct effect

Sub-questions of this research are:

- Which cities are considered to have top-down, and which ones are considered to have bottom-up urban morphology?
- What is street integration and how it is analysed?

Box 3 - Research sub-questions

1.5 Significance of the study

The analysis conducted and conclusions drawn from this research have majorly scientific relevance, but also give recommendations and assistance to city planners, policy makers and others involved in urban design and placemaking practice. Analysis of urban street networks is necessary for urban morphology studies, for human activities and movement behaviour study and for providing an input for city planning. Analysis of the characteristics and structures of the urban settlement obtained through this and similar studies are believed to lead to the preservation of present settlements through assigning them up-to-date functions (Hillier, Hanson 1984). This is also an inspiration for modern and contemporary designs. Recent research indicates that cities belonging to the same city type tend to exhibit similar local levels of spatial integration and that this was mainly a product of their street pattern (Omer; Zafrir-Reunen, 2010).

Why is it important to study street layout with Space syntax? Using SS method to measure spatial configuration, integration and connectivity (which are the most important syntactical measures), it is possible to discover or foresee streets with high integration and connectivity value (which are expected to be more often used than other streets) and give people more accessible choices (Long, Baran, Moore, 2007). Hillier and Iida (Hillier, Iida, 2005) showed that the configuration of urban street networks is a major factor in determining movement flows. If the streets with different connectivity and integration values are reflected clearly, it will contribute to people's choices of the path. Based on connectivity and integration (Peponis, et al, 2008), which simply indexes the direct link's in space, perception and occupation of that same space can be visualised and mapped for building plans as well. It is the same principle for city street networks (street layouts) which could also be used for city planning and other activities' analysis. Further, street connectivity and integration can be used to model pedestrian flows and identify the links between them (Peponis, et al, 2008) and research travel behaviour related to the urban form (Dill, 2004). Moreover, Jones and Fanek examine its effect for predicting crime occurrences in urban areas (spatial configuration could affect criminals, wherein streets with high connectivity or which are often used may have lower crime rates) (Jones, Fanek, 1997).

To continue, it has been shown that the axial representation (linear presentation of the street network), with derived measures from Space syntax method, can be useful for spatial studies especially for evaluating pedestrian and traffic movement patterns related to the spatial configuration (Figueiredo, Amorim, 2005). From the apparent hierarchical organisation, people can judge the object’s spatial characteristics (Hirtle, Jonides, 1985); therefore, streets based on axial lines (Hillier, Hanson, 1984), represented with hierarchical levels are developed to make such urban morphological study. Additionally, Marcus (Marcus, 2007) conducted a study of spatial accessibility of urban form and the analysis are based on the measurement of accessibility of each axial line on the map. For streets network analysis, the approach under the term of connectivity and integration focuses on the idea that some streets are more central and they are important than others (Porta, Crucitti, Latora, 2006). Streets with higher integration level are in real life the ones with markets, city centres, squares, central parks or important crossways.

This paper contributes to a better understanding of the relation between Space syntax and urban morphology. This knowledge can benefit both fields in their further development and more specifically, this study will show how this relatively new approach in urban morphology can be helpful in explaining variations in correlations between spatial measures, regardless the criticism (chapter 1.2).

To conclude, the significance of the study is to generalise and conclude on the difference between planned and unplanned cities, integration-wise. Which city is more integrated, top-down or bottom-up? To answer this question, further research needs to be conducted, by quantifying or investigating the relations between urban morphology and street integration.

1.6 Scope and limitations of the study

To indicate the scope of this study, it is important to note that the research concentrates on 68 cities all around the world. The city selection process is based on the date of origin, from 3000 BC old towns (Jerusalem, Jericho, etc.) towards modern city plans. Choice of the cities is as diverse as possible, from developing countries to prosperous hi-tech cities of the future. Moreover, not only traditional cities which exist today are analysed, but also experimental cases such as the utopian idea (Almere, The Netherlands) built on Ebenezer Howard Garden city idea, and the UAE tech cities.

Being sure that particular city is unplanned is a challenge. Most cities today are a mixture of planned and unplanned parts, while layers of the urban growth and decline on the same territory just make the task more demanding. Such an example is Paris, an old medieval street pattern transformed with Haussmann’s geometric grid plan. Other cities such as Riga, Tallinn or Bucharest old town, have preserved old walled medieval towns, inside today’s modern city centres or outskirts. Many bottom-up cities from Africa and Asia, still existing today, happened to lack digital data (no visible street map) in GIS’s OpenStreetMap extension used as a background layer for conduction of axial maps. This is due to the fact that many streets of those cities are narrow pedestrian passages, not visible even on Google Maps website (www.maps.google.com). This obstacle downsised the sample and limited the choice of data collection process.

Another limitation of city classification is pairing cities from BU group with their counterparts from TD, since they do not always evidently and clearly belong to one or another pattern group. Finding appropriate TD pair for each BU city is a challenge since many new towns are also not (yet) visible on Google Maps website nor OpenStreetMap.

Now, the limitations arise during the generation of the axial lines in GIS when a few isolated lines appear. This happens because axial lines are represented by straight lines and as such adjust the curve streets to straight shapes segmenting it into several parts (their original forms are not preserved) and cannot be presented as curves (Figure 6). Considering this phenomenon, spatial analysis performed on axial lines differ from natural streets. Moreover, the generation of axial lines can be time-consuming and subjective. Each software user has his/her own way in generating axial lines - for example, the way open spaces, roundabouts or parking lots are perceived and presented with axial line is a matter of "style" although there is a general agreement how it should be solved and presented (Jiang Claramunt, 2002; Ratti, 2004). There are some functions (extensions) that have been written in GIS to generate them automatically (Jiang, 2012) and avoid manipulation of data, however they are not used in this study because the SS's program DepthMap cannot "read" properly in order to calculate the integration levels.

Figure 6 – Adjustment of a curvy road into axial lines

The summary of the thesis limitation and challenges:

- A challenge in distinguishing which city is unplanned, i.e a problem in tracing the planning history;
- A challenge in identifying the exact street pattern type (medieval, grid, Roman etc.) due to the fact that most cities have layers of different street patterns because as a consequence of many factors (colonialism, war, technology, economy, infrastructure etc.);
- There is a conceptual issue because many different authors are interpreting bottom-up cities differently (Benevolvo, Lynch, Kostof, Radovic etc.);
- Open street map platform shows technical limitations and does not always present the genuine updated maps. Especially it is the case in the bottom-up group (old Asian and African cities which have many narrow pedestrian pathways);
- Limitation lays in conduction of axial lines, already previously elaborated (Figure 6);
- This thesis is concentrated on clinical analysis of SS and doesn't take into consideration any social implications (human behaviour, liveability etc.), infrastructure characteristics (land use, land price, transportation system etc.), or topological conditions;
- SS limitations consider axial lines regardless its function (two-way street, one-way street, pedestrian or motorway, does it have any barriers, crossings, roundabouts etc.). SS analyses natural road as a straight line and calculates its integration without taking into consideration the abovementioned factors. Integration is not taking into consideration density, population, number of streets etc.;
- The selection process for the pairing of the cities does not guarantee that replacing the city with one that is similar (in shape and size) will lead to the same results.
- The integration is observed on the local level only, without taking into consideration the global level (without continuity and the shape of the street network).

2. Theory review

2.1 State of art in urban morphology and Space syntax theory

The following literature review elaborates on the background and motivation of this urban morphology study. It reveals how Space syntax theory is combined with GIS, suggests a way to study spatial configuration and describes classification and types of urban form. The literature selected to be elaborated below gathers prior theories and studies, and dates from XV century to last year (2015) published books and papers, among which all are traceable and academic.

2.1.1 Theory review scope

The purpose of the introduction to theory review is to explain why this research has a starting point not in urban planning or Space syntax theory but in geography science. Vitruvius noted that education of one who is about to become an architect has to comprise of different knowledge, for the reason that architect should be able to judge the value of works originated from several spheres of science (Vitruvius, 1486). Affirmative to this statement, today's architecture science became greatly wide and complex. But then again the extended list of tasks architect should be able to perform made the whole image of profession blurry. It became unclear where the boundaries of architecture stop, and where they come to be. Starting from 50's and 60's[2], the profession identity crisis still is on-going. Blame-to-be belongs to a massive industrial production and the additional set of challenges (and new knowledge), therefore the attempt to adjust to the present time became even more puzzling. In order to understand certain phenomena, an architectural researcher is obliged to seek for the answers and theories in various disciplines, discovering clues combining different methods and concepts. This study, in particular, has far more implications in other scientific fields than what is just thought to be examined once terms "city" and "street" are brought up.

Where do architects stop being architects and start performing as urban planners or, for example, geographers and vice versa?

The explanation for this phenomenon might be in the fact, which Batty stresses fifty years ago, that theory of how cities were structured in spatial terms hardly even existed (Batty, 2005). He states that there was a small but significant tradition in spatial economics, location theory, as well as equally articulate yet descriptive ideas about the geographical structure of land use patterns, and that there were no integrated theories about how cities evolve to become spatially ordered. What theory attempts to describe rather than explain (what can be directly observed on the assumption that the spatial structure of cities was long standing) was that cities were essentially systems that moved back quickly to equilibrium. Patterns based on spatially ordered hierarchies suggest that the kind of radial concentric organisation of land (around key commercial and industrial centres), could be explained by simple market models where individuals and firms outbid each other for land (Batty, 2005). In addition to methods currently used in Space syntax and to analyse complex networks in cities (Batty, 2013), Isobenefit lines analysis (D'Acci, 2013) gives insights that pedestrian distances and flow in the city are not

[2] **Architectural crises started in early 50's, late 60's in the United States with urban reconstruction projects, moving out from cities to suburbs, architectural student protest, suspicious National awarding of Pruitt-Igoe and its demolition afterwards. In Europe, the crisis was evident due to the massive after-war reconstruction, the closing of ENSBA (Ecole Nationale Superieur des Beaux-Arts) in 1968 and unclear circumstances around Les Halles construction in Paris (Ellin, 1996).**

defined only by street pattern and interconnectivity, but by how fast, cheap, pleasant and by how much people “like” to move among locations, as well (D’Acci, 2015).

Furthermore, Batty indicates that finally, the time has come when a new programming language is able to consider models that deal with a large number of units by disaggregating space, time and the typology of activities which are located in cities. He argues that there is a vision that such computer data analysis is able to capture the way spatial structures form, emerge and develop, and as such, give recommendations of how cities should be planned (Batty, 2005).

During the last two decades, advances in spatial analysis methods and improved capacity of computers have made possible to quantitatively analyse a large number of urban morphological features. In this respect, this study analyses two main concepts (urban morphology and street integration), other disciplines (urban geography), theory (Space syntax), supportive technique (conduction of axial lines) and supportive softwares (GIS and DepthMap). Specifically, theory review starts in deep roots of urban planning and urban history. The review carries on with the analysis of numerous city shapes justifying the simplified classification of urban form made for the purpose of this research (TD and BU).

2.1.2 Urban geography

Studying urban geography helps to answer a various question concerning city issues. The urban geographer’s approach is based on location and the study of processes that create urban patterns. The spatial perspective, in fact, provides the central subject of geography science. And finally, maps complement additionally to geographic research by demonstrating the importance of place in urban analysis.

One of the strongest arguments for the study of urban geography today is the important preparation it provides for careers in planning and consulting related to physical and community development (Hartshorn, 1992).

The focus on the morphology or internal structure of the city, gradually established an identity for the geographers as urban planner professionals. The contemporary interest in Geographic Information Systems (GIS) involves the geographers/planners as data researchers of diverse information from both socioeconomic and environmental disciplines. In 70’s and 80’s, especially after David Harvey’s *Social justice and the city*, *The Urbanisation of capital* and *The Urban experience*, practitioners became aware of the uneven development of the city and city’s parts (Harvey, 1989). But the most significant contributions to urban geography in the structural approach probably lies in the areas of urban housing research (gentrification, homelessness, ethnic and cultural issues), industrial development and in the transformation of urban economies associated with the appearance of the post-industrial information age (Hartshorn, 1992).

Unfortunately, the study of cities has no dominant elementary language of its own. It mostly borrows languages from geography, mathematics, and architecture and this is only useful to some extent. Defining the city is a difficult task. The term “urban” also has a somewhat unclear connotation, even just from seeking its definition in dictionaries.[3] For various urban sciences and theories, understanding the urban geography principles is crucial, thus for this study of urban morphology, GIS, and Space syntax is, too.

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[3] “Urban” (Latin *urbs*), meanings: of, relating to, or designating a city or town; living in a city; characteristic of or accustomed to cities - citified; city-like; a city with a population of at least 50,000 people etc.

2.1.3 Urban morphology

Urban morphology studies the form of human settlements and their creation and transformation. In this essence, urban morphology is used as an important assessment tool in determining the transformation processes of urban fabrics, making sense of the historical roots of spatial and functional structures and bringing them to the present day. The development of urban morphology, which constituted a component of urban geography as a subject, dates back to the first half of the twentieth century. As an independent scientific discipline, it is used as a method for urban physical structure analysis (Whitehand, 1986). The dynamic state of the city and the pervasive relationship between elements (buildings, gardens, streets, parks and monuments) have led many urban morphologists to prefer the term “urban morphogenesis” to describe their field of study (Moudon, 1997). In Conzen’s approach, urban morphology is the study of the form and shape of settlements. He considered land use, building structure, plot pattern and street pattern to be the most important elements of urban morphology (Conzen, 1960). The same attitude about streets shares his colleague, who calls them the most enduring element of urban morphology (Carmona, 2001). Another interpretation tends to define urban morphology as a spatial arrangement of persons doing things, the resulting spatial flow of people, goods and information and the physical features which modify space in some way significant to those actions, including enclosures, surfaces, channels, ambiences and objects (Lynch, 1981).

The city shape formation is influenced by various factors: social structure, economic structure, geophysical factors, geomorphological factors, natural geographic factors, technical/technological inventions etc. Physical structure of the city is directly based on land use and its function (Radovic, 2003). In *Urban land use planning*, land use is simply defined as a spatial configuration of city’s functions and it represents the base and the source of urban-whole visualisation i.e. the source of concrete urban morphology (Chapin, 1965). Le Corbusier in *Vers une architecture* reminds that a city plan acts inside towards out, meaning that the outside shape represents a result of what is taking place inside of it (Le Corbusier, 1923). Other factors responsible for spatial configuration of the city are: randomness (arbitrary, unexplainable reasons), historical accident (technological development, invading quests), physical determinism (geographic, nature, physical boundaries), natural advantage (existence of resources) or comparative advantage (level of facilities or services and the access to them, market potential, and accessibility) (Batty, 2005). Batty explains the development of urban morphology with complexity. He claims that cities grow mainly from actions based on individual decisions about development made locally. Even citywide decisions in the name of planning or corporate management are implemented locally and adapted to individual circumstances. Batty claims that cities do not (and should not) develop in strict accord with any grand plan. They are too complex and diverse to be so controlled, too heterogeneous and responsive to their wider environments to be managed in their totality. In this sense, they are no different from any living system whose code of development and growth resides in its most local parts. Science is gradually getting used to the fact that the most efficient, in the fact the only possible, strategy for the development of complexity is coordination of the parts at the most local level. The architecture of complexity is built from local actions that are coordinated in such a way as to produce well-integrated and workable systems differentiated hierarchically that at first might suggest the action of some central planning. But central planning is not, there are only the actions of individual elements whose coordination results from the remorseless processes of competition and adaptation. Many, if not most complex systems consist of local actions that give rise to global patterns whose appearance suggests some overall design. Regular forms emerge from the routine operations of local processes. Such patterns are formed from basic units of development that grow and change so that some balanced social and economic self-sufficiency is achieved (Batty, 2005). Kevin Lynch states that the modification of settlement's shape is a human act, done for human motives (Lynch, 1981). Which are those motives? Why human created them in the first place? The answers to these questions are gratefully due to the archaeology findings and myths legacy studies in the first place and lastly due to map analysis, written artefacts, and observation.

To continue, symbolic schemes and city plans carrying a certain message are often a phenomenon in the history of urban planning and even today, cities are marked with certain appeal and representation their form transmits (the airplane shape of Lucio Costa's Brasilia city plan). The circle and the square basically are considered to be traditional city shapes. City shape cannot be observed either analysed as a result of any urban life aspect in particular (economic activity, social relationships, tradition, politics, technology or natural factors), but the city shape always signifies the expression of overall society activities in lasting time period (Radovic, 2003).

"Physical structure of the city is always and irrevocably reflected in the entirety of the truth and paradox of the world, environment and culture of each one of us."

(Ranko Radovic, The form of the city, 2003)

Lastly, urban morphology has become a common and important research method for the analysis of the physical structures of cities through the numerical content (Space Syntax) brought in by Hillier, especially with the support of the technological innovations in recent years (Hillier, Hanson 1984; Hillier, Iida, 2005; Hillier, 1996). Space Syntax is a technique that is used for morphological analysis of both architectural and urban plans. An additional literature review about Space Syntax is specified further on in this research.

2.1.4 Evolution of urban form

Some authors argue that cities firstly appeared as, for example, warehouse places, central places for trade, war fortress centres or centralised public spaces for managing complex agricultural questions and problem. On the contrary, some authors vouch for other truth, that these activities appeared after the emergence of the city. Lynch claims that first settlement had two main activities: market and administrative centre and that the actions were held on the very first street crossing (Cardo and Decumanus, main streets in ancient Rome). According to his theory, most new urban settlements in history were created for two reasons (Lynch, 1981):

- Either to control a certain resource, or
- To relieve overpopulation at home.

Overpopulation is even today the main motive for the growth of new cities, but in addition, for experimental purposes as well (Masdar or Chinese ghost towns). Lynch describes old new cities as completely planned, pure geometric and simple (Lynch, 1981). The theory about Lynch's city morphology is partial, not only because it is kept in the physical aspect, but because this theory should be connected with a theory of "how city functions/works" in each and every physical form. Good city form doesn't necessarily mean good city function.

Whatever the actual practices of urbanization may have been, ancient traditions insisted that making cities was an intentional act, approved and implemented at the highest level. It was believed that the gods made cities and took charge of them (Figure 7). This is not at all surprising since in many ancient cultures, the city on earth was supposed to represent a holy model of what was believed to be happening in the "sky", which in turn meant an artificial layout, often of some geometric purity (Kostof, 1991).

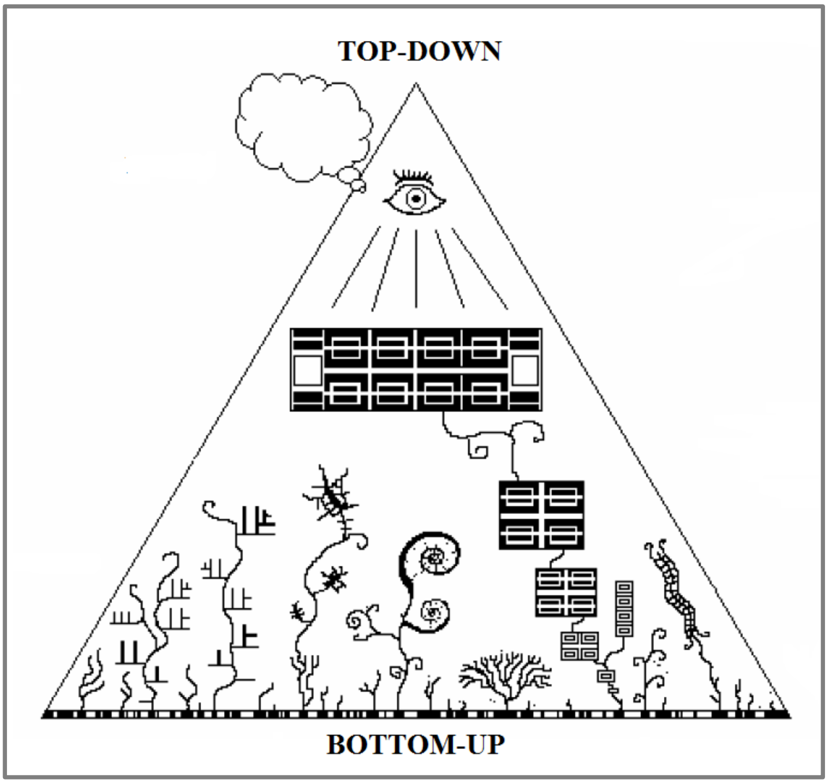


Figure 7 – All-seeing eye, the evolution of urban form
SOURCE: Stephen Marshall, The Probabilistic Generation of Characteristic Urban Structure, UCL, 2005

Continuing the analysis of urban form evolution, very important study appeared: Benevolo's (Benevolo, 1980) comprehensive examination of the changes that have occurred in the city's physical environment throughout the history. Benevolo, similarly to Kevin Lynch, classified urban structures as following[4]: prehistoric, Greek city, roman city, medieval city, Islamic city, Middle Age city, renaissance city, European colonial city, European baroque city, Industrial Revolution city, post-liberal city and modern city.

One more approach somewhat revolutionary, fractal dimension theory, which determines the extent to which cities fill the space they occupy, is also a method for classifying cities using their relative densities and accessibilities. This theory relates to how cities develop in terms of their network structure and provide the perspective for understanding the effects that define cities in the first place (Batty, 2013).

Is it possible to make a broad statement about the settlement, observed from morphology point of view? Is there one declaration, relevant and responsive to any human context, time or place? For this research purpose, the city shape is analysed purely from the standpoint of its starting point in development, i.e. planned or unplanned (top-down or bottom-up). Such classification of city morphology is not proposed by any author per se, and then again was mentioned by many either as a part of more comprehensive classification or as a description of the same. To conclude on behalf of further analysis, for this research purpose, cities are considered to be either top-down or bottom-up (or a mixture of two).

[4] **Interesting to note that an alternative urban structure division, derived from more modern author Paul Knox, is insinuating how actually our perception of the cities have changed greatly in the past decade (Knox, 2014). His division is as followed: foundational city, networked, imperial, industrial, rational, global, celebrity, megacity, instant, transnational, creative, green and intelligent city.**

2.1.5 Top-down

"Man walks in a straight line because he has a goal and knows where he is going. On a plain where no (im)pediment obliges, it cannot be supposed that men would go by a crooked line, where they could arrive by a straight one."

(Sir William Chambers, Treatise on Civil Architecture, 1862)

What designs cities are the power, and the rawest form of power is control of urban land (Kostof, 1991). When the state is the principal possessor, it can put down whatever pattern it chooses. This was true of the royal cities of ancient Persia, the imperial capitals of China, and the baroque seats of European princes. It was true of company towns, and it is still true in the Soviet Union and the socialist countries of Eastern Europe where the rights of private property were/are severely reduced. Kostof emphasizes that the very first kind of the city is the planned or so-called created city, which is set down in one moment, and which pattern is determined once and for all by some overseeing authority. Until XIX century, this pattern was seen as orderly, geometric diagram. At its purest, it would be a grid, or else a centrally planned scheme like a radial scheme, a circle or a polygon with radial streets disbursing from the centre; but often the geometry is more complex, marrying the two pure formulas in modulated and refracted combinations (Kostof, 1991). New settlements (in far history) were designed fast, deliberate, on purpose, sharply defined from surroundings, simple, with order and full of home symbols for homesick reasons. These new settlements are ones emerged along Mediterranean and Black Sea coast and they had repetitive pattern, 90' angle main street crossing, unequal grid block between them and they were enclosed with irregular wall which was dependent on terrain, without apparent relation to the street pattern (Lynch, 1981).

On the other hand, already existing cities, which partly experienced development of above elaborated new forms, are ones with bipolar features. These cities have two zones, old and new (Barcelona, Havana, New Delhi, Johannesburg) and are ones which experienced internal colonization, often situated on the borders (similar to the cities between Mexico and United States).

Colonial and other new cities had/have absolute top-down morphologies with following features (Lynch, 1981):

- Visible and concrete social structure
- Feeling of separation, control, fear, exile sense, pride, parade, military, power, clean, ritual, regulations
- Spatial separations, gates, barriers
- Symmetry, order, formality, naming, marking

Box 4 - Top-down city features

Classical examples of top-down, planned city forms are:

- Grid (chess/square) pattern,
- Circle (radial) pattern,

But also, later versions of planned form, which is less geometrical:

- Nature-lake (Organic) pattern,
- Cul-de-sac (dead end street pattern) or so-called "dormitory cities".

First planned city form is the grid (gridiron, square, chess, checkerboard) which is a substitute for orthogonal planning and is by far the commonest pattern for planned cities in history. The advantage of straight through-streets for defence has been recognised since Aristotle time, and a rectilinear street pattern has also been resorted to in order to keep under watch a restless population. Generally speaking, gridded towns serve most of the purposes of towns: defence, religion, agricultural development and trade. The grid also serves the symbolic needs of the most absolute governments (China and Japan). But the most persistent belief that urban grid represents an egalitarian system of land distribution is expressed in the context of modern democracies, principally in United States. Historically, the grid serves two main purposes. The first is to facilitate settlement orderly (colonisation in its broad sense) and the other application of the grid is an instrument of modernisation. Motives for its creation are various: military arrangements, religious covenants, mercantile capitalism or industrial planning (Kostof, 1991). Orthogonal planning is a manner of creating urban order, not a simple formula of urban design. Even though the urban grid is omnipresent in the history of cities, it is neither standard nor predictable. On flat terrain, it is the sensible method of land division. But the grid also readily climbs hills or curve its lines to fit a river bend. The virtue of a grid is, in fact, its unending flexibility. Tailor-made for moderate urban scales, it is able to ingest the superblocks of the modern metropolis (Kostof, 1991).

- Examples of grid-pattern cities:

Mohenjo-Daro, Indus Valley	Suzhou, Ancient China	Milton Keynes, UK
Babylon, Mesopotamia	Barcelona, Spain	San Francisco, US
Smyrna, Sicily	Cosa, Italy	New York, US
Timgad, Algeria	Richelieu, France	Savannah, US
Brasilia, Brazil	Amsterdam South, The Netherlands	Salt Lake City, US
Jaipur, India	Middlesbrough, UK	Washington, US

Second planned city form is circular (radial) one. By their nature city plans of circular shapes often remain on a theoretical plane. It is possible to find more ideas on paper than on the ground. Best existing examples are in Italy (Palmanova) and in the United States (Arcosanti). When these types of cities actually do get built, they often are very short-lived, overtaken by grid reality. These cities obey rigid modes of centrality and radial convergence or axial alignment. Some utopian ideas tended to respect exactly these rules (Bartolomeo Delbene’s City of truth, 1609, Filarete’s Sforzinda city, 1460, etc.).

- Examples of radial-pattern cities:

Nahalal, Israel	Lucignano, Italy	Hamina, Finland
Corona, US	Karlsruhe, Germany	Neuf, Brisach, France
Cotati, US	Palmanova, Italy	Saline de Chaux, France
Circleville, US	Karlsruhe, Germany	Philippeville, Belgium
Arcosanti, US	Villa Piloto, Brasil	

Third planned city form is nature-like (organic) pattern. These irregular but planned city types are picturesque, organic-like shapes, like ones from England and United States suburbs (Glendale, Ohio, 1851; Riverside, Illinois, 1869). The tendency to create “the city in the park” (Garden cities, Ebenezer Howard) became the official solution to post-war urban problems in England (Kostof, 1991). Like the animals, humans and plants, which do have definite boundaries (city walls) and self-regulating systems of growth, which are prompt to get sick and change (like slums in the cities); real organic cities are following the same structural logic and functional processes. Ebenezer Howard’s *Garden cities of tomorrow* to one extent represents the planned organic city but it contradicts the theory in separating the functions, then in predicting optimum size for the city and thirdly by resisting change and the notion if the continuous growth (Howard, 1902).

- Examples of nature-like planned cities:

Römerstadt, Germany
Toulouse-Le Mirail, France
Almere, The Netherlands

Fourth planned city pattern is often a resultant of previous TD type. Cul-de-sac streets existed from Ancient Egypt to Roman Empire time as it does today. England once banned its use by the end of XIX century because this type of city making is encouraging sprawl, but again dead end streets found their way in Garden Suburbs (Raymond Unwin). A cul-de-sac is created to limit through-traffic in residential areas and increase spontaneous activity by children. The design reflects the predominance of pedestrian movement on a local level. Such street pattern is typical for neighbourhood development but in order to reach amenities, usage of motorised transportation is needed. This is why this type of urban planning has many criticisms regards environmental, health, traffic and crime issues.

- Examples of cul-de-sac cities:

Welwyn Garden City, UK	Milton Keynes, UK
Wildwood Park, Canada	Radburn, New Jersey, US
Calgary, Alberta, US	Berkeley, US
Milton Keynes, UK	

2.1.6 Bottom-up

"The pack donkey's way is responsible for the plan of every continental city. The packed donkey meanders along meditate a little in his scatterbrained and distracted fashion, he zigzags in order to avoid the larger stones, or the ease the climb, or to gain a little shade; he takes the line of least resistance."

(Le Corbusier, Urbanisme, 1924)

The planned city is usually built for obvious reasons but, it is more difficult to untangle the motives behind a more gradual development. For example, clues can be found from the way cities were reconstructed after major disasters (London after the fire Sept 1999, Chicago after the fire Oct 1871, Managua after the earthquake 1972, Warsaw after the holocaust 1942 etc.). The spontaneous city, with a geomorphic pattern, is presumed to develop without the benefit of designers, subject to no master plan but the passage of time, the lay of the land, and the daily life/activities of the citizens. The resultant form is irregular, non-geometric, and organic, with crooked, curved streets and randomly defined open spaces. To stress process over time in making of such city forms, it is possible to name it *unplanned evolution*, or *instinctive growth* (Kostof, 1991).

"The irregular city is the result of development left entirely to individuals who actually live on the land. If a governing body divides the land and disposes of it before it is handed over to the users, a uniform pattern will emerge."

(Fernando Castagnoli, Orthogonal town planning in antiquity, 1971)

The notion of the city as an organism is not very old. It is related, of course to the rise of modern biology, the science of life, and that does not antedate by much the mid-XVII century. One can recognize the venation of leaves in Muslim medinas, the pattern of tree rings in the ringed expansion of a town like Nördlingen or Aachen. Open spaces and parks are perceived as city lungs, while the city centre is the heart pumping the blood (traffic) through the arteries (streets) etcetera.

"The relation of the city to its parts is similar to that of the human body to its parts; the streets are the veins."

(Francesco di Giorgio, Trattato, XV century)

On the other hand, Kevin Lynch does not support the previous theory and points out that it is a human purpose and human wilfulness that drives the city creation.

"Cities are not organisms. They do not grow or change of themselves, or reproduce or repair themselves."

(Kevin Lynch, The good city form, 1981)

Kostof agrees and adds the fact that no city, however, arbitrary its form may appear to us, can be unplanned. Beneath the strangest twist of lane or alley, behind the most fitfully bounded public place, lies an order beholden to prior occupation, to the features of the land, to long-established conventions of the social contact, to a string of compromises between individual rights and the common will (Kostof, 1991).

Most bottom-up cities originate from XIX century and could be seen today in Africa, Asia and European countries (Paris, London, Prague, Tallinn, etc.). These cities do have essentially fractal properties, in common with all living systems. The organic theory is the habit of looking at a settlement as a whole of many functions, whose diverse elements are in the constant and supportive interchange, and whose process and form are inseparable. Lynch introduced following classification of normative theory (Lynch, 1981):

- Cosmic model - Holy city (Roman cross and Greek layout *per strigas*); A spatial diagram of social hierarchy;
- Grid model - Machine city (Radiant city, Le Corbusier); A functional construct of interrelated parts;
- City as an organism - Biological city (self-organizing and self-regulating); An indivisible, living organism.

Organic forms, according to Kevin Lynch's *Good city form* have following features:

- Radial patterns	- Irregularly curvy organic shapes
- Bounded units	- Natural materials
- Greenbelts	- Moderate to low density housing
- Focused centres	-Visual proximity to earth, plants, animals
- Romantic layouts	- Plentiful open space

Box 5 – Bottom-up city features

Lynch's normative theory served highly inspirational for this research. His third model, the city as an organism is partly a TD version used for the purpose of this study where the tree is admired model (Tapiola, Bedford Park, Hampstead Garden, Radburn, Chatham village, Chandigarh). The affection for nature and the desire to be close to natural, living things are feelings very widely held throughout the urbanised world. Settlements built according to the organic rule are attractive to us predominantly because they allow for close contact. It is curtailing, though, that we come to see ourselves as an integral part of the total living community (Lynch, 1981). Christopher Alexander noted that for the human mind, the tree is the easiest vehicle for complex thoughts (Alexander, 1965).

"But the city is not, cannot and must not be a tree. The city is a receptacle for life. If the receptacle severs the overlap of the strands of life within it, because it is a tree, it will be like a bowl full of razor blades on edge, ready to cut up whatever is entrusted to it. In such a receptacle life will be cut to pieces. If we make cities which are trees, they will cut our life within to pieces."

(Christopher Alexander, A city is not a tree, 1965)

2.1.7 Top-down versus Bottom-up[5]

Analysing city plans across the range of history and the world, a more fundamental reason to question the usefulness of urban dichotomies based on geometry is given. It is evident that the two primary versions of urban arrangement (TD and BU) often exist side by side, one in another (Old and New Delhi, Back Bay and Boston, Barcelona and Barrio Gothic, Tallinn old town and rest of the city). Furthermore, the two types of urban form do not always stand in a contiguous relationship. They change, they metamorphose. The adaptation of previous geometries over time leaves urban signature where a once regular plan was hidden within a labyrinth of cul-de-sacs (dead-end streets) or narrow zigzagging streets.

According to Batty (Batty, 2013), those changes from one urban shape to another, occur because of particular circumstances:

- Movement from geometrical order, due to the inflexibility of grid in terms of human movements,
- Reorganization of the blocks, by grouping into neighbourhoods or reorganization of public spaces, and possibly by
- The impact of new public focus on the urban fabric, like traffic flow or running water.

The background for the urban economization and readjustment in post-Roman Europe is well known (depopulation, reduced circumstances, social revolution) and there was no place in the new social structure for theatres, amphitheatres, temples or baths anymore. This is how, for example, the disintegration of the rationally ordered and publicly administered Roman *urbs* got under way (Batty, 2013).

Another argument on using TD/BU typology is led by Lynch's study of "imageability" (Lynch, 1960). When a person attempts to move from point A to point B, while doing so, it creates the image of the path in mind. The need to recognize and map the environment is vital as it has long roots in the past and lastly wide, useful and emotional significance to the individual. Obviously, a clear image enables one to move around easily and rapidly. But a well-ordered environment can do more than this. It may serve as a broad frame or a reference, an organizer of activity or belief of knowledge. The argument also stands in people's need for order in the environment to navigate easier. He gives an example where only professionals are able to navigate among the Polynesian islands, and this only after extensive training, where the environment is very disordered, while on the other hand, almost everyone can handle navigation in Jersey City, United States (Figures 8 and 9) (Lynch, 1960).

Figure 8 – Jersey City, the United States

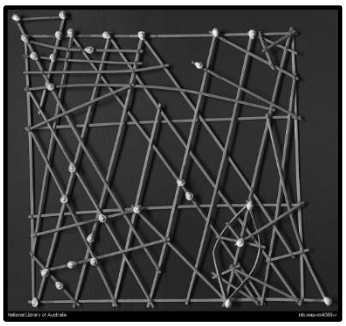


Figure 9 – Polynesian navigation map

[5] **Reviewing the literature, many interesting opposites (antonyms) related to top-down and bottom-up terms appeared and some of them are listed below:**

Top-down - Bottom-up	**Planned – Unplanned**	**Geometric - Organic**
Machine – Organism	**Foreign – Native**	**Rich - Poor**
Sprawl – Dense	**Order – Disorder**	**Designed – Spontaneous**
Ville créée – Ville spontanée	**Created – Grown**	**Regular - Irregular**
Imposed - Generated		

But what is missing in Lynch theory about the urban image is the emotional satisfaction that moving through an environment can provide. It must be granted that there are some values in mystification, labyrinth, or surprise in the surrounding, which unplanned city shapes certainly do bring, such as, for example, psycho-economical distances and personal isobenefit lines. They may also serve as bases, or parallel tools, to understand citizen movement decisions within cities (D'Acci, 2015).

"Complete chaos without a hint of connection is never pleasurable."

(Kevin Lynch, The image of the city, 1960)

An additional argument for using TD/BU typology is one of a physical form by itself. Lynch argues that the way we live in certain physical shape has no important influence on human satisfaction (as long extremes and inhuman conditions are not taken into consideration), comparing the traditional Eskimo families and North American family living requirements. In addition to that, he argues that physical form cannot be variable because its manipulation does not induce change (Lynch, 1960). Contrary to this thought, in this research physical form (urban morphology) plays the most important role being an independent variable.

Another perspective is based on economic development, which emphasised the difference between the planned and unplanned urban areas. There are even shanty towns in the rich oil-producing countries, such as Kuwait, which has the highest per capita income in the world. It is already a cliché saying that more than half of the global population lives in the cities, but it doesn't make it less true. In the very near future the majority of people will be housed in unplanned settlements (slums); in fact, while the world's total population is doubling every thirty years and the urban population every fifteen tears, the "marginal" urban population is doubling every seven and half years (Benevolo, 1980). Meanwhile, the properly planned city, weather post-liberal or modern, is no longer within the reach of everybody. The majority of the world's population is crammed into unplanned cities and towns, which resemble on a much larger scale the "liberal" settlements of the early industrial era (Benevolo, 1980). Modern architecture and urban planning now stand at a crossroad: it can content itself with improving the environment of the dominant minority and become an instrument of a new, world-wide discrimination, or it can start to analyse the division between the two types of urban development. This urban dualism results from the policy of declaring illegal the homes and districts built spontaneously by the inhabitants, and of the building, instead, great complexes of purpose-built homes along conventional modern lines (Benevolo, 1980).

What, at that point, determines the apparently characteristic shapes of evolved or generated cities? The most widely acknowledged causality, the natural landscape, rings possible truth because it is visually the easiest to understand (Rio de Janeiro and the hills, walls of Idalion-today's Cyprus terrain contours, Italian hill towns - Cinque Terre, river towns, sea cities, and harbour cities). Those cities are perfect examples of the evident connection between the human-made and the natural.

Those cities tell they have adopted one or several configurations depending on the character of their settle-place. If the side is a ridge, the town will have a linear shape usually fixed with architectural accents like castles and churches at one or both ends, or along one side of the ridge. Other main roads will run parallel to this spine further down the slope. Tributaries will strike out in the direction of principal neighbouring cities, giving us the tentacles form of towns like Perugia. On the round, domical hill sites, the main buildings are likely to be at the top, and the streets taking descending concentric circle shape. Arrayed upon a steep slope, the town has the terraced composition of Assisi or Gubbio. At the same time, we have to remind ourselves that the linear town and its blueprint, the rib plan, is as much on the level ground as along land folds. The same holds for rounded city form, whether the wavering street system tends to a concentric or radial disposition. Going back to the beginning, to Mesopotamia and Egypt, it is important to remember that sites of irregular cities like Ur and Thebes were flat, built in the flat mud plains of the Tigris and Euphrates (Kostof, 1991).

Irregular city form occurs often due to a small number of topographic peculiarities. Seen in the aggregate, there is perhaps as widespread tendency in city-making to amend the natural landscape as there is to work with it. It does not necessarily mean that planned city is strictly regular. Both Venice and Machu Picchu were designed on difficult land they sit, one by solidifying the lagoon, other on steeply terracing vertiginous heights.

> *"The urban design of Machu Picchu is a patterned blanket thrown over a great rock."*
>
> *(George Kubler, The shape of time, 1962)*

2.1.8 Integration

Street network patterns are a dominant component of a city's spatial form. Importance of streets and street patterns in urban morphology analysis is of great importance and as such discussed by many authors. Michael Batty noted that density, accessibility and finally, integration remain the key elements in the vocabulary of what is referred to as the physical shape of the city (Batty, 2013). The theory emphasizes the significance of streets for human spatial behaviour, including transportation, mobility and accessibility (Batty, 2005), active traveling (Frank et al., 2005), human path-finding and "imageability" (Lynch, 1960) and urban life safety and vitality (Jacobs, 1961). Jane also states that streets are the heart and a vital part of a physical city.

Lynch elaborates the importance of streets differently in his young and mature professional life (access and path). The paths, the network of habitual or potential lines of movement through the urban complex, are the most potent means by which the whole can be ordered. Firstly, when Lynch was a young professional he named paths, edges, districts, nodes and landmarks as most important elements of city image (Lynch, 1960). He indicates that paths are creators of city image, its shape and structure, its morphology. Paths may be imaged as a network which explains the typical relations between all paths in the set without identifying any particular path. Paths are the channels among which the observer customarily, occasionally, or potentially moves. They may be streets, walkways, transit lines, canals, railroads. For many people, these are predominant elements in their image. People observe the city while moving through it, and along these paths the other environmental elements are arranged and related. Proximity to special features of the city gives a path increased importance. The fundamental quality of paths is their continuity. People regularly depend on this quality and they tend to think of path destinations and origin points, meaning that they like to know where paths come from and where they lead to. Paths with clear well-known origins and destinations have stronger identities, they help tie the city together, and give the observer a sense of his bearings whenever he crossed them. Once a path has directional quality, it may have the further attribute of being scaled: one may be able to sense one's position along the total length, to grasp the distance traversed or yet to go.

Furthermore, in regular patterns, people tend to count blocks. But most often, scaling is accomplished by a sequence of known landmarks or nodes along the path. The vital point is a street cross, an intersection since it is the point of decision. The simplest perpendicular relationship seems to be easier than other to handle. Chaotic crossings and circles often fail to communicate its structure. Paths are dominant in many individual images and are a principal in the organisation at the metropolitan scale, and at the same time they have intimate interrelations with other element types (Lynch, 1960). Observers from the Lynch's study were impressed, even in memory, by the apparent "kinaesthetic" quality of a path, the sense of motion along it: turning, rising, falling. A city is structured by an organised set of paths. The strategic point in such a set is the intersection, the point of connection and decision for the man in motion. If this can be visualised clearly, if the intersection itself makes a vivid image and if the lie of the two paths with respect to each other is clearly expressed, then the observer can build a satisfactory structure (Lynch, 1960).

Example: Imagine that you as a tourist are exiting Central Park (New York, US) after a walk, raising your hand in order to stop the yellow cab with the intention to have lunch into the city centre. A taxi driver has a whole city map in his mind and immediately knows that the best and fastest way to reach the desired destination is to drive three blocks straight and then turn instantly left and take the second right. But if you are a tourist in Siena, Italy and if you stop a local ice-cream seller to ask for the directions how to get to the city centre, he will most probably say: "Go this direction, and after 5 minutes you will come across a big fountain. Turn left and just before the small bakery with the blue windows turn right."

Secondly, in Lynch's mature professional life, he identifies basic performance dimensions of the city: vitality, sense, fit, access, control, efficiency and justice. Access is the ability to reach other persons, activities, resources, services, information, places, including the quantity and diversity of the elements which can be reached. A significant analysis of the place is mapping of these communication channels and the extent to which they can exclude certain people from the use of these channels, as well (Lynch, 1981).

There are many categorisations for streets outlines, but most significant street patterns classifications are:

- Irregular, radial-concentric, rectangular and grid (Dickinson, 1951),
- Star, satellite, linear, rectangular grid, other grid, baroque network and lacework (Lynch, 1981),
- Regular, concentric and irregular (DTLR, CABE, 2001),
- Radial, grid, tree and linear (Marshall, 2004).

Urban street networks are analysed with respect to their geometric and formal assets, their dynamics and their relationship to other morphological components such as buildings, plots etcetera. One distinctive approach which focuses on the integration between urban streets and their relative accessibility is the configuration analysis approach (Batty, 2009). Mentioned aspects, investigated principally from the perspective of topology-based methodologies, are used to compare different street patterns (Hillier, 2002), to distinguish different modes of street pattern development (top-down versus bottom-up cities) (Porta et al, 2006) and to understand the role of human movement in modelling urban street networks (Hillier et al, 1993).

Nonetheless, spatial integration is affected not only by the overall form of a settlement's street system and the variety of local street pattern types but also by the partitions found within the street network. While more technical definition of what integration is, a measure which describes its accessibility or how easy it is to get to from all other segments (Hillier, 2009), Hillier also (Hillier, 2002) suggested a general theory of partitioning to explain the effect produced by partitions (buildings, blocks, or open spaces) on the spatial configuration and integration of a given spatial form.

The theory includes four basic laws/principles to explain the formation of spatial integration during a settlement's growth (Figure 10):

- Centrality[6] (a partition placed in the middle of a spatial system will create more gain in depth than one placed at the perimeter),

[6] The principle of centrality suggests (Hillier, 2002) (1.) that a centrally-placed partition decreases spatial integration more than a peripherally placed partition, (2.) that the more compact a partition (i.e., the more its shape approximates a circle), the less the decrease in spatial integration in the surrounding space. According to the principle of contiguity

- Compactness (adding a linear partition creates more depth than adding a compact, “L” or “U” -shaped one of the same lengths),
- Contiguity,
- Extension (adding a longer partition will add more depth to the system than a shorter one, and similarly adding a single, contiguous partition of a given length will add more depth than several shorter, non-contiguous partitions that add up to the same length).

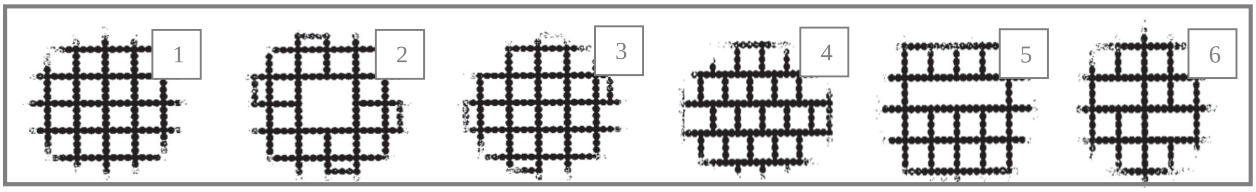


Figure 10 - Effect of partitions on spatial integration according to four spatial principles, for four pairs of grids: centrality (2, 3), compactness (2, 5), contiguity (5, 6) and extension (1, 4) (Hillier, 2002)

2.1.9 Axial lines

In Space syntax theory, the description and identification of a city's spatial form originate from a topological analysis of an axial map. The axial map is the set of longest straight lines of direct visibility that pass through all of a city's streets and open spaces -squares, parking lots, parks, connecting them into a continuous network. Axial lines represent generalised streets (“lines of sight” or “lines of unobstructed movement” along mapped streets). A topological analysis of an axial map treats the individual axial lines as nodes and all axial line intersections as edges of a connectivity graph (Hillier, Hanson, 1984).

The network analysis has a primal approach where intersections are turned into nodes and streets into edges. That representation seems to be the most intuitive for networks characterised by a strong connection to the geographic dimensions (networks where distance has to be measured not just in topological terms –steps, but rather in properly spatial terms-meter, like in urban street systems). The primal approach is followed by traffic engineers, economic geographers and geo-archaeologists others (Porta, Crucitti, Latora, 2006).

On the other hand, in the process of building the dual graph (reducing streets into nodes), the distance gets lost. No matter its real length, one street is represented in the dual graph as one point. Moreover, as long as a generalization model is run and the “identity” of one real street is extended over a conceptually unlimited number of real intersections, in the dual graph it is possible to find one street (node) with unlimited number of intersections (edges), a number which heavily depends on the actual length of the street itself. Thus, the longer the street, in reality, is the more central (by degree) it is likely to be in the dual graph. The dual approach makes impossible to account for the variations which so often characterize one single long street (Porta, Crucitti, Latora, 2006).

The example of dual approach challenge is 3km long Via Etnea in Catania (Sicily), the perfectly straight street from XVII century that connects baroque city centre and Etna volcano countryside. Via Etnea presents different social, economic, demographic and environmental settings while crossing apparently all possible urban landscapes (Figure 11).

(3.), contiguously-arranged partitions increase depth more than do discretely arranged partitions. Finally, the principle of extension suggests (4.) that, when more lines are shorter due to its offset internal lines, integration decreases.

Figure 11 - Via Etnea, Catania, Sicily

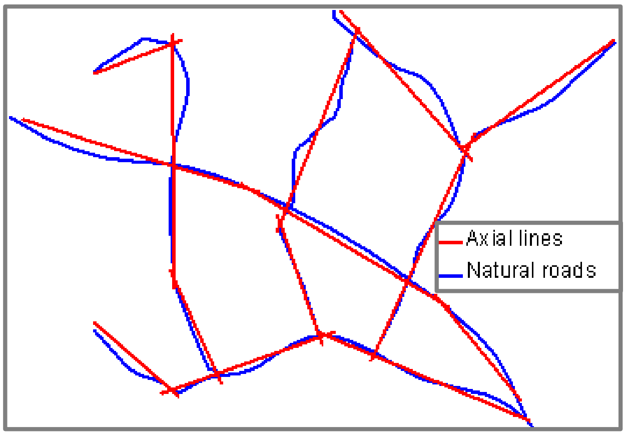


Figure 12 - Generated axial lines based on natural roads

What are axial lines? Axial lines are the longest visible lines in urban street networks (Jiang, Liu, 2010). They have been widely applied to urban morphological study and are used to simulate the continuous movement and are one of the first ways of representing urban structure (Jiang, Claramunt, 2002). For large cities, besides the conventional definition of axial lines based on visibility Liu and Jiang propose a definition of axial lines as individual straight lines intersected along self-organised natural roads (Jiang, Liu. 2010) (Figure 12). In general, axial lines can provide a way to uncover urban patterns. They have a meaningful effect on city residents and these patterns can help people gain a better understanding of the urban structure. In addition, the hierarchical patterns of streets can be used to model pedestrian and traffic flows, predict crime occurrences, make spatial plans etcetera. The hierarchical representation of streets can also contribute to people's wayfinding performance (Lynch, 1960).

In the following example, three different possibilities of generating axial line are presented (Figure 13):

- Both ending streets are convex,
- One ending street is convex and one is concave or
- Both ending streets are concave.

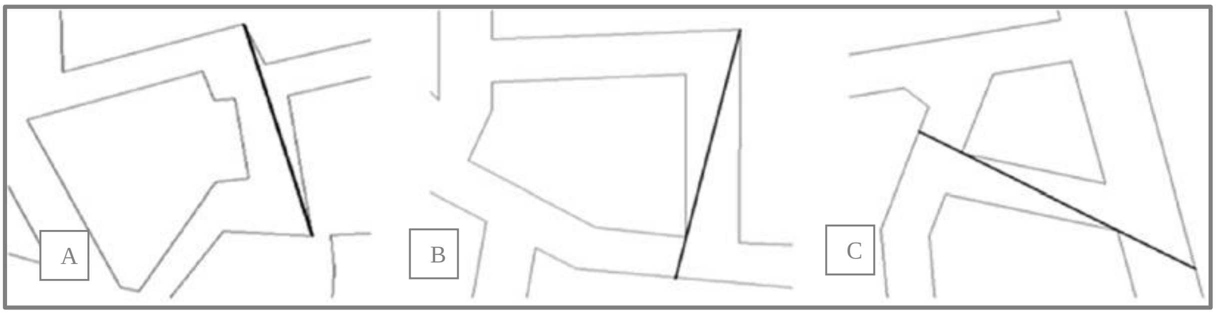


Figure 13 – Three different possibilities when generating axial lines

It is tremendously important how one is generating axial lines. The reduction to a single minimal axial-line map is based on the following rule: When two lines have the same connection, the longest line is chosen and the other one is removed. This condition needs to be applied to obtain the preservation of topological rings and surveillance of the entire system. To complete the topological rings, the algorithm performs a triangulation around a polygon edge so that it is visible from the three axial lines that are around the geometry (Figure 14).

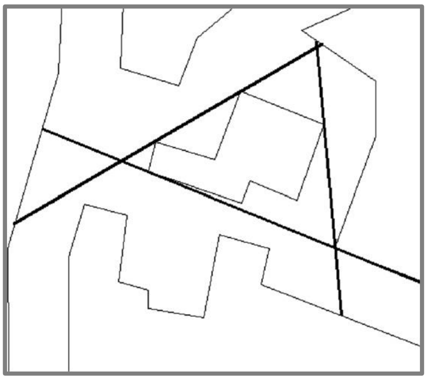


Figure 14 – Triangular presentation of the circular geometry

The measurement of spatial integration on the basis of individual axial lines is normally accomplished by first order measures that include (Hillier, Hanson, 1984):

- Connectivity (the number of directly linked axial lines),
- Global Integration[7] (the closeness of an axial line to all other axial lines in the system by computing the shortest topological distance- number of turns (or step depth) of the respective line from every axial line in the entire urban area),
- Local Integration (integration only up to a defined radius of topological distance, (which is usually 3 and it measures integration up to 2 axial steps away in every direction from each line under consideration), and
- Intelligibility[8] (second order measure that describes the correlation coefficient between the Local and Global Integration values for the set of axial lines comprising a given axial map).

Considering the fact that extended long axial lines are essential for maintaining a city's high level of spatial integration, it becomes clear that "obstacles" located in analysed area, arranged in contiguous, linear form (non-compact) or ones that interrupt the extension of axial lines, actually minimize urban spatial integration. Hillier (Hillier, 2002) suggests that it is useful to differentiate centrality and compactness in terms of their potential effects on aspects of city form. He argues that the centrality principle considers an area's spatial dimensions, specifically, the location of lines, their length, and relative location, whereas compactness addresses the area's physical dimensions, such as the size and shape of aggregate built objects (i.e., blocks, open spaces).

However, others claim that in addition to partitions, consideration should also be given to the overall urban shape or the geometric shape of the entire street network, which may also affect the integration values (Shpuza, 2007). Similar to the case of Space Syntax research (Hillier, 1996; Shpuza, 2007), the geometric shape of cities in a geographic context is often characterised through a compactness indicator (Coffey, 1981; MacEachren 1985) that describes the overall form of a given city based on how far that form deviates from a specified standard shape, most commonly a circle (the most compact shape).

With respect to compactness, it is also needed to note the difference between the metric and visible properties of space. Theoretically, the more linear the shape of a space, the greater

[7] This measure allows well-integrated, accessible streets reliably to be distinguished from segregated, more inaccessible streets, and the mean or average global integration value provides a rough and ready guide to the overall accessibility of the entire settlement (Hillier, Hanson, 1984).

[8] High Intelligibility indicates a strong correspondence between the distributions of Local and Global Integration values. This means that the degree of connection between individual spaces - the urban space that can be seen and experienced synchronically - provides a good guide to the integration of that space into the system as a whole at the global level (the urban space that cannot be directly seen and experienced). An intelligible system is one in which well-connected spaces also tend to be well-integrated spaces (Hillier, 1996).

is the metric trip length and the lower is the observed integration. The opposite logic holds with respect to movement efficiency. Visual integration increases as lines lengthen, with many cells covered by a single line. Hillier (Hillier, 1996) calls this differential effect of shape on movement and visual integration the "paradox of visibility". However, empirical findings have shown that the spatial integration in real-world cities does not necessarily increase with shape expansion (the length of axial lines is also affected by irregularities and distortions that characterize some urban grids) (Shpuza, 2007).

2.1.10 Geographic information systems – GIS

To represent a slice of the earth's surface, GIS provides the spatial illustration and modelling of the required data (Frank, 1992). With analytical capability and database management features, GIS can conduct automated mapping application and it is able to capture the topological relationships of objects (Thill, 2000). Additionally, GIS can encourage and enable the difficult representation of urban structure spatial characteristics (Oliveira, Pinho, 2009).

Geographic Information Systems developed two types of generalization:

- Cartographical generalization – applied for analysing the potential of graph-based principles for the generalization of linear objects and for deriving information at the topological level (Mackaness, Beard, 1993).
- Model-based generalization - applied for the generalization of linear objects such as streets (Jiang, Claramunt, 2002).

For the purpose of this research, GIS is used for generating axial maps from street maps all around the world. Spatial data have become widely available for topological analysis (Volunteered Geographic Information - VGI), an especially massive amount of street data (Goodchild, 2007). VGI is a shared extension of GIS (Elwood, 2008). Many projects are based on the user-generated mapping. A kind of user-generated content, OpenStreetMap (OSM) is an example of user-generated content (Graham, 2010) and this particular extension provides the voluntarily distributed geographic data. The free and editable map data can be taken from OpenStreetMap online web platform and added as a plugin to GIS software. It aims to create a set of free to use and editable map data (Haklay, Weber, 2008).

2.1.11 Space syntax

Space syntax is developed by Hillier and Hanson at the Unit for Architectural Studies, University College London (Hanson 1989; Hillier, 1987, Hillier, Hanson 1984) and represents a technique used for morphological analyses architectural and urban plans. Space syntax is one of the few theories which allows understanding how culture and society are embedded in the specific relational patterns constituting architecture and urban design. Space syntax theory produces culturally-grounded classifications of city street patterns according to their spatial integration characteristics which are why it is used as a method in this study.

The purpose of the SS is to describe different aspects of relationships between the morphological structure of human-made environments and social structures and events. This methodology contributes greatly to the understanding of the physical structure of the city sample from this study. SS theory provides computational support and can describe the configuration of urban structures. Those structural analysis help urban planners to obtain a better understanding of urban form evolution and correspondingly provide a useful supporting tool for the city design (Jiang, Claramunt, 2002).

The central concept of SS is integration. The technique allows one to express integration in numerical values. As is the case with many other measures of spatial structure, these values are dependent upon the urban area. The integration of space is a function of the mean number of lines and changes of direction that need to be taken to go from that space to all other spaces in the settlement system. Integration is therefore about syntactic not metric accessibility, and the word "depth" (the least number of syntactic steps in a graph that are needed to reach one from the other (Björn Klarqvist, 1993)) rather than "distance" is used to describe how far space lies. Every line in a settlement layout has a certain depth from every other line. The integration value of a line is a mathematical way of expressing the depth of that line from all other lines in the system (Hillier, 1996). It is assumed that the distribution of integration across an urban area correlates with the movement pattern of an area. Urban areas can be distinguished by and compared in terms of different levels of integration (Hillier, 1996). Integration is used as a measure of quality for urban areas. By calculating integrated and segregated parts of the settlement, it is also possible to know whether a new design proposal fits into the existing structure of an area.

Urban morphology rather examines the individual components of urban form, such as streets, squares, and blocks, often including the historic process of its development, while SS stresses the relative or systemic dimension of such components and how they aggregate into neighbourhoods and cities, that is, urban morphology expands urban form in time, while space syntax expands it in space, if you like. Urban morphology also deals with larger aggregates but generally sticking to the methodology of classifying specimens into types due to their form, hence creating typologies of neighbourhoods and even cities as a whole, such as organic, grid or circular cities. Or as Peponis and his colleagues described it, urban morphology is good at classifying and even quantifying the differences between areas but is not able to quantify the differences in the same area (Peponis et al, 2008). Syntactic measures, on the other hand, typically also capture these differences.

Furthermore, urban morphology defines urban elements from a conceived rather than perceived point of view. For instance, one characteristically concerns oneself with such elements as the urban block, which typically is easy to identify on a map but actually is very difficult to perceive in urban space. The morphological descriptions developed within space syntax on the other hand typically have their *rationale* from the point of view of human perception and cognition. We here find a vital characteristic to space syntax, namely its strong link to cognition science, but especially the ecological approach to human perception developed by James Gibson (Gibson, 1979), where SS means of geometric representation, such as the axial map, prove highly interesting extensions of this theory (Marcus, 2015).

2.1.12 DepthMap

The concept of *pervasive centrality* (Hillier, 2009) came from the power of DepthMap to detect delicate local structures which hardly seem to even exist in the certain spatial structure. DepthMap generates data either automatically from axial lines, maps, or derives from open source data allowing whole regions and even whole countries to me modelled and computed. DepthMap uses three types of distance between each segment and each of its neighbours:

- Metric (the distance in metres between the centre of a segment and the centre of a neighbouring segment i.e. systems of shortest path maps for integration and choice),
- Topological (1 or 0 value if there is a change of direction or not between a segment and a neighbouring segment i.e. systems of fewest turns maps),

- Geometric (the degree of the angular change of direction between a segment and a neighbour, i.e. systems of least angle change maps).

Furthering, the software calculates two kinds of relationship measures:
- Choice,
- Integration.

The least angle change definition of distance is the default setting in DepthMap for angular analysis (Hillier, Iida 2005). So the standard measures used in DepthMap based studies are least angle integration (for angular analysis) and choice measures (Hillier, 2009).

In this study, DepthMap is used to calculate integration of axial lines, previously generated from street pattern plans. To remind, integration measures the distance from each spatial element to all others in a system (up to a certain radius and given distance) and so corresponds to mathematical closeness. Other DepthMap function, like choice, measures the quantity of movement (how many times) that passes through each spatial element on shortest or simplest trips between all pairs of spatial elements in a system (again up to a certain radius and given distance), and as such corresponds to mathematical "betweenness". Maybe easier to understand, integration represents the *to-movement* potential of a space, and choice the *through-movement* potential, pointing out also that the two measures correspond to the two basic elements in any trip: selecting a destination from an origin (integration), and choosing a route, and so the spaces to pass through between origin and destination (choice) (Hillier, Hanson, 1984).

Since the selection of a destination and the selection of a route are the two prime components of any trip, we have then a well-grounded set of techniques for identifying movement related structural patterns in cities, and looking for functional correlates (Hillier, 2009). Each of the six measures (two measures with three definitions of distance) can be mixed up to 18 measures, which can, of course, be applied at any radius, so yielding a potentially very large set of possible measures.

2.2 Existing scientific knowledge about the topic

Previous studies based on Space syntax measures, conducted in different spatial philosophies (Hillier, Hanson, 1984; Hillier, 2002) show that the spatial integration values have the potential to classify local street patterns as well as to give a rigorous description of the overall configuration of settlement form. For example, these measures were found to be sufficiently powerful to distinguish the Turkish traditional street network from others (Asami et al, 2001) and to characterise the types of different street patterns found in a sample of Dutch cities (Read, 1999).

Space syntax theory (Hillier, 1996; Hillier, Hanson, 1984) has provided a way to measure spatial configuration for a better understanding of urban space (Long, Baran, Moore, 2007). It is shown that description developed within SS works better than the conventional description for accessibility research such as predicting pedestrian movement (Ståhle, Marcus, Karlström, 2005), and it is proposed to provide a better way for this morphological study. Jiang, Claramunt and Klarqvist (Jiang, et al, 2000) believed that SS integrated into GIS can extend the modelling capability of GIS and provide users a way of managing and planning urban systems. Peponis (Peponis et al, 2008) pointed out that one procedure involved in SS can deal with topological properties such as the patterns of connection, which are based on the intersection, and people can understand them from the direct perception of the represented graphs. These previous researchers have provided the foundation to carry out an analysis of urban street networks with space syntax methods.

There is an example of the paper that examines the spatial configuration of twenty-four cities, major city types in Israel, classified according to the conditions under which they were originally established. An initial analysis indicated that cities belonging to the same type have broadly similar street patterns, but then again at the same time they can be distinguished according to the continuity and shape of networks. The analysis of spatial integration is conducted using the methods of Space syntax. In this research, it is observed to what extent these different city types display fundamental share parameters and patterns of spatial integration and how might the process of growth and change affect spatial integration. The syntactic (spatial integration) values obtained in this research revealed that Israeli cities are comparable to U.K. and European ones (Omer, Zafrir-Reuven, 2010).

Another study analyses the Turkish city Antakya (Antioch), which has undergone various physical and functional transformations over the years of its development. The study investigates city's morphological transformation in terms of spatial integration including the comparison of traditional and modern parts of the city (a 2300 years old city between natural boundaries and 100 years' new city characterised by radial development). The relations of the city with different structures of the urban pattern were exemplified partly by using the SS morphological approach method. In conclusion, it is observed that there is a very strong relationship between the integration values and morphology for the selected sample areas (Topcu, Kubat, 2012).

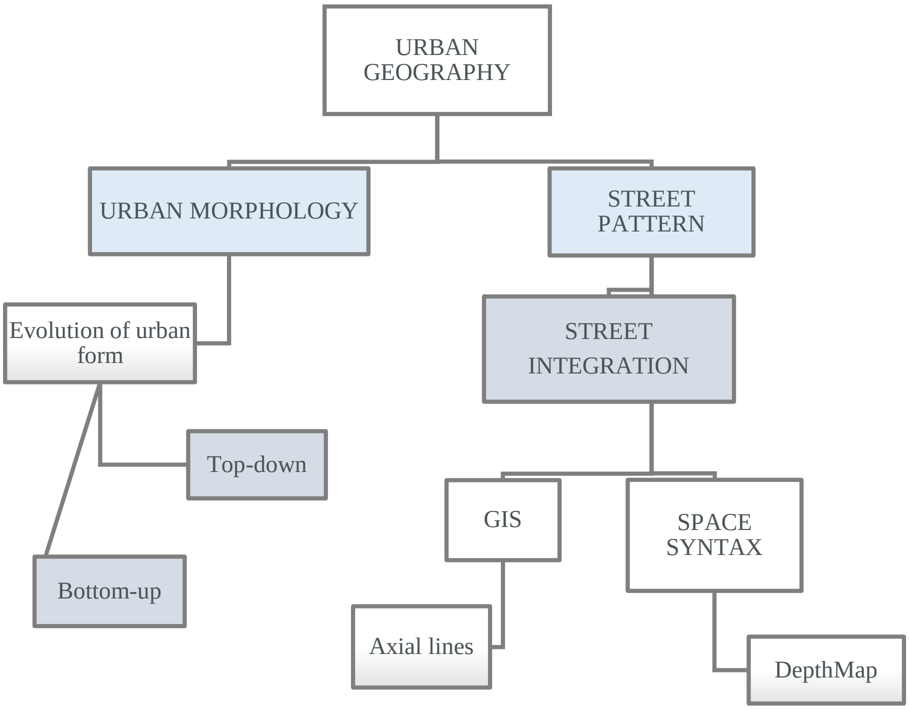
The mathematical techniques of SS, and knowledge of normalisation, especially of choice, leads to a new and deep understanding of the spatial morphology of cities. Hillier and Iida's research (Hillier, Iida, 2005) and other projects since then, used normalisation of choice and integration for the segment angular case and proved the best predictor of both vehicular and pedestrian movement (Hillier, 2009). Different DepthMap analysis show that human movement follows least angle change paths and not shortest paths (Hillier, Iida 2005). This could be explained by Kevin Lynch theory about "imageability" from 1960, that people use an angular geometric model of their environment to calculate distances or remember the path (Lynch, 1960).

2.3 The Conceptual Framework

The following chart illustrates the relations between the main concepts, gathered and analysed views and issues of the study elaborated in State of art literature review section. Chosen conceptual framework type is a "tree chart" (Rogers, 2003) and represents a guiding model for the following empirical study.

For better understanding of conceptual framework, brief specifics about the type of the research that is conducted are elaborated bellow:

- The aim of this study is to *explain* the influence BU/TD city morphology (independent variable) has on street integration level (dependent variable);
- This research is *quantitative* and also *deductive*,



Graph 2- A Conceptual framework

3. Research Design and Methods

3.1 Revised Research Questions

Final research question formulated in light of reviewed literature about the urban development features of different city morphologies and their relationship in respect to street integration remains the same:

"Which urban morphology influences street integration more: top-down or bottom-up?"

Revised sub-questions of this research remain the same too:

- Which cities are considered to have top-down, and which ones are considered to have bottom-up urban morphology?
- What is street integration and how it is analysed?

3.2 Operationalisation

This study analyses two main concepts which at the same time represent IV and DV:

- Urban morphology, which is examined from two different perspectives:
    1. Urban morphology of top-down cities,
    2. Urban morphology of bottom-up cities.
- Street integration.

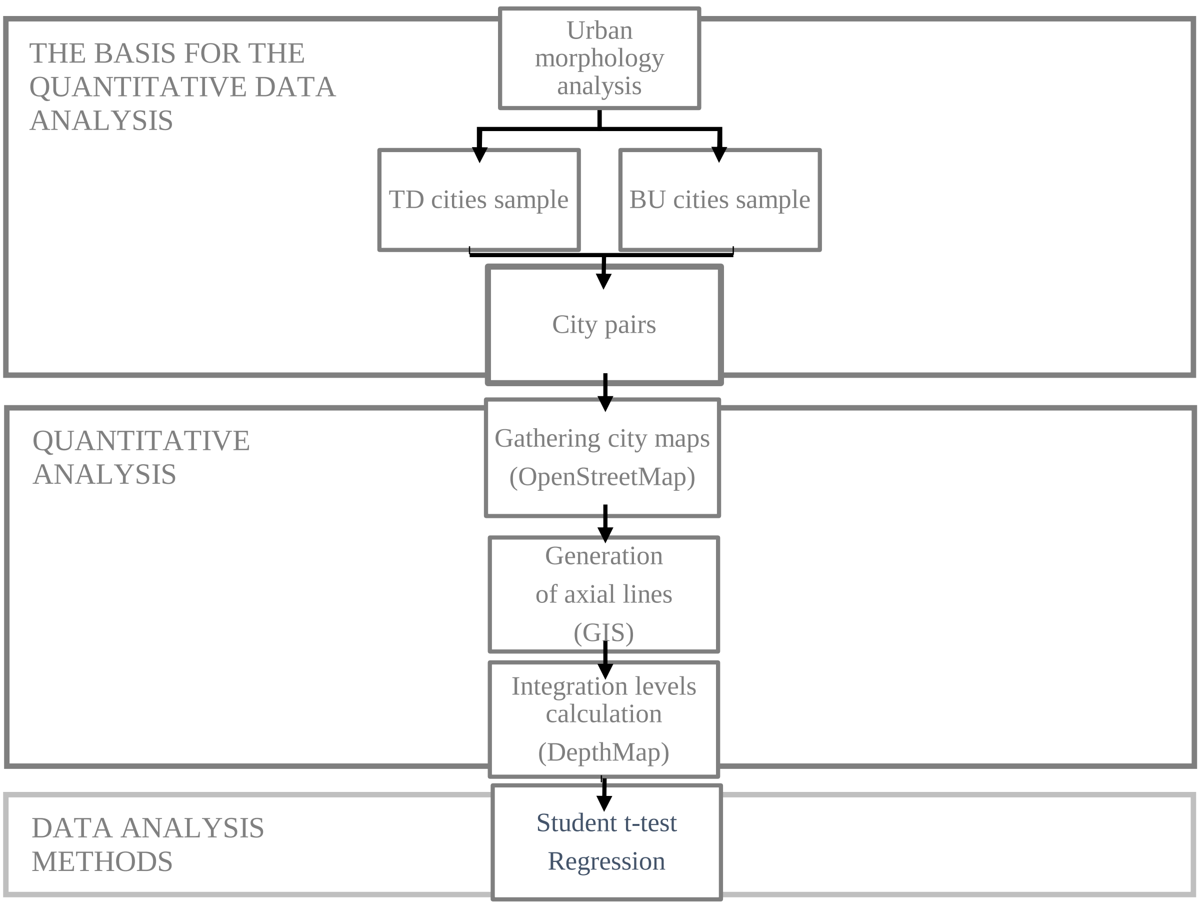
Following table is the overview of the research concepts, concepts definitions, indicators (the realistic measurements) and values (scores) used for furthering analysis:

CONCEPT	DEFINITION	INDICATOR	VALUE
Top-down urban morphology **(TD)**	"Planned or so-called created city is the one set down in one moment, and which pattern is determined once and for all by some overseeing authority." (Kostof, 1991)	-Square, grid, circle, radial, nature-like - Proof of existing plan	0 - TD
Bottom-up urban morphology **(BU)**	"Unplanned evolution, or instinctive growth, the spontaneous city is presumed to develop without the benefit of designers, subject to no master plan but the passage of time, the lay of the land, and the daily life of the citizens." (Kostof, 1991)	-Irregular form, rocked streets, randomly defined open spaces - Slums - No proof of existing plan	1- BU
Street integration **(HH)**	Integration is used as a measure which describes street accessibility or how easy it is to get to one street from all other streets (Hillier, 2009). Furthermore, integration explains how close each street is to all others of a different types of distance and at different scale, also known as closeness or "to-movement" (Hillier, 1996).	Integration formula from DepthMap software (Integration HH)	From 0.00 onwards < value, < HH > value, > HH

Table 1 – Urban morphology and street integration concepts overview

3.3 Research strategy

Following graph (Graph 3) illustrates the methods and techniques of data collection/analysis and a step-by-step process of the research strategy



Graph 3 - Flow chart of the data collection/analysis

Approaching the research question is challenging in its very begging already by combining various theories and classifying cities into two morphology groups (top-down and bottom-up). Since it is already explained in the previous chapter, it is not rare the case that city is not per se one or another type of urban morphology, but it is often a mixture or it contains both planned and unplanned segments. That is why this study takes into sample consideration only consistent cases, that is, either the whole BU/TD cities or BU/TD city parts, not the mixed or unclear cases.

3.4 Data Collection Methods and Techniques

This study of various urban forms and street integration uses secondary data gathered through a combination of several desk research sources and it is based quantitative analysis.

A basis for quantitative research is grounded on a study about cities history, study about their plans and maps, shape, size, and most importantly study about their origin and the way their street pattern emerged, planned or unplanned. Cities from different countries are studied and they have several different urban morphology types, for instance, the Greek city states, cities built with fortified roles or the harbour cities, a Roman city, cities developed in Renaissance time as fortifications, etc. These cities have their obvious urban structures and history. Several cities in European countries were planned for defence reasons and they had moats and walls. Athens has loosely spread walls and is planned as a whole. Cirencester has Roman gridiron, Paris has a radial pattern over medieval crooked layout and Amsterdam has its special radial canal planning. Not all the top-down or all bottom-up cities have the same underlying pattern and that is why a deep understanding of urban form evolution conducted in Literature review section is needed. Correspondingly, it is studied to which type of urban morphology their street pattern belongs to (grid, radial, cul-de-sac, Roman, Israeli, circular etc.). This part of the study respectively includes the revision of the books and articles related to the city planning history. Besides, different web sources are used, such as municipally websites, map databases (www.discusmedia.com, www.oldmapsonline.org) and history, architecture, and archaeology related websites. Review of literature related to the research topic is done in order to give an in-depth understanding of relevant theories and concepts of urban morphology and history of cities all around the world. Identifying bottom-up cities is a greater challenge since the majority of the cities today are planned or partially planned. That is why many cities from the bottom-up list are old European city centres, old medieval walled towns, and ancient Islamic settlements.

Alvin Toffler's (Toffler, 1981) and Tertius Chandler's (Chandler, 1987) study indicates that ten thousand years ago, the first towns developed when men slowly shifted from a nomad way of life to a society and more sophisticated trade based on a settled agriculture. Revolution of towns was characterised more by natural/organic growth even though there are many examples of planned developments with straight streets such as ancient Babylon city Ur, Harrapan city Mohenjo-Daro or Egyptian city Tel-elAmarna (Morris, 1979). Chandler, in his book "*Four thousand years of urban growth*" offered a map which served greatly useful as a starting point for sample collection process of this particular research. This is why the map of bottom up cities chosen for this study (Figure 20) looks similar to the map presented on Figure 25 due to the fact that the most unplanned cities remained today, not taking into consideration informal slum settlements, are at the same time the oldest ones. This similarity confirms that the bottom-up cities present in this thesis sample are correctly identified in accordance to Chandler's research of ancient urban growth.

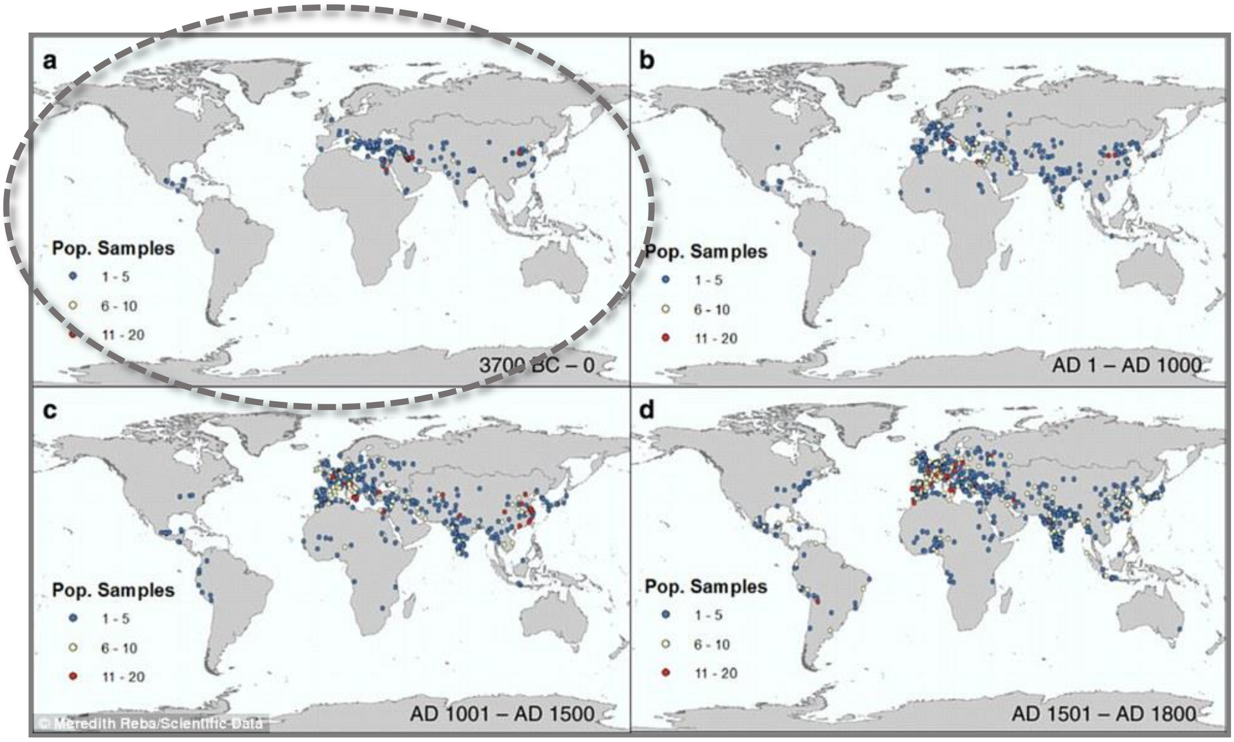


Figure 15 – Alvin Toffler's map of estimated city population levels
SOURCE http://www.dailymail.co.uk/sciencetech/article-3644485/How-cities-took-world-Maps-reveal-rapid-spread-urban-areas-6-000-years.html

On the other hand, for planned cities a single source is used, New town Institute, Rotterdam, Netherlands (www.newtowninstitute.org). This free on-line source is highly useful and up-to-date, containing a list and information about planned cities all around the world. The basic data analysis for quantitative research provided not only complete list of bottom-up and top-down cities needed for this research but also information required to link these two groups of cities by size and shape and put them in comparable pairs, explained previously. City pairing is accomplished by comparing cities or city parts by land area and shape, for which supporting tool - online platform MapFrappe is used (www.mapfrappe.com). This web platform allows the comparison of outlines in scale 1:1. City shape is defined as the polygon that includes the entire street network.

Quantitative analysis of this research consists of two different methods. Firstly, conduction of axial lines in QGIS (Essen 2.12.2 version) software and secondly, analysis of these axial lines in DepthMap (version 8.15, UCL) software using Space syntax theory. QGIS provides a platform for doing this research using the OpenStreetMap extension, allowing easier and up-to-date creation of axial maps. The boundary of each city is determined using on-line Google Maps database. The aim of SS, in this particular research, is to describe integration levels within the morphological structure of human-made environments. The technique allows one to express integration in numerical values. The integration of space is a function of the mean number of lines and changes of direction that need to be taken to go from that space to all other spaces in the settlement system. Integration is therefore about syntactic not metric accessibility, and the word "depth" rather than "distance" is used to describe how far space lies. It is assumed that the distribution of integration across an urban area correlates with the movement pattern of an area (Hillier, 1996). When using the Space syntax methodology, the description and identification of a city's spatial form are often derived from a topological analysis of an axial map which is as already mentioned, defined as the set of longest straight lines of direct visibility and movement that pass through all of a city's streets and open spaces, thereby connecting them into a continuous network. Technically, a topological analysis of an axial map treats the individual axial lines as nodes and all axial line intersections as edges of a connectivity graph. The resulting graph forms the basis for measuring spatial integration. SS parameter (Integration HH) is calculated automatically.

3.5 Processing the street data

The conduction of axial lines and analysis of the urban street networks is based on the roadmaps. Axial lines are projected with Pseudo Mercator coordinate system in QGIS. Regardless of the feature, these roads have (vehicle or pedestrian, one-way or two-ways, local or highway, motorway, primary, secondary etc.), they have all been taken into account for the analysis because the integration of the whole city/city part street network is questioned. An example of how an axial line map looks like, conducted in QGIS software, using OpenStreetMap extension as a data background layer is seen in Figure 16. Some general exceptions and rules do exist, even though each software user has her/his own “style” in axial line conduction process. The process is recursive which is why particular roads or road parts which appear parallel to each other (main road, bike road and pedestrian road one to each other) are deleted for the computational analysis. This duplication of data increases the integration of streets unnecessarily. Other logic is applied to roundabouts and traffic loops. The axial line (road) is interrupted with the roundabout and the obstacle cannot be ignored and presented as a single straight line even though in the reality it serves to regulate and improves the traffic flow (Figure 17). Parks, open spaces, squares and parking places are perceived as integration enhancers because pedestrian flow on these locations is free and has multiple choices of directions. These positions are presented with an additional axial line linkage/s (Figure 18).

Figure 16 – An example of QGIS axial map with OpenStreetMap layer in the background

After the conduction of all axial lines in GIS within one city or part of the city is over, the map has to be prepared for next software. The axial map file in GIS is converted from .shp, meaning shape-type file into .dxf file, meaning vector-type file in order to be imported into DepthMap for proceeding analysis of integration calculation.

Figure 17 – Illustration of solving the roundabout situation

Figure 18 – Illustration of solving the open space situation

Now, when files are ready, and when one by one is imported into DepthMap, the analysis is simple and quick. Axial map analysis is run in less than three steps and Integration HH calculation is done automatically. The following illustration shows axial map before and axial map after axial analysis (Figure 19). Most integrated lines are coloured in red and represent streets with highest HH values, while on the other hand, most segregated streets are those axial lines coloured in blue.

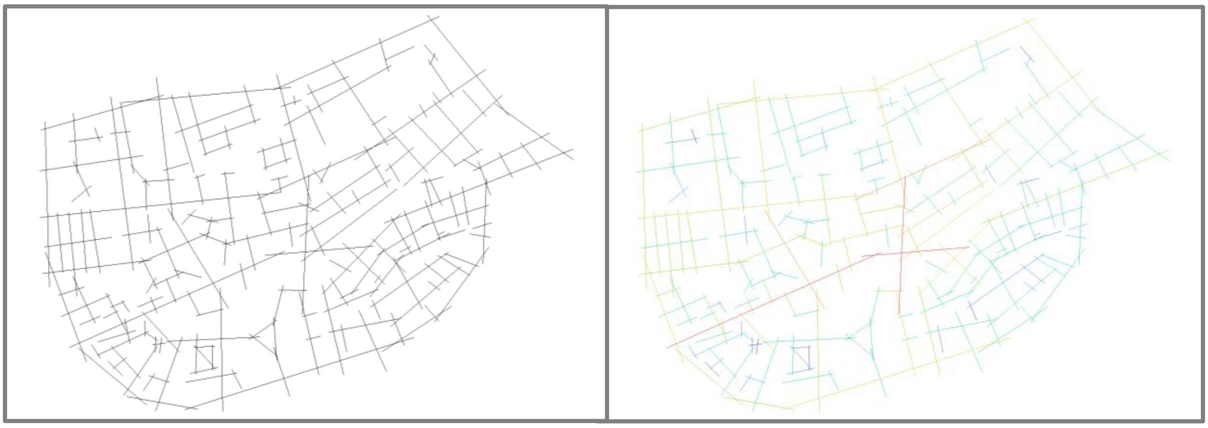


Figure 19 – Illustration of axial map and analysed axial map in DepthMap, Example of Kiryat Gat, Israel

3.6 Data Analysis Methods

Following the data analysis and collection procedure, the results obtained are analysed and interpreted to shed light on the most important questions of this research, that is, how these results can contribute to the understanding of the differences between two urban morphology types and how this two types of morphology influence street integration level.

To answer this thesis questions, two groups of cities are compared in 34 pairs (One BU and one TD). Furthermore, the data is analysed using a Student t-test, a Simple linear regression, and a Multiple linear regression analysis.

In order to increase the accuracy of the analysis, and to focus on the aim of this study, cities were paired based on similar land area size and city shape, with the clear distinction that one would belong to TD and the other to BU. By isolating the impact of urban morphology on the integration level, and all things being equal (ceteris paribus), potential doubts regarding the validity are accounted for.

Outcome indicates which urban morphology contributes more to the level of streets integration, creates insight which type/s is/are more/less integrated than others and points out the impact and importance/irrelevance of controlled variables like land area size, date of origin, number of axial lines (number of streets), etc. in explaining integration HH level.

3.7 Reliability and validity

Reliability refers to the repeatability of the findings and if the study were to be done a second time, it would yield the same result if the researcher would use the same sample of 68 cities. The cities should be paired in the same way as in this particular research and use the same techniques and methodology regarding data collection and data analysis.

Because of the subjectivity of the way axial lines are conducted (chapter 1.6), a certain degree of change in integration level values might appear. If more than one person is to conduct these same axial lines, as conducted in this study, all observers might notice a slight difference in their results and the study would loose on its reliability.

In order to claim that the data is reliable, the following guidelines of how axial lines should be conducted are provided:

- First the longest axial lines in the model should be conducted;
- Curvy roads should be presented with as less lines as possible;
- Roundabouts should be presented with three lines;
- Pedestrian roads and parking lots should be also presented with axial lines;
- Squares and parks should be presented with one or more additional connecting lines in order to emphasise the level of integration.

Another issue regarding reliability might appear while the researcher is identifying the city's origin. As mentioned before, it is a challenge to delimit a city or a part of the city as the bottom-up one.

Internal validity is reflected in the fact that the instruments or procedures used in the study are measuring what they are supposed to measure. The methodology used to measure integration level is Space syntax by conducting axial lines from streets maps and running integration calculation in DepthMap tool. Integration is used as a measure which describes street accessibility or how easy it is to get to one street from all other streets.

External validity is reflected in the fact that the results can be generalised beyond the immediate study. In order to have external validity, 68 cities are analysed (34 from each city group). The validity of the study shows that for the chosen city groups (BU and TD) the results can be generalised, but not for the subgroups (medieval, grid, circle, cul-de-sac, Roman etc.), location nor size. The study would definitely benefit from even larger sample in which mentioned subgroups of top-down and bottom-up groups would have a larger number of representatives.

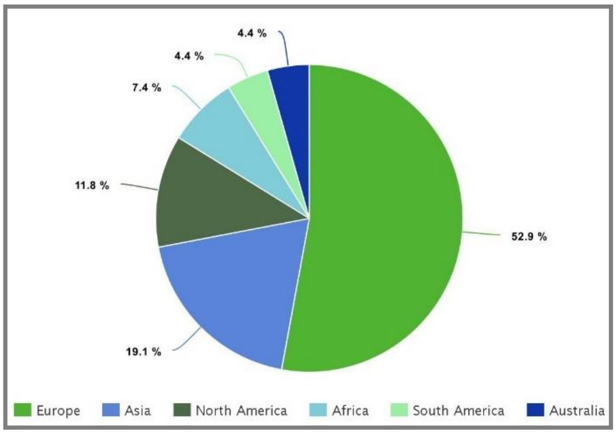
If data are valid, they must be reliable. That is why it is very important to draw attention to the process of identifying the city's origin, the way axial lines are conducted and the way cities are paired.

4. Research Findings

4.1 General sample description

Sample covers 68 cities worldwide from all continents excluding Antarctica:

- Europe: 36 cities (25 BU, 11 TD)
- Asia: 13 cities (6 BU, 7 TD)
- N. America: 8 cities (8 TD)
- Africa: 5 cities (3 BU, 2 TD)
- S. America: 3 cities (3 TD)
- Australia: 3 cities (3 TD)



Graph 4 – Selected cities, per continent

Cities examined in this research showcase 38 countries in total. The countries which are represented by a larger number of cities are US (7 cities), UK (4 cities), The Netherlands (3 cities), Australia (3 cities) and Russia (2 cities) with strong top-down cases. These countries, besides China, have the largest numbers of new towns in the world. On the other hand, Greece (5 cities), Israel (4 cities), Spain (4 cities), Romania (3 cities), Italy (3 cities) and Croatia (2 cities) are representatives of the bottom-up city group.

The sample includes 38 whole cities (city boundaries taken from www.maps.google.com) among which 28 are BU and 10 TD. Other 30 examples are city parts (city centres, neighbourhoods, blocks) among which 6 are BU and 24 TD. Old medieval walled cities positioned inside planned or TD/BU mixed cities are perceived as whole cities, while old historical city centres without clear boundaries (old city walls for example) are observed as city parts.

Beside TD and BU division, cities are classified by the typology their street pattern belongs to from the planning style point of view. The bottom-up sample contains 19 medieval cities, 5 Greek, 4 Roman, 3 Muslim, 2 Israeli cities and one Asian. Top-down sample includes 9 grid pattern cities, 5 circle towns, 5 organic-like cities, 5 cul-de-sac cities, 3 Israeli new towns, 3 Asian new towns and 2 Roman and 2 Greek cities with identified creator and planning history. Information about street pattern typology of each city, beside land area size and date of origin, is obtained due to the initial basis data analysis for quantitative research process in an earlier stage of the study and as such contributed to further data analysis in this chapter.

As far as areal size of the sample is concerned, chosen cities or parts of the cities are between 0.31 km^2 and 21.68 km^2 large. Most bottom-up medieval cities (old, fortified towns inside of bigger city centres) are “small” in size. That is why the sample has a great number of cities between just 1 and 6 km^2 in land area size (42 cities). Smallest city in the sample is BU medieval, Mediterranean city Riomaggiore, Italy with only 0.31 km^2 in land area size. The largest city in the sample is BU Israeli city Jericho, Palestine with 21.67 km^2 in land area size.

AREAL SIZE of the CITIES				
0 -1 km^2	1 - 2 km^2	2 -6 km^2	6 - 10 km^2	10 -21 km^2
8	18	24	10	8

Table 2 –Number of cities from the sample by areal size

Regarding the date of origin, the oldest city from the sample is Jericho whose street pattern originates from 9000-3000 BC while the youngest one is Asian new town Penang, Malaysia finished in 2005.

4.2 BU city sample description and typology

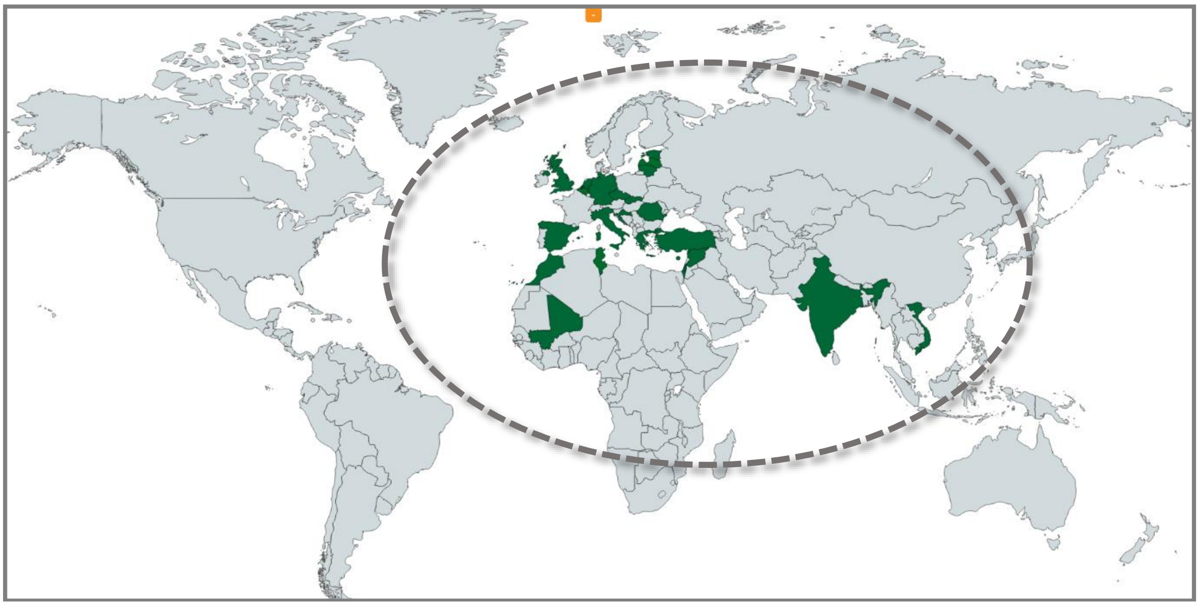


Figure 20 – A map of studied bottom-up cities locations, by countries

First cities emerged in Middle East, Europe and Asia, thus the starting point of locating BU cities started exactly investigating these territories. After initial data analysis of city originated on these locations, a list of bottom-up cities emerged (Table 3). Oldest cities in the world are included in the sample, for instance, Jericho, Old Damascus, Mytilene, and Göreme, while the youngest ones are Cadiz (the 18th century) and Old Delhi (1639).

Identified street pattern typology of the bottom-up sample is based on Benevolo, Lynch and Kostof street pattern/city classification from literature analysis. Examined cities in this study have medieval, Greek, Roman, Muslim and Israeli patterns.

The most common BU street pattern type, medieval, in the history of urban planning represent the end of Ancient World (fall of Roman Empire) and the period of tribal migration in Europe (4th century). It last until re-emergence of activity in the Early Middle Ages (13th century). These cities were not run well as Roman ones did because barbarians lacked the experience of urban life, expect in Spain (Gutjahr, 1999). The Medieval Age was the greatest town founding period in history. Existing villages and towns were extended spontaneously and also newly colonised towns flourished widely, especially in Europe. This is the period of castles and fortresses as dominant symbols for the people around which streets start to fill with merchants, tradesman, and craftsman shops. Density is high, the movement is vibrant and mysterious while the streets are crooked, winding, steep and narrow, according to the physical demands of the site. The whole city is characterised by closed and compact form. They were designed and organised for limited population (maximum 25,000-35,000 people) and built on a pedestrian scale (0.04-0.5 km^2 in LA size) (Gutjahr, 1999). Largest number of medieval cities emerged in Germany, France, Italy and other European countries, most of old Roman street layouts. These cities are oriented in relation to their topography and the town plans are delineated by the wall for the protection purposes. Unplanned medieval towns grew from the huddle of peasants in need of protection around a monastery or a local wealthy leader's property. Other reason in BU development takes place at junctions of trade routes, for the exchange of goods (Gutjahr, 1999).

In this study street integration levels of 19 medieval BU cities are analysed:

- Riomaggiore, Italy
- Rhodes OT, Greece
- Riga OT, Latvia
- Bucharest OT, Romania
- Bratislava OT, Slovakia
- Sibiu OT, Romania

- Nicosia OT, Cyprus
- Valencia OT, Spain
- Tallinn OT, Estonia
- Prague OT, Czech Rep.
- Siena, Italy
- Nuremberg, Germany
- York, UK
- Old Delhi, India
- Vilnius OT, Lithuania
- Sighisoara, Romania
- Ghent, Belgium
- Bruges, Belgium
- Agrinio, Greece

Figure 21 – Examples of medieval BU old towns; Riga, Latvia and Nicosia, Cyprus

Other BU street pattern types used in this study are Greek, Roman, Muslim and Israeli. Greek and Roman city type have a dominant fraction of small blocks with shapes broadly distributed. Greek city type spread away towards places including even Asia Minor and Northern Africa. Greek city was either like Athens, irregular in street plan, organically developed, or colonial new city with a grid street plan but both types had 3 parts: acropolis (religious monument), an agora (marketplace and the civic centre) and the town. Early BU Greek town has an irregular street pattern made up of only two-stories, small residential houses.

In this study street integration levels of 5 Greek BU cities are analysed:

- Cadiz, Spain
- Old Damascus, Syria
- Mytilene, Greece
- Kavala, Greece
- Dubrovnik, Croatia

Figure 22 - Examples of Greek BU old towns; Old Damascus and Mytilene

On the other hand, Roman city type compared with the Greek one is more rectangular, with streets crossing at right angles with blocks of houses. Roman street pattern, both planned and unplanned, is characterised with a four-fold principle for practical reasons (4-menaing not too few and not too many). The main streets are called cardo and decumanus and each block consists of smaller grid blocks. The chosen terrain is often flat. BU Roman cities are based on zones and districts that have uniform character, such is Rome. Streets are randomly disbursed with open spaces that serve the free movement of people and goods.

In this study street integration levels of 4 Roman BU cities are analysed:

- Avila, Spain
- Zadar, Croatia
- Göreme, Turkey
- Toledo, Spain

Figure 23 – Examples of Roman BU old towns; Toledo and Avila

Muslim bottom-up cities are ones built by Muslims or during the epochs dominated by Islamic civilisation whose architectural style and relationships are inspired by full adherence to the norms and values of Islam. Most Muslim cities originate in the river valleys of the Nile, Tigris and the Euphrates like Cairo. City plan responds to local conditions, and it is surrounded by a wall because of military attack and sand-laden desert winds. Main spinal roads are connecting main city gates and central mosque. Main streets accommodate schools and shops and markets while people live in narrow streets away. This public/private division is still visible in old cities of North Africa. Streets are plain and simple, with very few openings and public squares never achieved the prominence they have in Western cities.

In this study street integration levels of 3 Muslim BU cities are analysed:

- Djenne, Mali
- La Medina, Tunis
- Marrakesh, Morocco

Figure 24 - Example of Muslim BU old town La Median, Tunisia, Tunis

Lastly, Israeli bottom-up cities are characterised by a street pattern that is nearly orthogonal and oriented towards the pedestrian movement. The majority of Israeli cities developed in late 19th century but ones that are old and still existing today are among the oldest cities in the world. Israeli street pattern is characterised by unplanned, organic, self-organised and irregular form with a lot of dead-end-streets and narrow passages.

In this study street integration levels of 2 Israeli BU cities are analysed:

- Jerusalem, Israel
- Jericho, Palestine

Figure 25 - Example of Israeli BU city Jericho

The following table represent the sum of all 34 bottom-up cities analysed in this study:

	BOTTOM UP CITIES				
	City name	**Location**	**Date of origin**	**Area size km2**	**Type of the city pattern**
1	**Riomagiore**	Italy	**13th C**	**0.31**	**MEDIEVAL**
2	**Djenne**	Mali	**1000**	**0.63**	**MUSLIM**
3	**Avila**	Spain	**5th C BC**	**0.67**	**ROMAN**
4	**Zadar**	Croatia	**2nd C BC**	**0.75**	**ROMAN**
5	**Göreme**	Turkey	**1800-1200 BC**	**1.1**	**ROMAN**
6	**Bucharest**	Romania	**1300**	**1.19**	**MEDIEVAL**
7	**Rhodes**	Greece	**408 BC**	**1.2**	**MEDIEVAL**
8	**Jerusalem**	Israel	**11th C BC**	**1.43**	**ISRAELI**
9	**La Medina, Tunis**	Tunisia	**698**	**1.54**	**MUSLIM**
10	**Hanoi**	Vietnam	**1010**	**1.74**	**ASIAN**
11	**Cadiz**	Spain	**18th C**	**1.9**	**GREEK**
12	**Toledo**	Spain	**59 BC**	**1.91**	**ROMAN**
13	**Bratislava**	Slovakia	**13th C**	**1.96**	**MEDIEVAL**
14	**Riga**	Latvia	**1201**	**2**	**MEDIEVAL**
15	**Sibiu**	Romania	**300 BC**	**2.04**	**MEDIEVAL**
16	**Old Damascus**	Syria	**3000 BC**	**2.14**	**GREEK**
17	**Nicosia**	Cyprus	**13th C**	**2.3**	**MEDIEVAL**
18	**Valencia**	Spain	**14th C**	**2.63**	**MEDIEVAL**
19	**Tallinn**	Estonia	**1284**	**2.66**	**MEDIEVAL**
20	**Prague**	Czech Republic	**9th C BC**	**2.69**	**MEDIEVAL**
21	**Mytilene**	Greece	**11th c BC**	**2.93**	**GREEK**
22	**Siena**	Italy	**900-400 BC**	**3.56**	**MEDIEVAL**
23	**Nuremberg**	Germany	**1050**	**3.6**	**MEDIEVAL**
24	**York**	UK	**71**	**3.62**	**MEDIEVAL**
25	**Old Delhi**	India	**1639**	**4.62**	**MEDIEVAL**
26	**Kavala**	Greece	**7th C BC**	**6.04**	**GREEK**
27	**Marrakesh**	Morocco	**1070**	**6.65**	**MUSLIM**
28	**Vilnius old city**	Lithuania	**13th C**	**7.24**	**MEDIEVAL**
29	**Sighisoara**	Romania	**1191**	**8.85**	**MEDIEVAL**
30	**Ghent**	Belgium	**630**	**9.5**	**MEDIEVAL**
31	**Bruges**	Belgium	**1st C**	**10.11**	**MEDIEVAL**
32	**Dubrovnik**	Croatia	**7th C**	**12.66**	**GREEK**
33	**Agrinio**	Greece	**1822**	**14.6**	**MEDIEVAL**
34	**Jericho**	Palestine	**9000 BC**	**21.67**	**ISRAELI**

Table 3– List of 34 studied bottom-up cities

4.3 TD city sample description and typology

Top-down cities are easier to collect and identify, even by observing the city's map from the areal perspective. New Town Institute, Rotterdam, The Netherlands (www.newtowninstitute.org) is the main source for the sample assortment, triangulated with websites, books, maps, and articles about related cities. The idea is to analyse top-down cities from all around the world and to include respectively most of the TD morphology types, such as grid, circular (radial, star), cul-de-sac and organic-like. Top-down city sample list contains 10 grid street pattern cities, 5 cul-de-sac cities, 5 organic-like cities, 5 circle cities, 3 Israeli new towns, 2 Asian new towns, 2 Greek and 2 Roman cities.

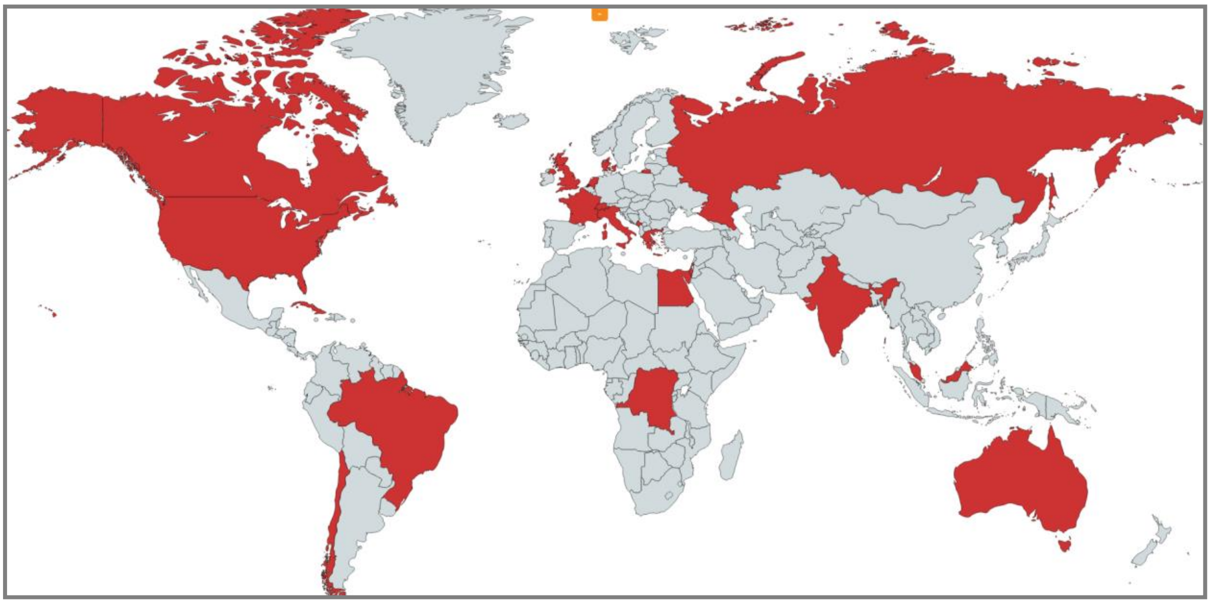


Figure 26 - A map of studied top-down cities locations, by countries

The most common TD morphology type is grid city plan/gridiron. This type of city plan is one in which streets cross at right angles to each other. This type originates from the culture of ancient Rome (Centuriation[9]). Even though the idea of the grid comes from Rome, it was used in Hellenic planning, ancient Asian countries (Japan and Korea), Europe, and the early United States. It became a popular solution in city planning, promoted by Ildefonso Cerda's plan for Barcelona in late the 19th century. American cities and downtown areas are almost always grid, and this trend continued until the end of the 20th century. With the rapid adoption of the automobile practice, the grid pattern showed low-security level in transportation sphere and after several decades of road safety improvements, planners also started to modify the city plans to create barriers (parks, squares, new roads). Such example is Milton Keynes in the UK, with a roundabout as barriers at every intersection.

In this study street integration levels of 10 grid TD cities are analysed:

- Naarden, The Netherlands
- Baracoa, Cuba
- Brazzaville, DR Congo
- Houston, USA
- Alexandria, Egypt
- Los Angeles, USA
- Washington DC, USA
- Adelaide, Australia
- Panchkula, India
- Abakan, Russia

[9] Centuriation is a method of land measurement used in ancient Rome. It is characterised by the regular layout of a square, used for planning roads, canals and agricultural plots.

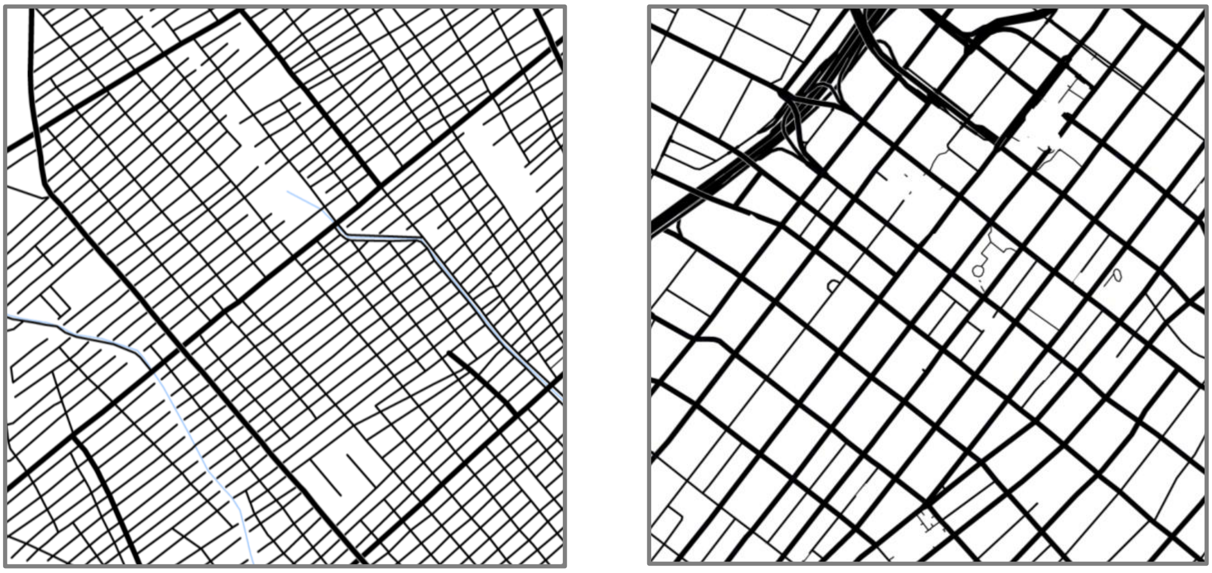


Figure 27 - Examples of grid TD cities: Brazzaville and Los Angeles

Cul-de-sac or dead end streets are those with only one entrance/exit. It is used in planning in order to calm the vehicle traffic flow and speed. These streets have a roundabout at their very ends, to ease the turn. But dead end streets existed in cities long before motor vehicles appeared, respectively in ancient Egypt, Rome and Greece for defence purposes.

In this study street integration levels of 5 cul-de-sac TD cities are analysed:

- Katty, USA
- Soledad, USA
- Brondby Strand, Denmark
- Radburn, USA
- Milton Keynes, UK

Figure 28 – Examples of cul-de-sac TD cities: Katy and Milton Keynes

Organic-like street pattern is characterised by segmented, discontinuous, varying width streets with frequently intervening, irregularly shaped open spaces. These patterns appear to evolve organically and naturally, their shape reminds on medieval street layouts and they tend to imitate the nature (leaves, tree branches, river deltas etc.). The map pattern is usually chaotic, serving majorly a local purpose and streets seem to be built in direction necessary at the time. This street pattern may look alike a park/garden plan with a little separation of land uses.

In this study street integration levels of 5 organic-like TD cities are analysed:

- Poundbury, UK
- Panther Creek, USA
- Ajax, Canada
- Brasilia, Brazil
- Belconnen, Australia

Figure 29 – Examples of organic-like cities: Poundbury and Belconnen

Circle and radial street pattern is the one which is spreading in all directions, usually developed on the levelled site. Inner outer ring roads are linked by radiating roads and, in most of the times, the core presents the business area. Industrial area is interspersed within the residential area are the periphery is covered in green belts.

In this study street integration levels of 5circl/radial TD cities are analysed:

- Paris, France
- Almere, The Netherlands
- Palmanova, Italy
- El Salvador, Chile
- Canberra, Australia

Figure 30 - Examples of organic-like cities: Almere and Palmanova

The following table represent the sum of all 34 top-down cities analysed in this study:

	TOP DOWN CITIES				
	City name	**Location**	**Date of origin**	**Area size km2**	**Type of the city pattern**
1	**Moreshet**	Israel	**1996**	**0.36**	**ISRAELI NEW TOWN**
2	**Paris, Place da la Nation**	France	**1859**	**0.68**	**CIRCLE**
3	**Naarden**	Netherlands	**1350**	**0.54**	**GRID**
4	**Baracoa**	Cuba	**1511**	**0.7**	**GRID**
5	**Penang**	Malaysia	**2005**	**1.2**	**ASIAN NEW TOWN**
6	**Sibay**	Russia	**1913**	**1.24**	**ASIAN NEW TOWN**
7	**Poundbury**	UK	**1993**	**1.23**	**ORGANIC**
8	**Katy, Grand Lakes**	US	**2008**	**1.41**	**CUL DE SAC**
9	**Radburn**	US	**1929**	**1.4**	**CUL DE SAC**
10	**Houston**	US	**1836**	**1.74**	**GRID**
11	**Budva**	Montenegro	**500 BC**	**1.8**	**GREEK**
12	**Zurich**	Switzerland	**15 BC**	**2.87**	**ROMAN**
13	**Doesburg**	Netherlands	**1237**	**2**	**ROMAN**
14	**Brazzaville**	DR Congo	**1963**	**1.93**	**GRID**
15	**Alexandria Karmouz**	Egypt	**292**	**2.1**	**GRID**
16	**Los Angeles**	US	**1781**	**2.1**	**GRID**
17	**Almere**	Netherlands	**1977**	**2.3**	**CIRCLE**
18	**Kiryat Gat**	Israel	**1955**	**2.66**	**ISRAELI NEW TOWN**
19	**Palmanova**	Italy	**1593**	**2.63**	**CIRCLE**
20	**Panchkula**	India	**1995**	**2.64**	**GRID**
21	**El Salvador**	Chile	**1957**	**2.9**	**CIRCLE**
22	**Panther Creek**	US	**1976**	**3.7**	**ORGANIC**
23	**Washington DC**	US	**1791**	**3.5**	**GRID**
24	**Soledad**	US	**1791**	**3.9**	**CUL DE SAC**
25	**Adelaide**	Australia	**1836**	**4.9**	**GRID**
26	**Ajax**	Canada	**1948**	**6.06**	**ORGANIC**
27	**Canberra**	Australia	**1913**	**6.78**	**CIRCLE**
28	**Milton Keynes**	UK	**1967**	**7.4**	**CUL DE SAC**
29	**Catania**	Italy	**730 BC**	**8.72**	**GREEK**
30	**Brasilia**	Brazil	**1957**	**9.2**	**ORGANIC**
31	**Bet Shemesh**	Israel	**1950**	**10.2**	**ISRAELI NEW TOWN**
32	**Brondby Strand**	Denmark	**1970**	**12.8**	**CUL DE SAC**
33	**Abakan**	Russia	**1931**	**14.56**	**GRID**
34	**Belconnen**	Australia	**1966**	**21.67**	**ORGANIC**

Table 4 – List of 34 studied top-down cities

4.4 Presentation of the findings

The Space syntax analysis method of axial maps provided integration level values for all 68 cities starting HH value range from 0.576 to 3.659. The lowest integration value belongs to the part of the city Belconnen, Australia as the most segregated street pattern. Belconnen street pattern belongs to the combination of its organic-like and cul-de-sac street planning style. On the other hand, the highest level of Integration HH belongs to Brazzaville, DR Congo. Brazzaville, being the most integrated example has grid street pattern shape. Both specimens belong to the top-down group of cities.

More specifically, the HH values of a bottom-up group of cities range from 0.624 (Marrakesh, Morocco) to 1.726 making Hanoi, Vietnam the most integrated street pattern in this group. Out of 19 medieval cities, least integrated one is Sighisoara with 0.783 Integration HH value while the most integrated medieval city is Zadar with 1.711 HH value. Among Greek street pattern examples, between Old Damascus, Cadiz, Mytilene, Kavala, and Dubrovnik, Dubrovnik has the lowest level of integration (0.702) while Cadiz is most integrated with 1.426 HH, followed by Old Damascus with 1.014 HH value. In general, Greek and Roman bottom-up cities happen to be in the group of low integrated ones.

The following table represent the integration level values of all 34 top-down cities analysed in this study:

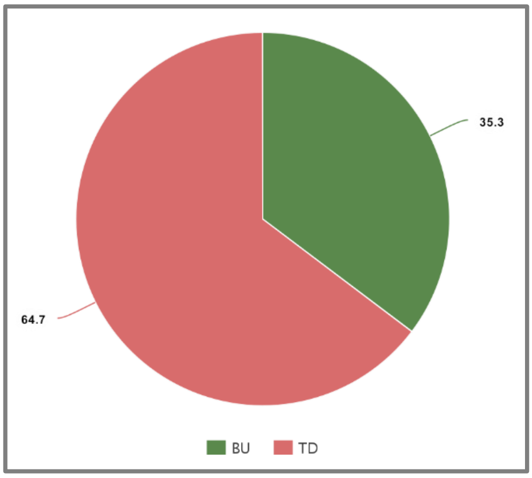
	BOTTOM UP CITIES					
	City name	**Location**	**HH**	**City name**	**Location**	**HH**
1	**Riomagiore**	Italy	0.795	**Moreshet**	Israel	1.088
2	**Djenne**	Mali	0.995	**Paris**	France	1.492
3	**Avila**	Spain	1.163	**Naarden**	Netherlands	1.610
4	**Zadar**	Croatia	1.711	**Baracoa**	Cuba	1.670
5	**Göreme**	Turkey	0.846	**Penang**	Malaysia	1.701
6	**Bucharest**	Romania	1.696	**Sibay**	Russia	1.316
7	**Rhodes**	Greece	0.998	**Pondbury**	UK	1.315
8	**Jerusalem**	Israel	1.313	**Katy, Grand Lakes**	US	1.069
9	**Tunis**	Tunisia	0.984	**Radburn**	US	1.296
10	**Hanoi**	Vietnam	1.726	**Houston**	US	2.005
11	**Cadiz**	Spain	1.426	**Budva**	Montenegro	1.128
12	**Toledo**	Spain	0.791	**Zurich**	Switzerland	1.398
13	**Bratislava**	Slovakia	1.445	**Doesburg**	Netherlands	1.073
14	**Riga**	Latvia	1.638	**Brazzaville**	DR Congo	3.659
15	**Sibiu**	Romania	1.191	**Alexandria**	Egypt	2.106
16	**Old Damascus**	Syria	1.014	**Los Angeles**	US	2.436
17	**Nicosia**	Cyprus	1.009	**Almere**	Netherlands	0.899
18	**Valencia**	Spain	1.277	**Kiryat Gat**	Israel	1.203
19	**Tallinn**	Estonia	1.087	**Palmanova**	Italy	1.783
20	**Prague**	Czech Rep.	1.452	**Panchkula**	India	1.165
21	**Mytilene**	Greece	0.821	**El Salvador**	Chile	1.820
22	**Siena**	Italy	0.871	**Panther Creek**	US	0.775
23	**Nuremberg**	Germany	1.697	**Washington DC**	US	2.724
24	**York**	UK	1.012	**Soledad**	US	1.062
25	**Old Delhi**	India	1.063	**Adelaide**	Australia	2.151
26	**Kavala**	Greece	0.854	**Ajax**	Canada	1.180
27	**Marrakesh**	Morocco	0.624	**Canberra**	Australia	1.106
28	**Vilnius**	Lithuania	0.864	**Milton Keynes**	UK	0.858
29	**Sighisoara**	Romania	0.783	**Catania**	Italy	1.895
30	**Ghent**	Belgium	1.007	**Brasilia**	Brazil	1.241
31	**Bruges**	Belgium	0.980	**Bet Shemesh**	Israel	0.718
32	**Dubrovnik**	Croatia	0.702	**Brondby Strand**	Denmark	1.507
33	**Agrinio**	Greece	1.007	**Abakan**	Russia	1.910
34	**Jericho**	Palestine	0.786	**Belconnen**	Australia	0.576

Table 5 – Integration HH levels of 68 cities

After completed SS analysis and after integration values have been computed for all 34 city pairs, the observed findings indicate that bottom-up city has a higher level of integration than its top-down pair. More precisely, the bottom-up city has a lower value of integration level in 12 compared pairs (out of 34), while 22 times top-down city has a higher level of integration than the bottom-up one.

Based on the results, it is stated the following:

- Comparing 34 BU/TD city pairs, the top-down city showed a higher value of integration level than its bottom-up city pair in 65% of the cases.



Graph 5 – The ratio of integration levels between 34 BU/TD city pair

Moreover, apart from previously explained observation of city pairs, two additional analyses are conducted: A Student t-test and regression analysis.

4.4.1 A Student t-test

A Student's t-test is used to determine whether there is a significant difference between the means of two groups of cities. Since the data is collected from two different sample groups (BU and TD), the test for the independent (unpaired) sample, also known as Welch's t-test[10], is more appropriate to be used. Welch's t-test defines the statistic *t* by the following formula:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}} = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{se_1^2 + se_2^2}}$$

Equation 1 – Welch's t-test formula

Where the X_1, s_1^2, N_1, se_1 are respectively the 1st (BU) sample mean, sample variance, sample size, and standard error.

T-test:

The sample size (N) is 34. Group A – a BU sample, denote a set obtained by 34 integration level values, while Group B – a TD sample, denote a second set of integration level values (see Figure 31) calculated previously using SS (Table 5). Before performing the test, the model is carried out with the null hypothesis that the means of both sample groups, A and B (BU and TD), are taken as equal. Additionally, the threshold value for probability, i. e. the chosen significance level of the test α is 5% ($p<0{,}05$).

Automatically calculated independent sample t-test gave the mean integration level of BU cities as 1.11 and mean integration level of TD cities as 1.50. This implies that the average value of integration levels among top-down city group is higher than the average value of integration levels among bottom-up city sample group, for the average difference of 0.39 HH (see Figure 32).

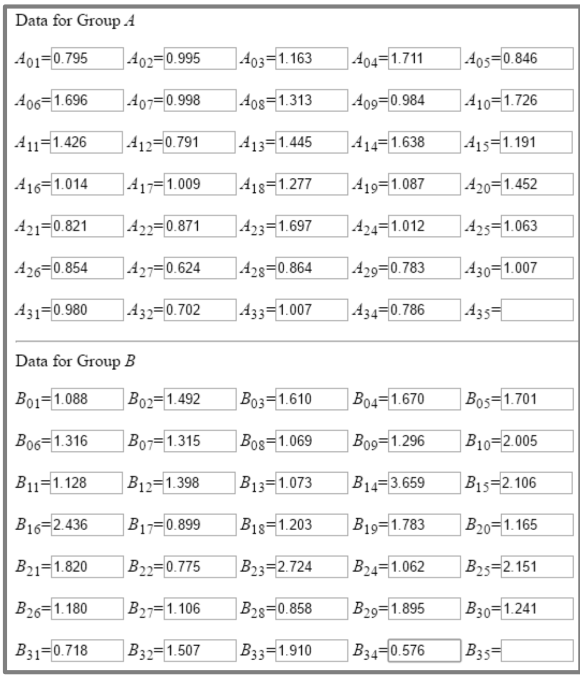
The t-test also provided the result of the t-value ($t=-3.24$) which measures the size of the difference relative to the variation in the sample data. Since the t-value is -3.24 and as such it is not close to zero, it is interpreted as the evidence against the null hypothesis.

The probability of this result (p-value), assuming the null hypothesis, is <0.05 (more precisely 0.002). The probability value of 0.002 means that there is a 2% likelihood that a BU city sample group cannot be distinguished from TD city sample group by integration levels alone. Since the resulting p-value is less than the significance level α, the test suggests that the observed data is inconsistent with the null hypothesis, so the null hypothesis can be rejected. In other words, the means of both sample groups, A and B, are not equal and the conclusion is that there is a statistically significant difference. Finally, bottom-up and top-down cities can be distinguished by the levels of integration.

[10] In statistics, Welch's *t*-test, or unequal variances *t*-test, is a two-sample location test which is used to test the hypothesis that two samples have equal means. Welch's *t*-test is an adaptation of Student's t-test that is, it has been derived with the help of Student's *t*-test and is more reliable when the two samples have unequal variances and unequal sample sizes. An "unpaired" or "independent samples" *t*-tests, as they are typically applied when the statistical units underlying the two samples being compared are non-overlapping. SOURCE: http://www.ruf.rice.edu/~bioslabs/tools/stats/ttest.html; https://en.wikipedia.org/wiki/Welch%27s_t-test

Based on the results, it is stated the following:

- There is a significant difference in mean integration level values between bottom-up and top-down cities.
- The average integration level value of top-down cities is higher for 0.39 than the average integration level value of bottom-up cities.



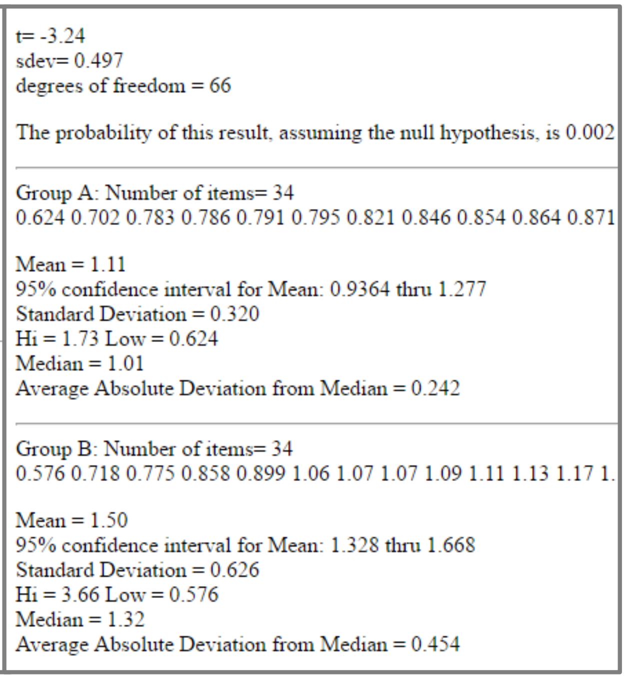
Data for Group A

A_{01}=0.795	A_{02}=0.995	A_{03}=1.163	A_{04}=1.711	A_{05}=0.846
A_{06}=1.696	A_{07}=0.998	A_{08}=1.313	A_{09}=0.984	A_{10}=1.726
A_{11}=1.426	A_{12}=0.791	A_{13}=1.445	A_{14}=1.638	A_{15}=1.191
A_{16}=1.014	A_{17}=1.009	A_{18}=1.277	A_{19}=1.087	A_{20}=1.452
A_{21}=0.821	A_{22}=0.871	A_{23}=1.697	A_{24}=1.012	A_{25}=1.063
A_{26}=0.854	A_{27}=0.624	A_{28}=0.864	A_{29}=0.783	A_{30}=1.007
A_{31}=0.980	A_{32}=0.702	A_{33}=1.007	A_{34}=0.786	A_{35}=

Data for Group B

B_{01}=1.088	B_{02}=1.492	B_{03}=1.610	B_{04}=1.670	B_{05}=1.701
B_{06}=1.316	B_{07}=1.315	B_{08}=1.069	B_{09}=1.296	B_{10}=2.005
B_{11}=1.128	B_{12}=1.398	B_{13}=1.073	B_{14}=3.659	B_{15}=2.106
B_{16}=2.436	B_{17}=0.899	B_{18}=1.203	B_{19}=1.783	B_{20}=1.165
B_{21}=1.820	B_{22}=0.775	B_{23}=2.724	B_{24}=1.062	B_{25}=2.151
B_{26}=1.180	B_{27}=1.106	B_{28}=0.858	B_{29}=1.895	B_{30}=1.241
B_{31}=0.718	B_{32}=1.507	B_{33}=1.910	B_{34}=0.576	B_{35}=

Figure 31 – A sample data input for independent sample t-test calculation



t= -3.24
sdev= 0.497
degrees of freedom = 66

The probability of this result, assuming the null hypothesis, is 0.002

Group A: Number of items= 34
0.624 0.702 0.783 0.786 0.791 0.795 0.821 0.846 0.854 0.864 0.871

Mean = 1.11
95% confidence interval for Mean: 0.9364 thru 1.277
Standard Deviation = 0.320
Hi = 1.73 Low = 0.624
Median = 1.01
Average Absolute Deviation from Median = 0.242

Group B: Number of items= 34
0.576 0.718 0.775 0.858 0.899 1.06 1.07 1.07 1.09 1.11 1.13 1.17 1.

Mean = 1.50
95% confidence interval for Mean: 1.328 thru 1.668
Standard Deviation = 0.626
Hi = 3.66 Low = 0.576
Median = 1.32
Average Absolute Deviation from Median = 0.454

Figure 32 – T-test results

SOURCE: http://www.physics.csbsju.edu/stats/ttest_NROW_form.html

4.4.2 A prediction of the dependent variable

Additionally, it is possible to predict which value of integration level a next bottom-up or top-down city will have.

If observing only one variable, (dependent one-integration level), the best prediction for other values is the mean of the dependent variable. The mean value (or expected value) of the variable is a weighted average of the variable values and it is calculated using the following equation:

$$E(X) = \mu_x = \Sigma [x_i * P(x_i)]$$

Equation 2 – The mean value formula

where x_i is the value of the variable for the outcome i; μ_x is the mean of variable X; and $P(x_i)$ is the probability that the variable will be the outcome i.

After calculation using Equation 2, mean values of integration levels for both city groups are:

- The bottom-up city group has 1.11 expected integration level value.
- The top-down city group has 1.50 expected integration level value.

Based on the results it is possible to conclude that, in a sample of 34 cities, top-down cities are expected to show a higher level of street integration than bottom-up cities.

4.5 Analysis of the findings

Analysis of the data is done by using linear regression analysis in Excel software with the following list of potential variables:

VARIABLE TYPE	VARIABLE NAME	VARIABLE MODALITY	VALUE
Dependent variable	Street integration level HH	/	>0.00 (0.576 - 3.659)
Independent variable	Urban morphology BU/TD	Bottom-up city (Reference)	0
		Top-down city	1
Control variable	Land are size in km^2 AREA	/	>0.00 (0.31 - 21.68)
	Date of origin in years DATE	/	-3000 – 2005

Table 6 - Variables used in regression analysis

The data of controlled variables is gathered throughout the data collection process and analysis of 68 cities and in this study, it is used to test the relative relationship between street integration level and urban morphology.

Control variable “land area size/AREA” represents the areal size of the city or part of the city in square km. Each city/city part measure is computed in GIS during axial line conduction process. It is taken into consideration due to the several studies indicating that larger cities are more segregated than the small ones (Kresl, Ietri, 2016; Orfield, Frankenberg, 2008).

Control variable “date of origin/DATE” represents the year in which the bottom-up city was found, established, first time mentioned etc. In many cases of bottom-up cities the exact year is unknown but instead, a century is approximated in the literature. In cases when only a century of city’s origin is known, a middle year is calculated by regression (for example, for the 17^{th} century, the input in regression analysis is 1650). In cases of top-down cities, the year when a pre-project is over, and city inhabited is taken into regression calculation. This variable is considered due to several theories which claim that older cities are oriented more towards the pedestrian movement and as such more integrated than bigger “car-prone” cities (Van Nes, 2014).

4.5.1 A simple linear regression analysis

Firstly, in order to describe how street integration is related to urban morphology, the method used in this study is a Simple linear regression. A simple linear regression is the least square estimator of a linear regression model with a single independent variable. A simple linear regression fits a straight line through the set of points making the sum of squared residuals (observed errors, i. e. vertical distances between the points and the fitted line) of the model as small as possible. A simple linear regression is calculated using following model and equation:

$$y=\beta_0+ \beta_1*x+\epsilon, \text{ or } E(y)= \beta_0+ \beta_1*x$$

Acknowledging that a sample data is used, the equation looks like following:

$$\hat{y}=b_o+b_1*x$$

Equation 3 – Simple linear regression model and equation

where

- y is the value of the dependent variable (integration level),
- ŷ is the mean value of y for a given value of x,
- x is the value of independent variable (urban morphology, TD/BU),

- β_0 (b_o) is the y-intercept parameter/ regression constant,
- β_1 (b_1) is the slope parameter/regression coefficient and,
- ϵ is an error term, i. e. unexplained variation in y.

Summary output of simple linear regression, using BU/TD (Urban morphology) as independent variable and HH (Integration level) as dependent variable, is following:

Regression Statistics								
Multiple R	**0.370901**							
R Square	**0.137568**							
Adjusted R Square	**0.124501**							
Standard Error	**0.497345**							
Observations	**68**							
ANOVA								
	df	***SS***	***MS***	***F***	***Significance F***			
Regression	**1**	**2.604062**	**2.604062**	**10.52776**	**0.001848**			
Residual	**66**	**16.32524**	**0.247352**					
Total	**67**	**18.9293**						
	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***	***Lower 95.0%***	***Upper 95.0%***
Intercept	**1.106706**	**0.085294**	**12.9752**	**7.92E-20**	**0.936411**	**1.277001**	**0.936411**	**1.277001**
BU/TD	**0.391382**	**0.120624**	**3.244651**	**0.001848**	**0.150549**	**0.632216**	**0.150549**	**0.632216**

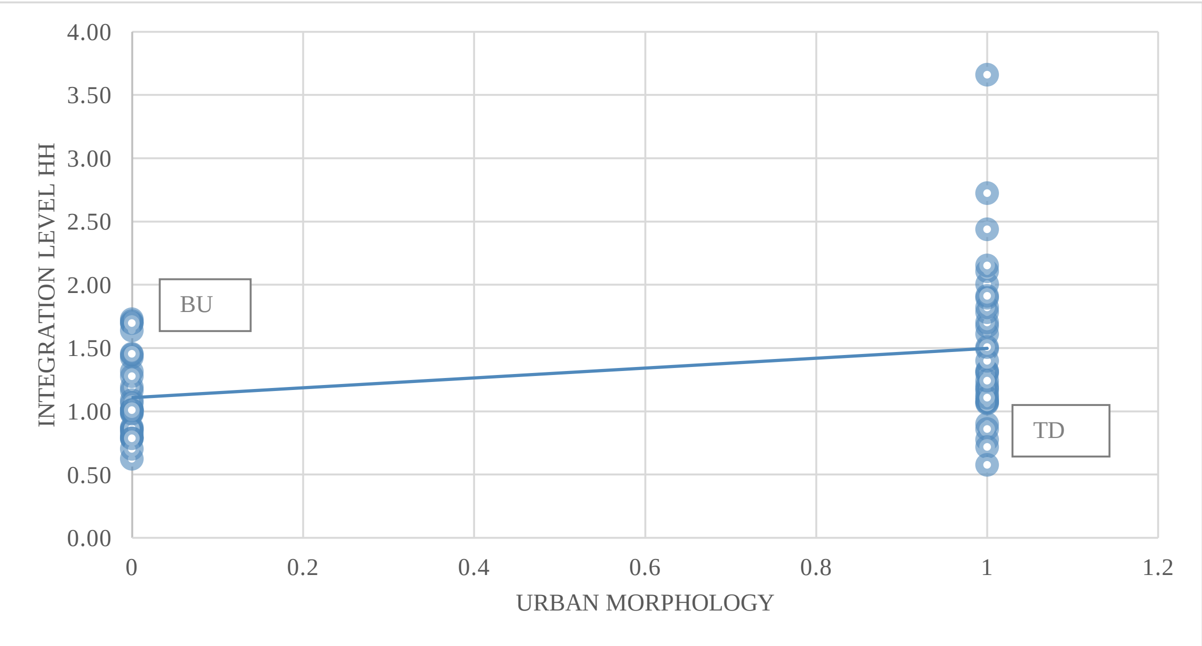
Table 7 – Simple linear regression summary output

After regression (Table 7), a linear equation is as following:

$$\hat{y} = 1.11 + 0.39x$$

Equation 4 – Linear equation after regression

where, the slope β_1=0.39, and a y-intercept β_0=1.11, as shown on the Graph 7.



Graph 6 – Linear regression graph of DV and IV

What does β_1=0.39 mean? When urban morphology variable (x) passes from 0 to 1 (from BU to TD) there is an increase in integration level value for 0.39. On the other hand, β_0=1.11 means that expected/predicted integration level value for BU city sample (when x=0) is 1.11, as already stated using equation 2, p. 54.

The average variation explained by the urban morphology is 10.53 (F) times larger than the average variation that cannot be explained by the urban morphology. This result is significant because there is only 0.18% chance of getting a ratio that large from pure chance variation. Since the p-value is smaller than 5% ($p<0.05$), the result is statistically significant.

But, is this regression model any good? How well does the estimated regression equation (Equation 4) fit our data?

Having in mind the following:

$$r^2=SSR/SST$$

Equation 5 – Coefficient of determination equation

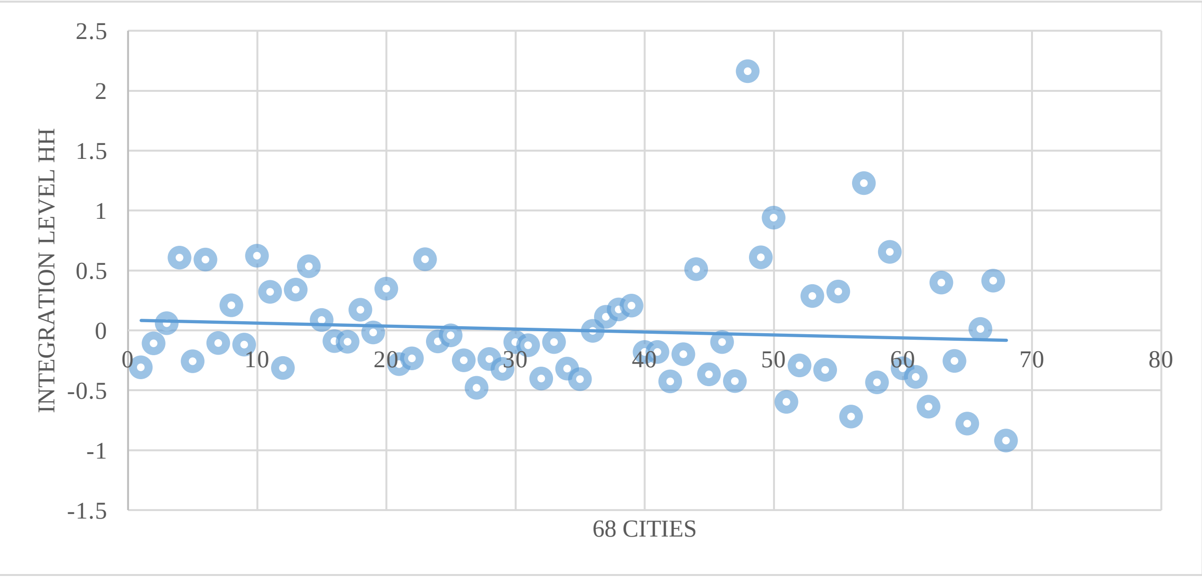
where the SST=18.93, SSE=16.33, and SSR=2.60, the r^2=0.138 or 13.8%.

The proportion of the total variance of integration level on urban morphology, or r^2 is 0.138, which implies that 13.8% of the total sum of squares can be explained by using the estimated regression equation to predict the integration level, i. e. 13.8% of the variability in street integration values is explained by urban morphology.

A simple linear regression with two variables determines how good the regression line fits the data by comparing it to the residual line, when β_1=0, i. e. when only dependent variable is taken into consideration.

When conducting simple linear regression with two variables, it is important to determine how good the regression line fits the data by comparing it to the residual[11] line. The residual plot needs to be checked in order to validate the model. It is important to assess whether the observed error (i.e. residuals) is consistent with randomness and unpredictability. The results of the residual plot below (Graph 8) indicate neither too high or too low residuals. Moreover, the residuals are normally distributed, centred on zero throughout the range of fitted values.

The model is correct on average for all fitted values, which indicated that the regression model is valid.



Graph 7– Residual plot of 68 cities and their integration levels

[11] The difference between the best-fit line (predicted value) and the observed value is called residual (or error).

4.5.3 A multiple regression analysis

A multiple regression analysis (many-to-one relationship) is an extension of a simple linear regression (one-to-one relationship). In multiple regression, each coefficient is interpreted as the estimated change in y corresponding to a unit change in a variable, when all the other variables are held constant.

A multiple regression model and equation are as following:

$$y= \beta_0+ \beta_1 * x_1+ \beta_2 * x_2+ \dots \beta_p * x_p+\epsilon$$
$$E (y)= \beta_0+ \beta_1 * x_1+ \beta_2 * x_2+ \dots \beta_p * x_p, \epsilon=0$$
And estimated regression equation:
$$\hat{y} = b_0+ b_1 * x_1+ b_2 * x_2+ \dots b_p * x_p$$

Equation 6 – A multiple regression model and equation

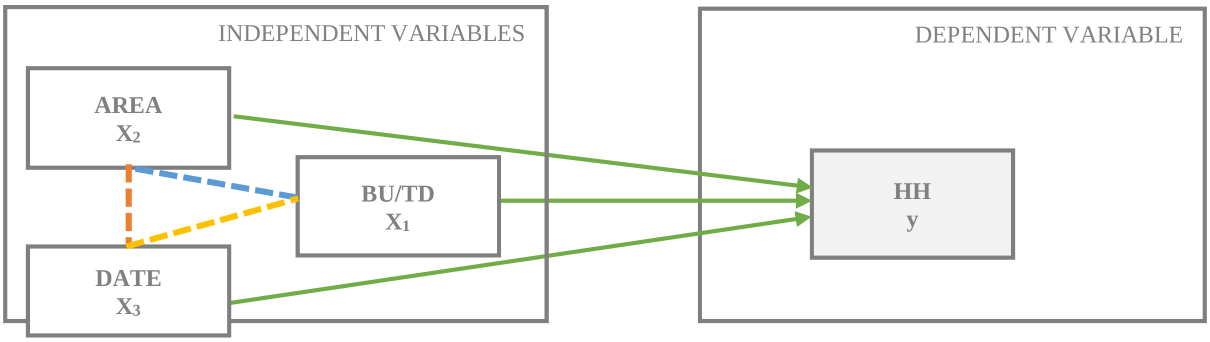
where

- p is the number of variables
- y is the value of the dependent variable,
- $\hat{y}$ is the mean value of y for a given value of x,
- x is the value of the independent variable,
- β_0 is the y-intercept parameter/ regression constant,
- β_1, β_2 is the slope parameter/regression coefficient,
- b_0, b_1, b_2, b_p are the estimates of β_0, β_1 β_2, β_p, and
- ϵ is an error term, i. e. unexplained variation in y.

With this analysis, it is desirable to predict the level of integration using additional variables besides urban morphology, namely Land area size/AREA, and Date of origin/DATE. In what way does integration level depend on these additional (control) variables?
Before conducting multiple regression analysis, a prep-work is needed to be done, such as

- Scatter plot (Graph 8), and
- Correlation (Table 8).

In multiple regression analysis it is ideal for all the independent variables (BU/TD, AREA, DATE) to be correlated with the dependent variable (integration level), but not with each other, i. e. it is ideal to avoid multicollinearity. Some independent variables are better at predicting the dependent variable than others, while some contribute nothing. This is why this step in the analysis is important, so it can be decided which variable to include in the model and which to exclude. Potential multicollinearity risk is the possibility of correlation in the relationship between the independent variables, and these relationships need to be checked.

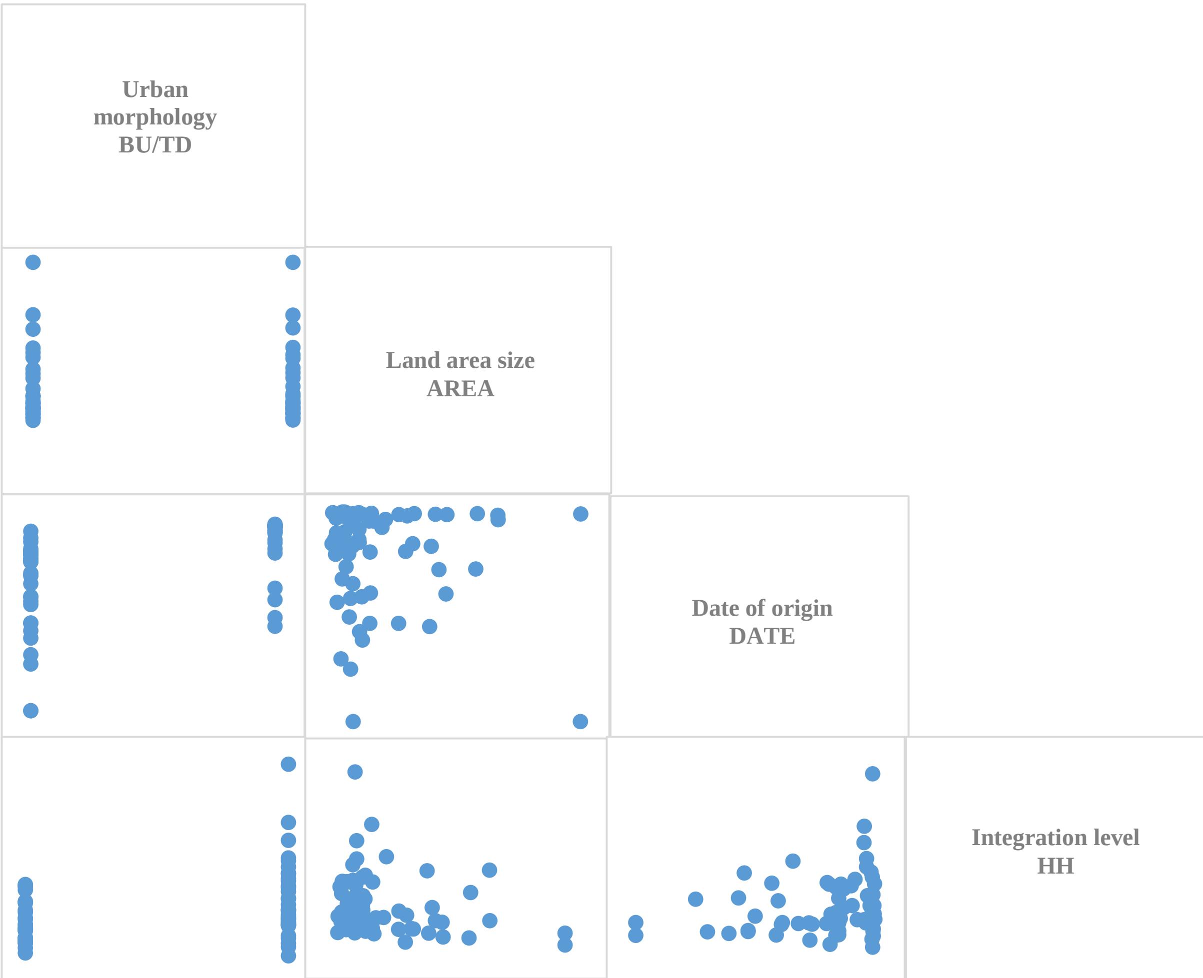


Graph 6 – Relationships between variables

As shown on Graph 7, there are 6 relationships to be analysed during the prep-work, more precisely, 3 relationships of IVs to DV, and 3 relationships between IVs.

An independent variable to dependent variable scatterplot helps to check the relevancy of each independent variable. A scatterplot matrix is used to evaluate the correlation or cause-effect relationship between variables. A dependent vs. independent variable scatterplot summary indicate that the integration level appears correlated with the urban morphology, land area size and date of origin (Graph 8).

An independent variable to independent variable scatterplots helps discover the multicollinearity, meaning, the correlation among independent variables themselves. Because of an unclear scatterplot and inexplicit presentation of Urban morphology variable due to only two values (0 and 1), all variables are used in further regression and analysis until significance is confirmed (Graph 8).



Graph 8 – Scatterplot matrix

	BU TD	AREA	DATE	HH
BU TD	1			
AREA	0.004412423	1		
DATE	0.523874381	-0.07483	1	
HH	0.370901375	-0.26007	0.220881	1

Table 8 – Correlation table

The correlation coefficient (a value between -1 and 1) indicates how strongly the variables are related to each other. A correlation of 1 or -1 indicates a perfect positive/negative correlation. As the independent variable increases, dependent variable increases, too., and vice versa. On the other hand, a correlation coefficient near 0 indicates no correlation.

Based on the correlation analysis (Table 8), it can be concluded that the integration level value is positively correlated with urban morphology (0.371) and date of origin (0.221) but negatively correlated with land area size (-0.260). Furthermore, date of origin is positively correlated with urban morphology (0.524) and negatively with land area size (-0.075). Land area size is positively correlated with urban morphology (0.004).

Because of very low correlation coefficients between AREA and BU/TD (0.004), and HH and DATE (-0.075), it can be concluded that these variables are not correlated. It is also visible that two independent variables DATE and BU/TD have the highest correlation coefficient (0.524), which confirms that the variable DATE should be left out from the regression, due to the rule that multicollinearity between independent variables should be avoided in the regression. Both BU/TU and DATE variables should not be included in the regression, but in this step, still cannot be clear which variable will be discarded.

Since the Excel is not calculating p-values for the correlation coefficients, and significance cannot be identified in this moment, all variables are being considered in furthering regression analysis.

Another approach to identify collinearity among explanatory variables is the use of the variance inflation factor (VIF) which asses how much the variance of an estimated regression coefficient increases if the independent variables are correlated. A VIF calculations are straightforward and easy to comprehend, meaning, the higher the value, the higher the collinearity. A VIF is used to describe how much multicollinearity exists in a regression analysis. A VIF for the independent variable is obtained using the r-squared value of the regression of that variable against all other independent variables. The variance inflation factor is calculated for each independent variable in such a way, that those indicating high value, should be removed from the regression (the rule of thumb says that the values of 5-10 are commonly used, meaning, if VIF>% then there is a problem with multicollinearity). The VIF equation is as following:

$$VIF_i=1/(1-R_i^2)$$

Equation 7 – VIF equation

where

- VIF for variable i is the reciprocal of the inverse of R^2 from the regression,
- R^2 of variable i is the multiple correlation coefficient of the variable x_i regressed on the remaining independent variables.

Coefficients [a]			
Model		Collinearity Statistics	
		Tolerance	VIF
1	BU TD(x1)	.724	1.381
	AREA (x2)	.992	1.009
	DATE (x3)	.719	1.390
a. Dependent Variable: HH (y)			

Table 9 – VIF and tolerance table

The following guideline to interpret the VIF is used:

- VIF=1 – not correlated
- 1<VIF<5 - moderately correlated
- 5<VIF<10 – highly correlated

Since in this case, the VIF values are 1.38 (BU/TD), 1.01 (AREA), and 1.39 (DATE), meaning, 1<VIF<5, it can be assumed that the independent variables are moderately correlated.

By adding first control variable in the regression model, i. e. Land area size/AREA, r^2 value increased from 0.138 to 0.206, indicating that integration level value is explained better than with the urban morphology variable alone. The result appears to be significant, with $p<0.001$.

Regression Statistics	
Multiple R	**0.453382**
R Square	**0.205555**
Adjusted R Square	**0.181111**
Standard Error	**0.480997**
Observations	**68**

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	**2**	**3.891012**	**1.945506**	**8.409063**	**0.000565**
Residual	**65**	**15.03829**	**0.231358**		
Total	**67**	**18.9293**			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	**1.236177**	**0.099087**	**12.47573**	**6.56E-19**	**1.038288**	**1.434066**	**1.038288**	**1.434066**
BU/TD	**0.391723**	**0.116659**	**3.357841**	**0.001317**	**0.158738**	**0.624707**	**0.158738**	**0.624707**
AREA	**-0.02966**	**0.012574**	**-2.35851**	**0.021366**	**-0.05477**	**-0.00454**	**-0.05477**	**-0.00454**

Table 10 – A multiple regression summary output with control variable Land area size

After regression (Table 9), the equation is as following:

$$\hat{y} = 1.24 + 0.39x_1 - 0.03x_2$$

Equation 8 – Equation after multiple regression with two IV

Based on the results, it is stated the following:

- In this case, 0.39 times is an estimate of the expected increase in integration level value, corresponding to a change from 0 to 1 in urban morphology, while the land area size is held constant. Or, -0.03 times is an estimate of the expected increase in integration level value, corresponding to an increase change of one km^2 in land area size, while the urban morphology is held constant.

By adding second control variable in the regression model, i. e. Date of origin/DATE, r^2 value did not increase, but remained the same as in the previous model (0.206), indicating that integration level value is not explained better than with the urban morphology and land area size variables. The result appears to be significant, with $p<0.001$.

Regression Statistics								
Multiple R	**0.453471**							
R Square	**0.205636**							
Adjusted R Square	**0.1684**							
Standard Error	**0.484716**							
Observations	**68**							
ANOVA								
	df	***SS***	***MS***	***F***	***Significance F***			
Regression	**3**	**3.892539**	**1.297513**	**5.522522**	**0.001953**			
Residual	**64**	**15.03676**	**0.234949**					
Total	**67**	**18.9293**						
	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***	***Lower 95.0%***	***Upper 95.0%***
Intercept	**1.234056**	**0.10326**	**11.95092**	**5.93E-18**	**1.02777**	**1.440342**	**1.02777**	**1.440342**
BU/TD	**0.385871**	**0.138161**	**2.792916**	**0.006881**	**0.109864**	**0.661879**	**0.109864**	**0.661879**
AREA	**-0.02957**	**0.012717**	**-2.325**	**0.023255**	**-0.05497**	**-0.00416**	**-0.05497**	**-0.00416**
DATE	**4.7E-06**	**5.83E-05**	**0.080616**	**0.935999**	**-0.00011**	**0.000121**	**-0.00011**	**0.000121**

Table 11 – A multiple regression summary output with control variables Land are a size and Date of origin

After regression (Table 10), the equation is as following:

$$\hat{y} = 1.23+0.39x_1-0.03x_2+0.00x_3$$

Equation 9 - – Equation after multiple regression with three IV

Based on the results, it is stated the following:

- In this case, 0.39 times is an estimate of the expected increase in integration level value, corresponding to a change from 0 to 1 in urban morphology, while AREA and DATE variables are held constant. Or, -0.03 times is an estimate of the expected increase in integration level value, corresponding to an increase change of one km^2 in land area size, while the BU/TD and DATE are held constant.

It is important to note that in this model regression coefficient of variable DATE is zero and that its p-value indicates no significance (0.94). This indicates that DATE variable does not show significant linear correlation, meaning that changes in the integration level values are not associated with the year when the city originated, and it is clear that this variable can be left out from the regression.

The summary of the analysis results:

- Comparing 34 city pairs the top-down city group showed a higher level of integration level than the bottom-up in 65% of the cases;
- The results show that there is a significant difference in mean integration values between BU-TD. The average integration level value of TD city groups is higher for 0.39 than the average integration level value of BU sample group;
- When urban morphology variable passes from 0 to 1 (TD to BU) there is an increase in integration level value of 0.39;
- The average variation explained by the urban morphology variable is 10.53 times larger than the average variation that cannot be explained by urban morphology;
- 13.8% of the variability in street integration values is explained by urban morphology;
- The date of origin of the cities has a small impact on the results of the study.

5. Conclusion

This study examines the urban morphology of 68 cities and their street integration levels. The sample cities are taken from different countries worldwide and they are categorised into two types based on the way they originated, planned or unplanned i.e. top-down or bottom-up. The study presents a quantitative analysis of various urban forms. The analysis is mainly carried out from the topological analysis of urban street networks, and certain conclusions are drawn from this study.

As some recent analysis specify (Omer; Zafrir-Reunen, 2010), the obtained results from this particular research also indicate that cities belonging to the same type tend to reveal similar spatial integration level, which is affected by their street patterns and geometric properties of their spatial structure. Specifically, in 65% of the cases (22 out of 34), after comparing cities by pairs, the results indicate that the bottom-up cities have lower levels of street integration.

A comparison of the average spatial integration values for all the cities examined from the sample, indicates higher spatial integration level values in top-down city group than the bottom up group. Even though some of the most segregated city examples, cul-de-sac (Milton Keynes, UK with 0.86 HH) and organic-like (Belconnen, Australia with 0.58 HH), belong to the top-down sample group, the mean integration level value is still higher by 0.39 HH than the mean bottom-up integration value. This is due to the fact that, among all the subtypes analysed, the grid street pattern type (TD) has the highest mean level of integration (2.14 HH). On the other hand, Muslim city group (BU) showed the lowest mean integration level from all other types (0.87 HH) (Table 12).

MORPHOLOGY TYPE	NO. OF CITIES	CITY SUBTYPE	SUBTYPE HH MEAN	TYPE HH MEAN
BOTTOM-UP	19	Medieval	0.907	1.11
	5	Greek	0.963	
	4	Roman	1.127	
	3	Muslim	0.867	
	2	Israeli	1.049	
	1	Asian	1.726	
TOP-DOWN	10	Grid	**2.14**	1.50
	5	Cul-de-sac	1.16	
	5	Organic-like	1.02	
	5	Circle/Radial	1.42	
	3	Israeli new town	1.00	
	2	Asian new town	1.51	
	2	Roman	1.24	
	2	Greek	1.51	

Table 12 – Integration level means, by subtypes

Observing each city group alone, the lowest mean integration level value is obtained by Muslim and medieval cities, while the highest mean integration level value is obtained by Roman and Asian cities. This is explained by the fact that both Asian and Roman street patterns are in fact grid.

In the top-down group, the Israeli new town, cul-de-sac and organic-like cities obtain the lowest mean integration level value. This is due to the fact that cities planned using these street pattern types have the highest number of dead-end streets. The grid pattern cities have the highest mean integration level value of 2.14.

The date of origin of the cities has an insignificant impact on the results of the study ($p>0.05$), while the land area size does have significant impact on the results of study ($p<0.05$). Based on the regression results, it can be stated that 0.39 times is an estimate of the expected increase in integration level value, corresponding to a change from 0 to 1 in urban morphology, while the land area size is held constant. Or, -0.03 times is an estimate of the expected increase in integration level value, corresponding to an increase change of one km^2 in land area size, while the urban morphology is held constant.

To remind, a central question of this research is:

- Which city morphology indicates a higher level of street integration: bottom-up or top-down?

The spatial integration of cities all around the world examined here, tend to vary by city types. However, a comparison of cities belonging to the same type indicates that the outcome is attributed to the variation in street pattern. This result answers the main question stated at the beginning of this study, that the street integration is affected by urban morphology.

Cities originating from different continents, developed in different periods of time have various urban forms and thus special urban street networks. Through the traditional data analysis perspective, it is seen that the morphology of cities from different locations is determined by different factors and that top-down and bottom-up cities have their individualities.

Using Space syntax method, the quantitative analysis of urban street networks did not find clear evidence of the existence of individual peculiarities. Specifically, there is no clear difference between cities belonging to TD and BU subtypes. The only exception is presented by the TD grid and BU Muslim city types, which showed significantly higher, respectively lower levels of street integration compared with other city street pattern subtypes.

This indicates that the morphology pattern can be recognised using the traditional way of morphological study, but they cannot be clearly identified with the Space syntax method. One explanation is based on the working principle of SS, that it does not recreate true street shape, but slices curvy streets into several straight lines. Space syntax is, after all, a new field of study for the analysis of urban forms but it does offer precise measures of spatial configuration which can serve useful in further understanding of urban morphology.

These research findings can be linked to two generative processes affecting the development of settlement forms. First, the socio-cultural process which generates differences in patterns and reflects differences in spatial culture, and second, the microeconomic process that generates the spatial structures which contribute to the integration of urban areas. Socio-cultural processes are responsible for the similarities found between cities belonging to the same type, whereas micro-economic processes are responsible for their differences. (Hillier and Hanson, 1984; Hillier, 1996, 2002)

The findings obtained from this analysis of bottom-up and top-down cities illustrate how the geometric characteristics of the spatial structure are expressed in their configurational-topological properties. This study also provides a way to analyse the urban morphology from the traditional and contemporary point of view.

Going back to literature and referring to Kevin Lynch's imageability, the street integration level helps people find the highly interconnected streets and it can be useful for their path selection. The integration analysis provides people with a choice regarding their living areas. If city dwellers want to have a quiet living environment, they can select the areas surrounded by the streets with low integration such as organic-like or cul-de-sac.

Public institutions in charge of traffic planning, according to the integration levels, can regulate traffic flow, plan locations for public transportation stops, and set more traffic lanes along the streets with high integration. High integration streets in general have more pedestrian movement and this knowledge can be useful in not only urban planning, but in business (positioning of the shops), tourism sector (developing touristic points), or even in crime prevention (streets with high level of integration have higher crime rate).

Further research is needed to link the configurational properties of cities included in the current research with their developmental, geographic and topographic features, adding variables such as terrain characteristics, population, density or even number of street. Additional investigation is needed to research the implications that space has in everyday space use. Consequently, future work is needed to explain how these differences in street integration levels affect spatial behaviour by including social implications and the human factor in the study. In the near future researchers could intend to do so by examining the impact of street integration levels on social residential patterns, neighbourhoods, pedestrian movement and even liveability.

Appendix

<table>
<tr><th>BOTTOM-UP cities</th><th>TOP-DOWN cities</th></tr>
<tr><td>

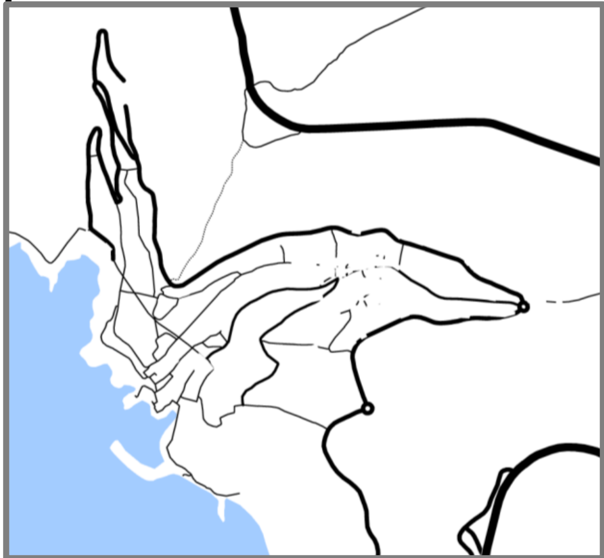
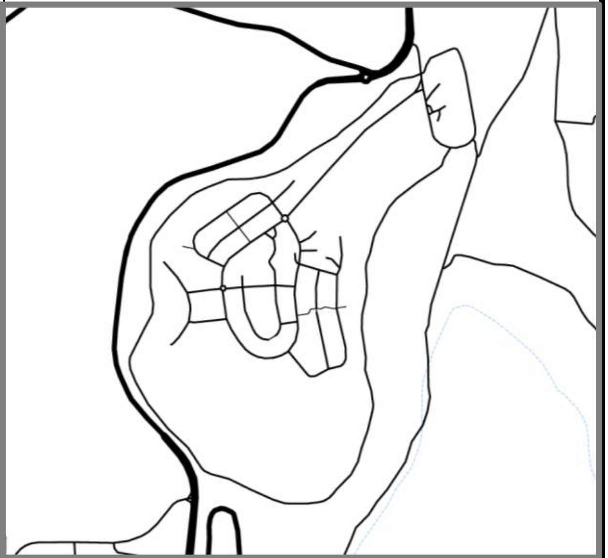
Riomaggiore, Italy

- Type: Medieval/Mediterranean
- Origin: 13th century
- Size: 0.31 km2
- Population: 1,694 (2008)

</td><td>

Moreshet, Israel

- Type: Israeli new town
- Origin: 1996
- Size: 0.36 km2
- Population: 1,200 (2013)

</td></tr>
<tr><td></td><td></td></tr>
<tr><td>

Djenne, Mali

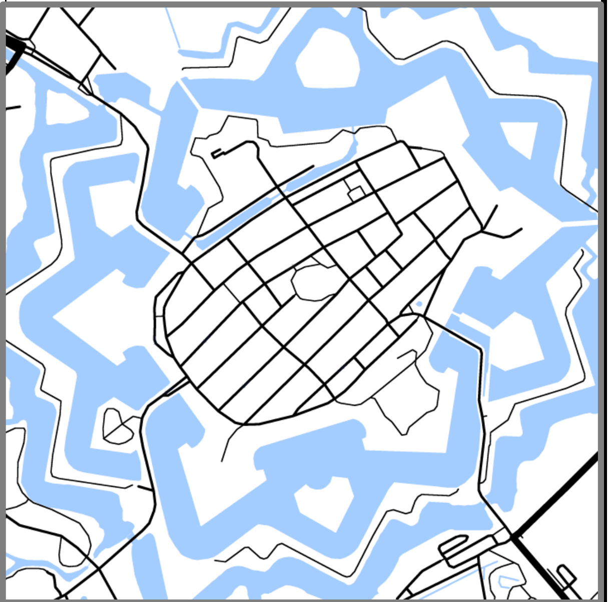
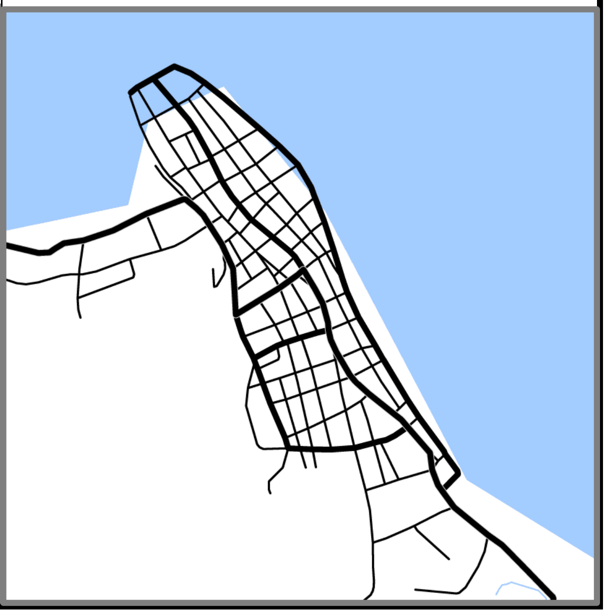
- Type: Muslim/Sudanese city
- Origin: 1000
- Size: 0.63 km2
- Population: 32,944 (2009)

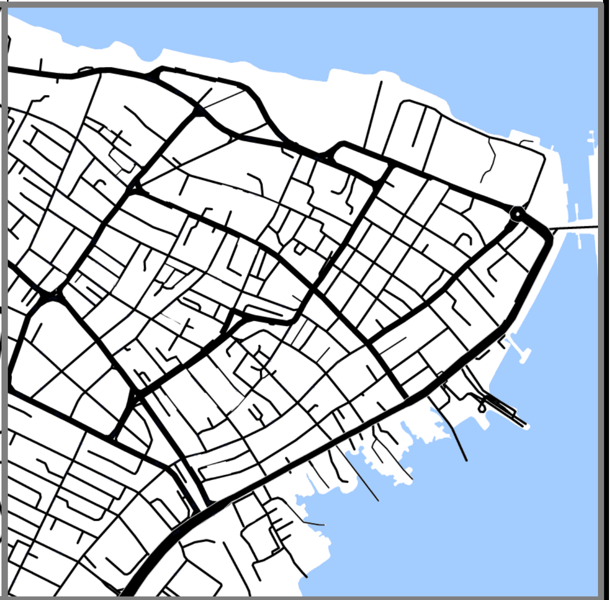
</td><td>

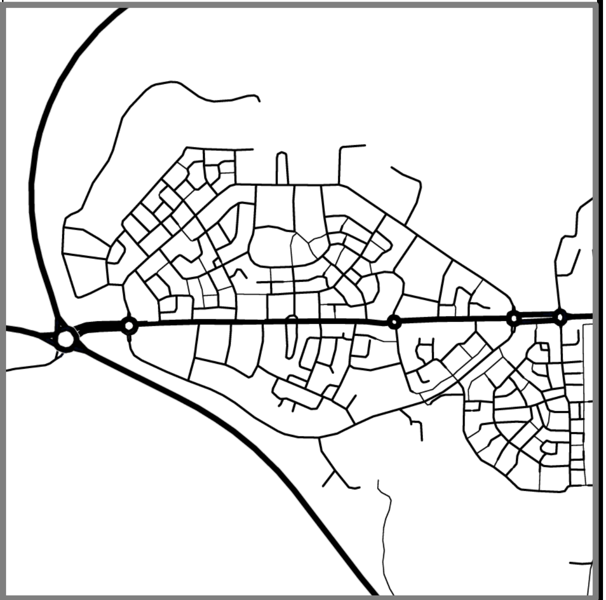
Paris, Place de la Nation, France

- Type: Circle/Radial
- Origin: 1859
- Size: 0.68 km2
- Population: /

</td></tr>
<tr><td></td><td></td></tr>
</table>

BOTTOM-UP cities	TOP-DOWN cities
Avila, Old town, Spain • Type: Roman/Walled • Origin: 5th century BC • Size: 0.67 km2 • Population: /	**Naarden, The Netherlands** • Type: Grid/Star/Walled • Origin: 1350 • Size: 0.54 km2 • Population: 17,204 (2014)
	
Zadar, Old town, Croatia • Type: Roman/Grid • Origin: 2nd century BC • Size: 0.75 km2 • Population: /	**Baracoa, Cuba** • Type: Grid • Origin: 1511 • Size: 0.70 km2 • Population: 81,794 (2001)
	

BOTTOM-UP cities	**TOP-DOWN cities**
Göreme, Turkey • Type: Roman/Byzantine • Origin: 1800-1200 BC • Size: 1.10 km2 • Population: 2,000 (2009)	**Penang, city centre, Malaysia** • Type: Asian new town • Origin: 2005 • Size: 1.20 km2 • Population: /
	
Bucharest, Old town, Romania • Type: Medieval • Origin: 1300 • Size: 1.19 km2 • Population: 18,000 (1825)	**Sibay, residential block, Russia** • Type: Asian NT/Russian new town • Origin: 1913 • Size: 1.24 km2 • Population: /
	

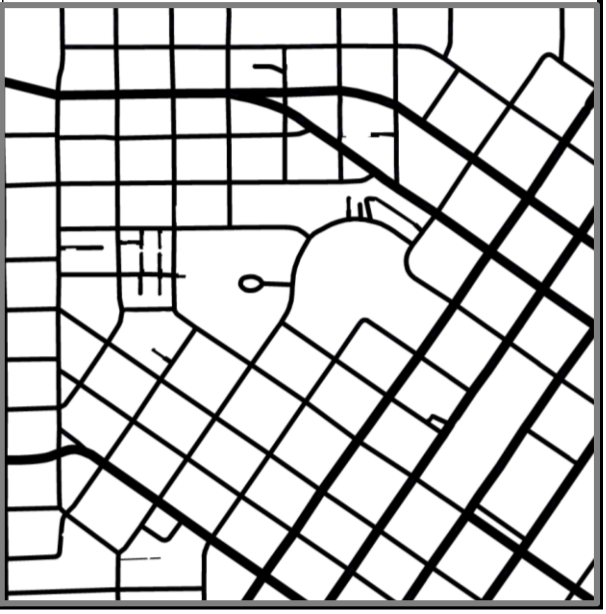
BOTTOM-UP cities	**TOP-DOWN cities**
Rhodes, Old town, Greece • Type: Medieval/Walled • Origin: 408 BC • Size: 1.20 km2 • Population: 6,000 (2009)	**Pondbury, UK** • Type: Organic-like • Origin: 1993 • Size: 1.23 km2 • Population: 6,000 (2010)
	
Jerusalem, Old town, Israel • Type: Isreali city/Walled • Origin: 11th century BC • Size: 1.43 km2 • Population: 36,965 (2007)	**Katy, residential block, USA** • Type: Cul-de-sac • Origin: 2008 • Size: 1.41 km2 • Population: /
	

<table>
<tr><th>BOTTOM-UP cities</th><th>TOP-DOWN cities</th></tr>
<tr><td>Tunis, La Medina, Tunisia

Type: Mulsim city/Roman
Origin: 698
Size: 1.54 km2
Population: 1,000,000 (2005)
</td>
<td>Radburn, residential block, USA

Type: Cul-de-sac/English garden city
Origin: 1929
Size: 1.40 km2
Population: 3,100 (2013)
</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Hanoi, Old quarter, Vietnam

Type: Asian/Vietnamese city
Origin: 1010
Size: 1.74 km2
Population: /
</td>
<td>Houston, residential block, USA

Type: Grid
Origin: 1836
Size: 1.74 km2
Population: /
</td></tr>
<tr><td></td><td></td></tr>
</table>

<table>
<tr><th>BOTTOM-UP cities</th><th>TOP-DOWN cities</th></tr>
<tr><td>Cadiz, Barrio de la vina, Spain
• Type: Grid/Greek/Andalusian
• Origin: 18th century
• Size: 1.90 km2
• Population: /</td><td>Budva, Montenegro
• Type: Greek
• Origin: 500 BC
• Size: 1.80 km2
• Population: /</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Toledo, Old town, Spain
• Type: Roman
• Origin: 59 BC
• Size: 1.91 km2
• Population: /</td><td>Zurich, Old city centre, Switzerland
• Type: Roman
• Origin: 15 BC
• Size: 1.87 km2
• Population: 5,600 (2005)</td></tr>
<tr><td></td><td></td></tr>
</table>

BOTTOM-UP cities	TOP-DOWN cities
Bratislava, Old town, Slovakia • Type: Roman/Medieval • Origin: 13th century • Size: 1.96 km2 • Population: 42,241 (2005)	**Doesburg, The Netherlands** • Type: Roman • Origin: 1237 • Size: 2.00 km2 • Population: 11,447 (2014)
	
Riga, Old town, Latvia • Type: Medieval/Walled • Origin: 1201 • Size: 2.00 km2 • Population: /	**Brazzaville, residential block, DR Congo** • Type: Grid • Origin: 1963 • Size: 1.93 km2 • Population: /
	

BOTTOM-UP cities	TOP-DOWN cities

Sibiu, Old town, Romania

- Type: Medieval/Walled
- Origin: 300 BC
- Size: 2.04 km2
- Population: /

Alexandria, Karmouz, Egypt

- Type: Grid/Roman
- Origin: 292
- Size: 2.10 km2
- Population: /

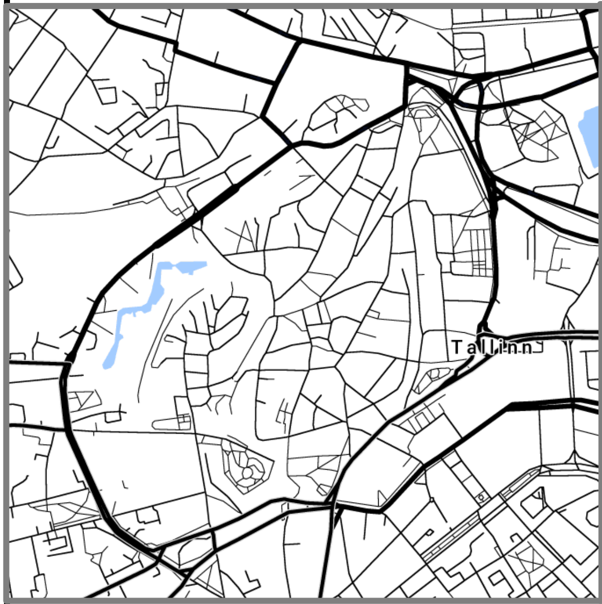
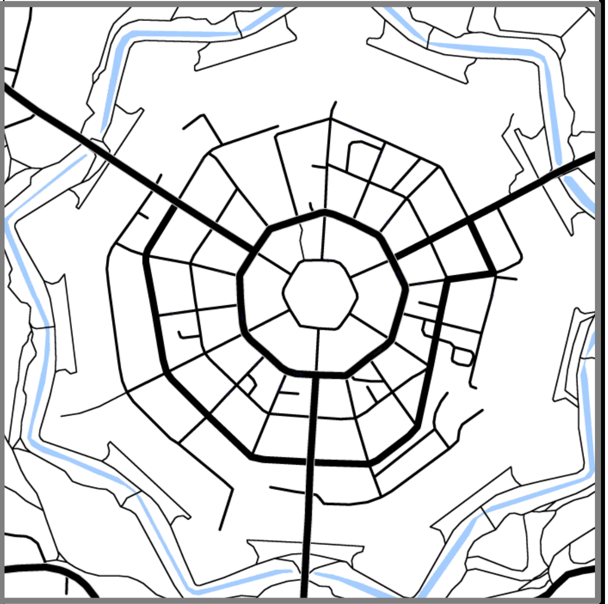
Old Damascus, Syria

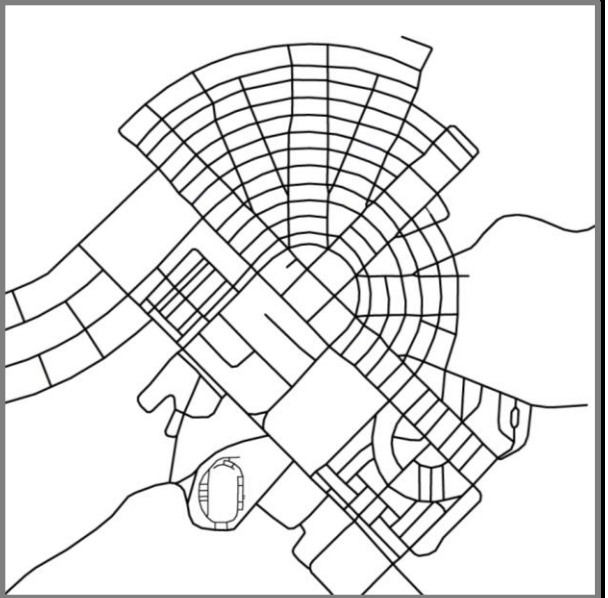
- Type: Greek/Arab city
- Origin: 3000 BC
- Size: 2.14 km2
- Population: /

Los Angeles, residential block, USA

- Type: Grid
- Origin: 1781
- Size: 2.10 km2
- Population: /

<table>
<tr><th>BOTTOM-UP cities</th><th>TOP-DOWN cities</th></tr>
<tr><td>Nicosia, Old town, Cyprus
• Type: Medieval/Circle/Walled
• Origin: 13th century
• Size: 2.30 km2
• Population: /</td><td>Almere, Residential block, NL
• Type: Circle/Radial
• Origin: 1977
• Size: 2.30 km2
• Population: /</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Valencia, Ciutat Vella, Spain
• Type: Medieval
• Origin: 14th century
• Size: 2.63 km2
• Population: 25,788 (2008)</td><td>Kiryat Gat, City centre, Israel
• Type: Israeli development city
• Origin: 1955
• Size: 2.66 km2
• Population: /</td></tr>
<tr><td></td><td></td></tr>
</table>

BOTTOM-UP cities	**TOP-DOWN cities**
Tallinn, Old town, Estonia • Type: Medieval/Walled • Origin: 1284 • Size: 2.66 km2 • Population: /	**Palmanova, italy** • Type: Circle/Radial/Walled • Origin: 1593 • Size: 2.63 km2 • Population: /
	
Prague, Old town, Czech Republic • Type: Medieval • Origin: 9th century BC • Size: 2.69 km2 • Population: /	**Panchkula, Residential block, India** • Type: Cul-de-sac • Origin: 1995 • Size: 2.64 km2 • Population: /
	

<table>
<tr><th>BOTTOM-UP cities</th><th>TOP-DOWN cities</th></tr>
<tr><td>Mytilene, Greece
Type: Greek
Origin: 11th century BC
Size: 2.93 km2
Population: /</td><td>El Salvador, Chile
Type: Circle/Radial
Origin: 1957
Size: 2.90 km2
Population: 24,000 (2000)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Siena, Old town, Italy
Type: Medieval/Renesanse
Origin: 900-400 BC
Size: 3.56 km2
Population: /</td><td>The Woodlands, Panther Creek, USA
Type: Organic-like /Cul-de-sac
Origin: 1976
Size: 3.70 km2
Population: /</td></tr>
<tr><td></td><td></td></tr>
</table>

<table>
<tr><td>BOTTOM-UP cities</td><td>TOP-DOWN cities</td></tr>
<tr><td>Nuremberg, Old town, Germany
• Type: Medieval/Walled
• Origin: 1050
• Size: 3.60 km2
• Population: /</td><td>Washington DC, Lincoln Park, USA
• Type: Grid/Radial
• Origin: 1791
• Size: 3.50 km2
• Population: /</td></tr>
<tr><td></td><td></td></tr>
<tr><td>York, Old town, UK
• Type: Medieval/Roman /Walled
• Origin: 71
• Size: 3.62 km2
• Population: /</td><td>Soledad, USA
• Type: Cul-de-sac
• Origin: 1791
• Size: 3.90 km2
• Population: 25,738 (2010)</td></tr>
<tr><td>
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</td></tr>
</table>

<table>
<tr><th>BOTTOM-UP cities</th><th>TOP-DOWN cities</th></tr>
<tr><td>

Old Delhi, India

- Type: Medieval/Walled
- Origin: 1639
- Size: 4.62 km2
- Population: /

</td><td>

Adelaide, City centre, Australia

- Type: Grid
- Origin: 1836
- Size: 4.90 km2
- Population: /

</td></tr>
<tr><td></td><td>
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<tr><td>

Kavala, Old town, Greece

- Type: Greek
- Origin: 7th century BC
- Size: 6.04 km2
- Population: 54,027 (2011)

</td><td>

Ajax, Residential block, Canada

- Type: Organic-like
- Origin: 1948
- Size: 6.06 km2
- Population: 78,000 (2002)

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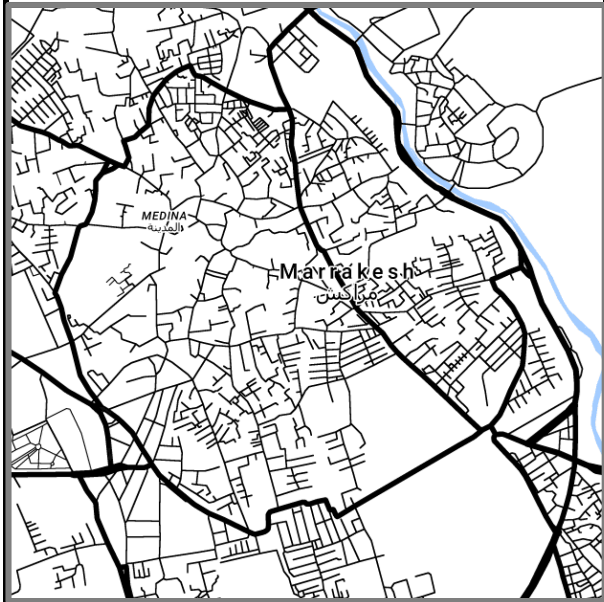
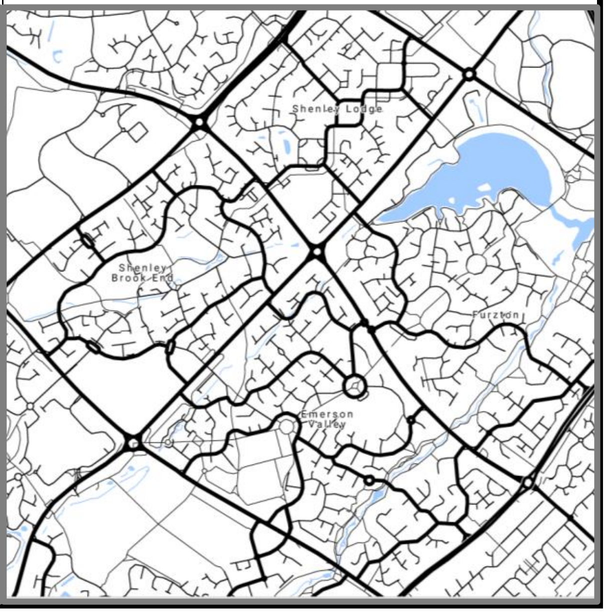
</table>

<table>
<tr><td>BOTTOM-UP cities</td><td>TOP-DOWN cities</td></tr>
<tr><td>Marrakesh, Medina, Morocco
• Type: Muslim/Walled
• Origin: 1070
• Size: 6.65 km2
• Population: /</td><td>Canberra, City centre, Australia
• Type: Radial/Circle
• Origin: 1913
• Size: 6.78 km2
• Population: /</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Vilnius, Old town, Lithuania
• Type: Medieval
• Origin: 13th century
• Size: 7.24 km2
• Population: /</td><td>Milton Keynes, Residential block, UK
• Type: Cul-de-sac/Organic-like
• Origin: 1967
• Size: 7.40 km2
• Population: /</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

<table>
<tr><th>BOTTOM-UP cities</th><th>TOP-DOWN cities</th></tr>
<tr><td>

Sighisoara, Romania

- Type: Medieval
- Origin: 1191
- Size: 8.85 km2
- Population: 26,370 (2011)

</td><td>

Catania, Italy

- Type: Greek/Grid
- Origin: 730 BC
- Size: 8.72 km2
- Population: /

</td></tr>
<tr><td>

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</td></tr>
<tr><td>

Ghent, Old city centre, Belgium

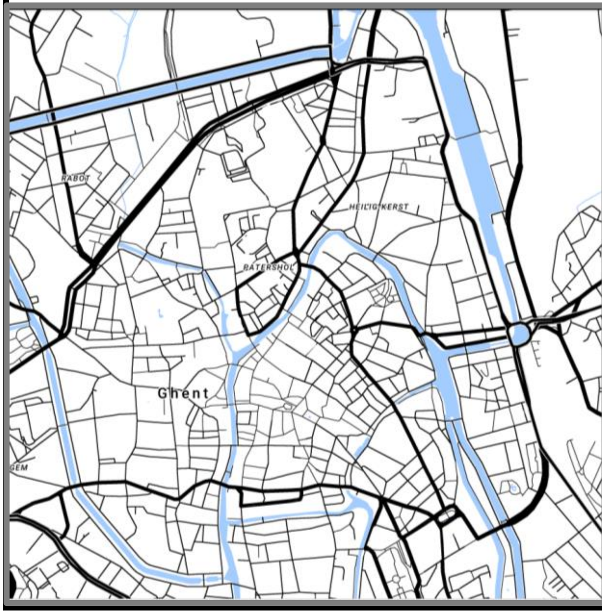
- Type: Medieval
- Origin: 630
- Size: 9.50 km2
- Population: /

</td><td>

Brasilia, residential block, Brazil

- Type: Organic-like/Grid
- Origin: 1957
- Size: 9.20 km2
- Population: /

</td></tr>
<tr><td>



</td><td>

</td></tr>
</table>

<table>
<tr><th>BOTTOM-UP cities</th><th>TOP-DOWN cities</th></tr>
<tr><td>

Bruges, City centre, Belgium

- Type: Medieval/Gothic
- Origin: 1st century
- Size: 10.11 km2
- Population: /

</td><td>

Bet Shemeesh, Israel

- Type: Israeli city
- Origin: 1950
- Size: 10.20 km2
- Population: 66,000 (2005)

</td></tr>
<tr><td>


</td><td>


</td></tr>
<tr><td>

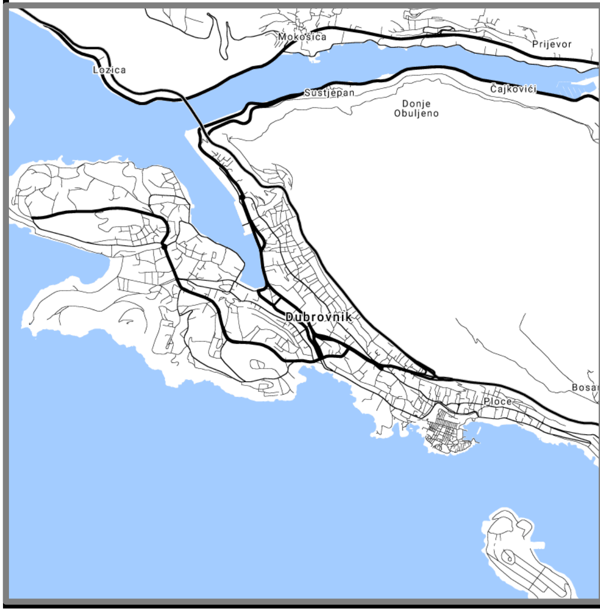
Dubrovnik, Croatia

- Type: Greek
- Origin: 7th century
- Size: 12.66 km2
- Population: 42,615 (2011)

</td><td>

Brondby Strand, Resid. Block, Denmark

- Type: Cul-de-sac
- Origin: 1859
- Size: 0.68 km2
- Population: /

</td></tr>
<tr><td>


</td><td>


</td></tr>
</table>

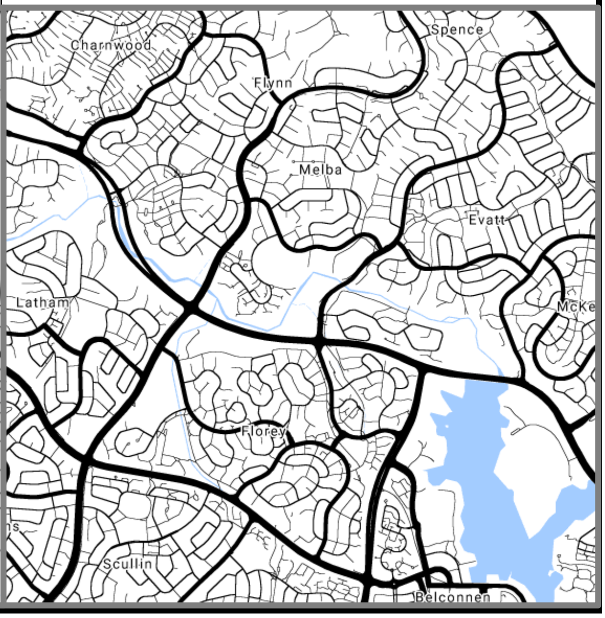
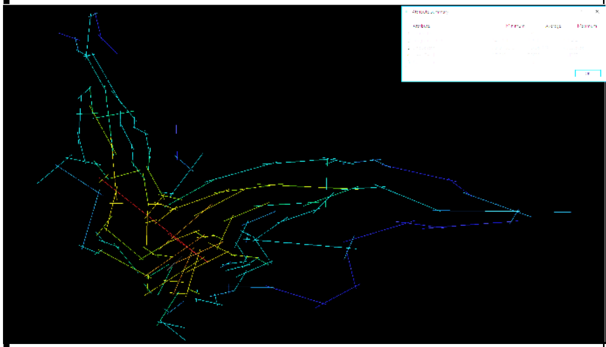
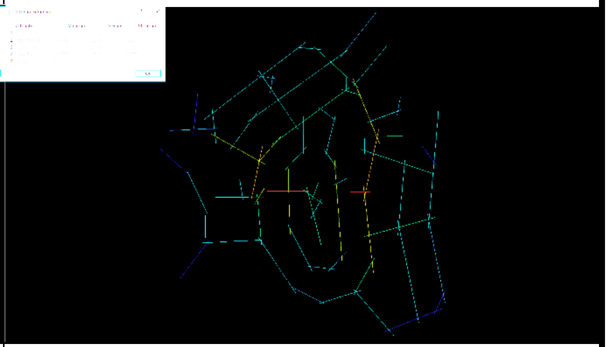
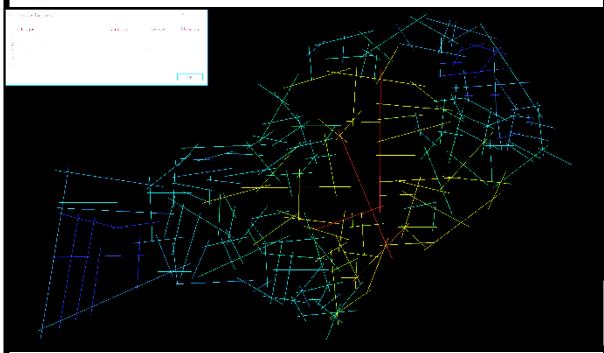
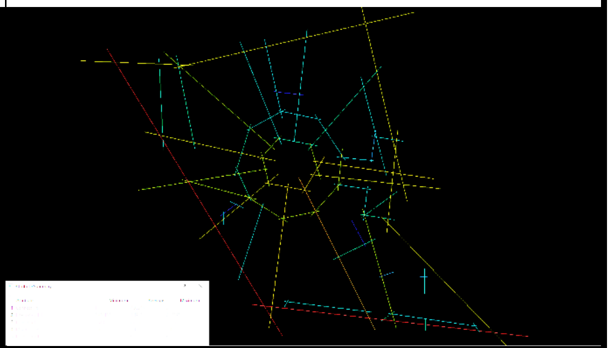
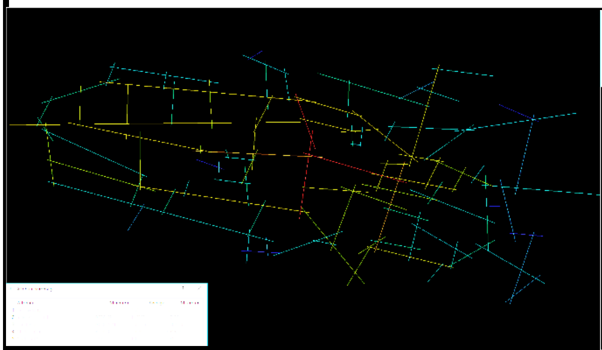
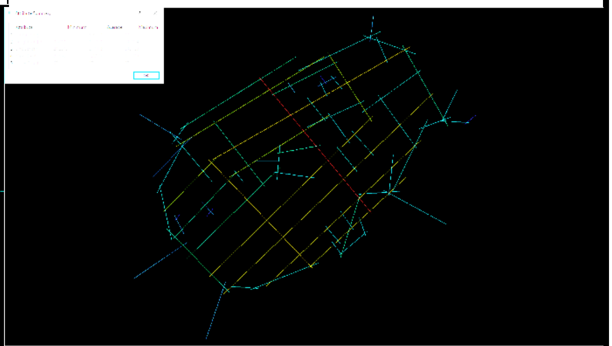
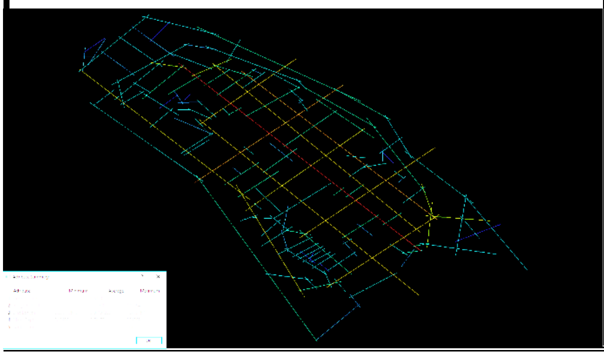
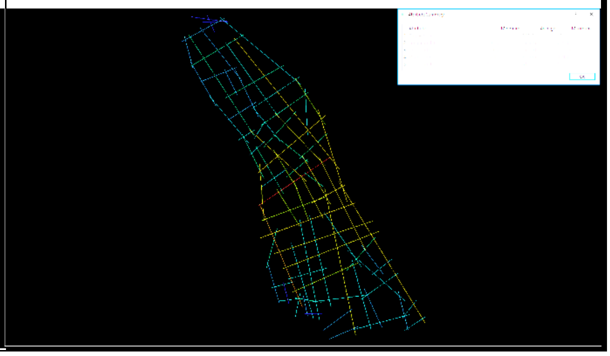
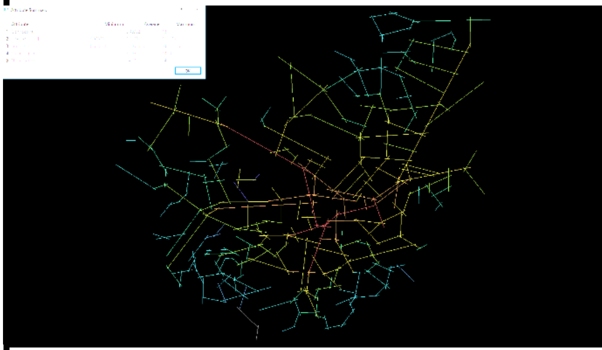
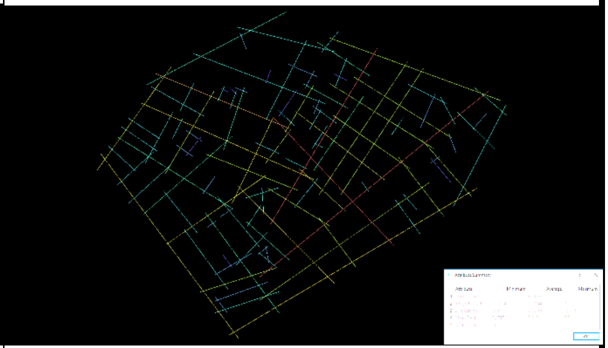
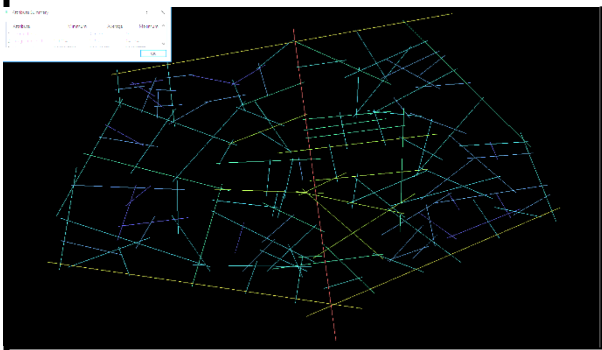
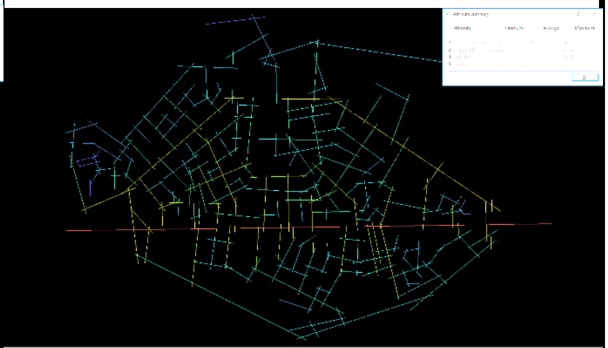
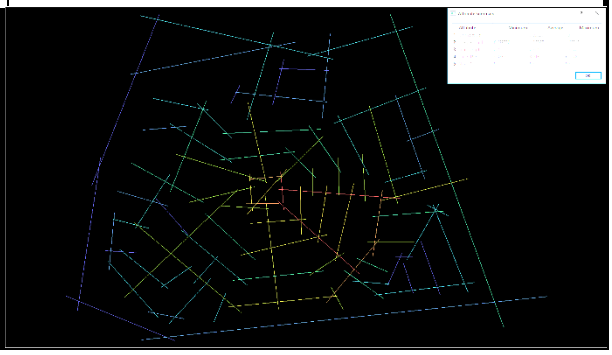
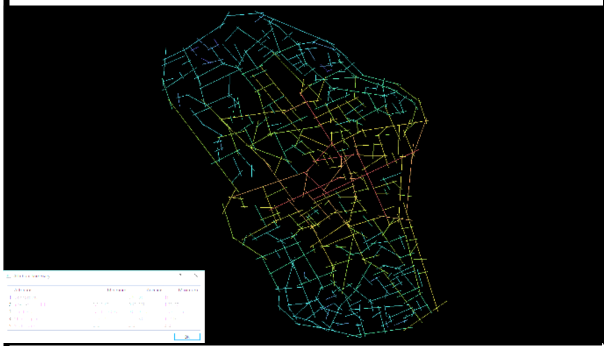
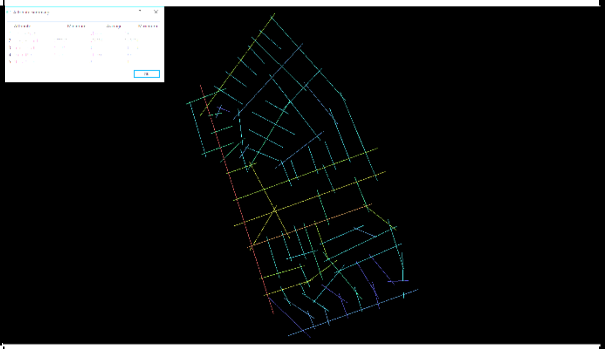
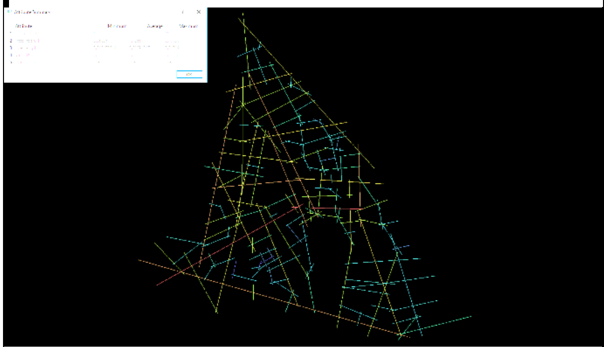
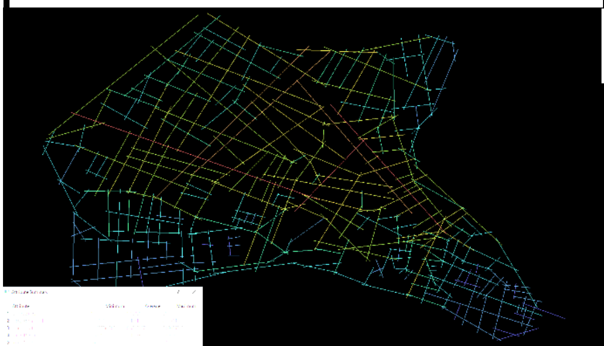
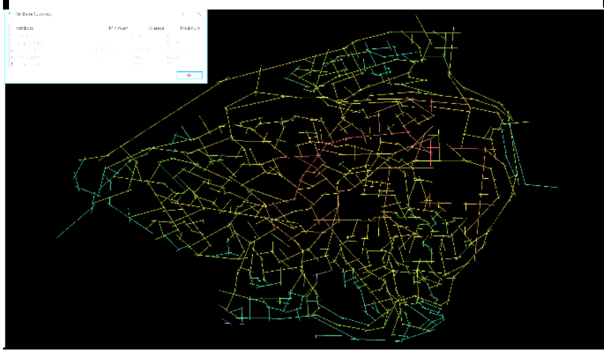
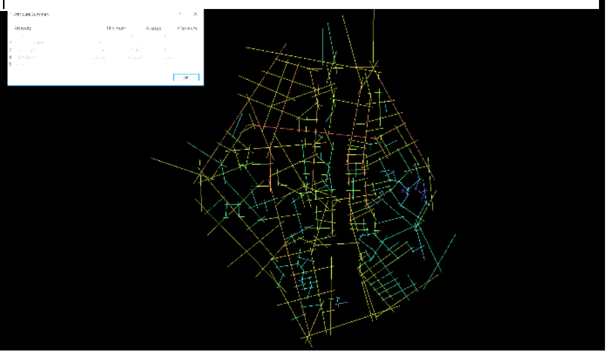
<table>
<tr><th>BOTTOM-UP cities</th><th>TOP-DOWN cities</th></tr>
<tr><td>Agrinio, Greece
• Type: Medieval
• Origin: 1822
• Size: 14.60 km2
• Population: 48,645 (2011)</td><td>Abakan, City centre, Russia
• Type: Grid
• Origin: 1931
• Size: 14.56 km2
• Population: /</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Jericho, Palestine
• Type: Israeli city
• Origin: 9000 BC
• Size: 21.67 km2
• Population: 17,346 (2007)</td><td>Belconnen, Residential block, Australia
• Type: Organic-like/Cul-de-sac
• Origin: 1966
• Size: 21.68 km2
• Population: /</td></tr>
<tr><td></td><td>
</td></tr>
</table>

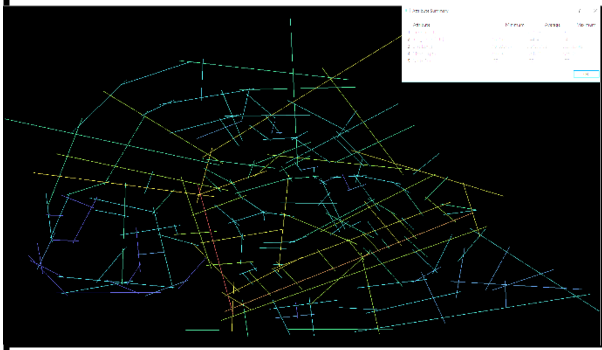
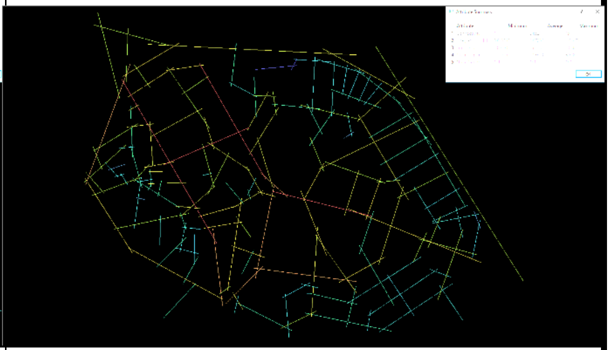
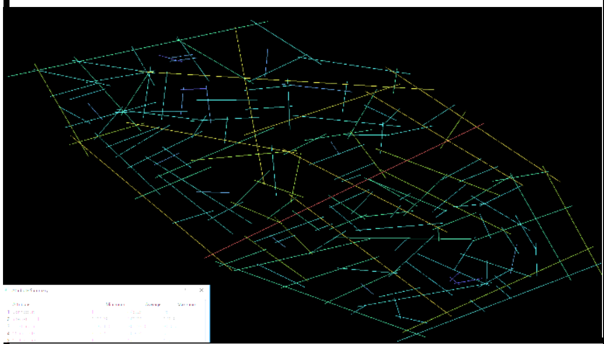
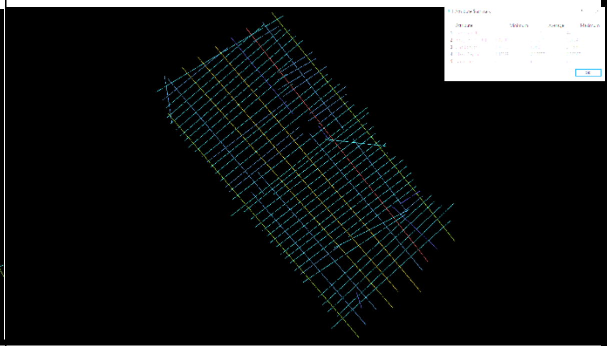
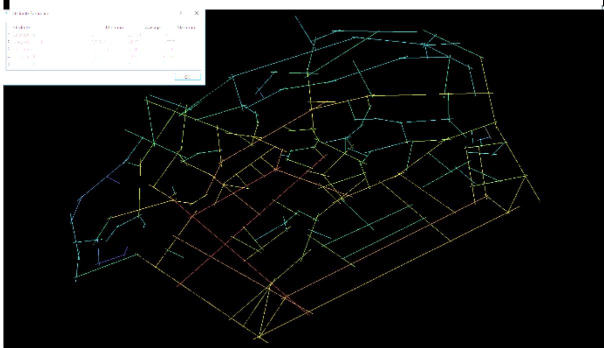
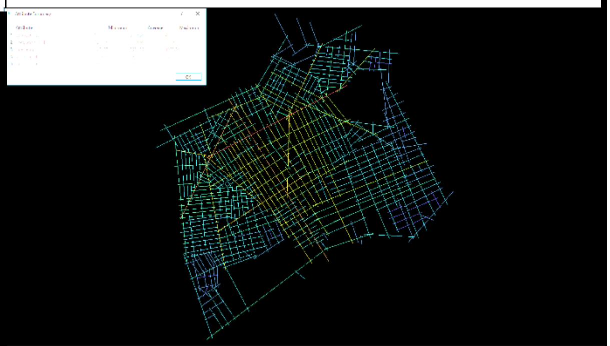
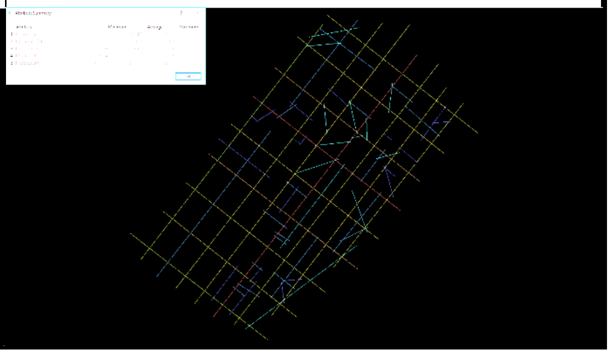
Table 13 – 34 BU-TD city pairs with their general information

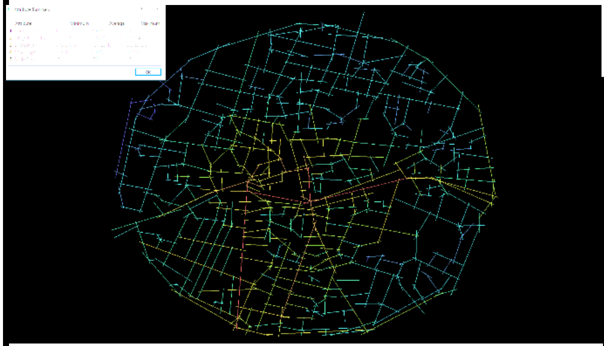
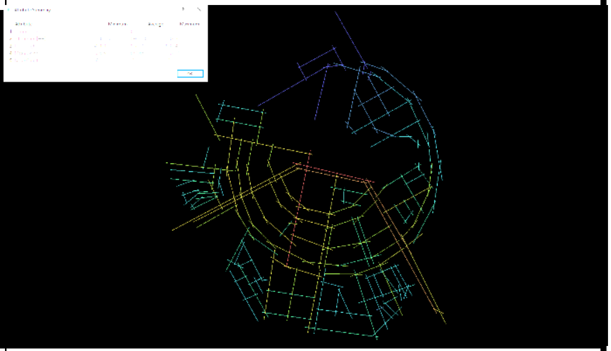
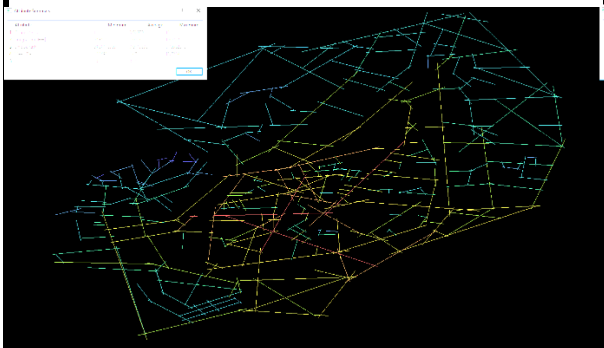
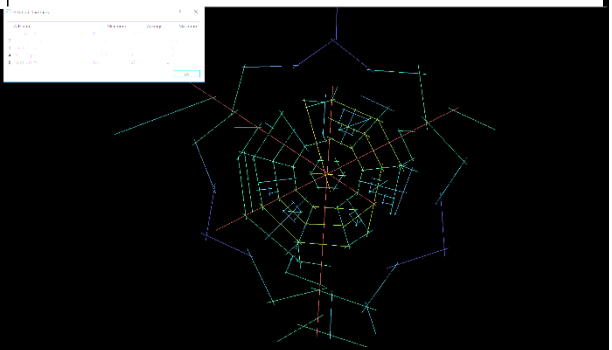
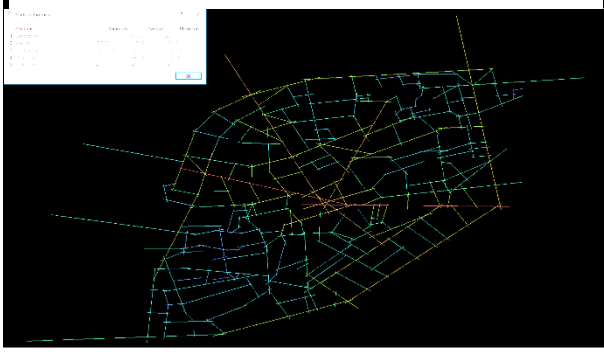
Following table is visual presentation of axial maps and their Integration HH values:

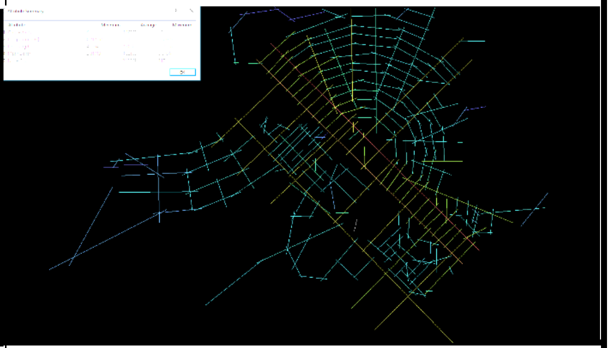
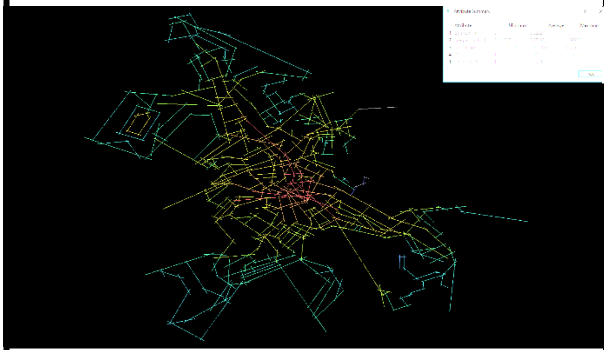
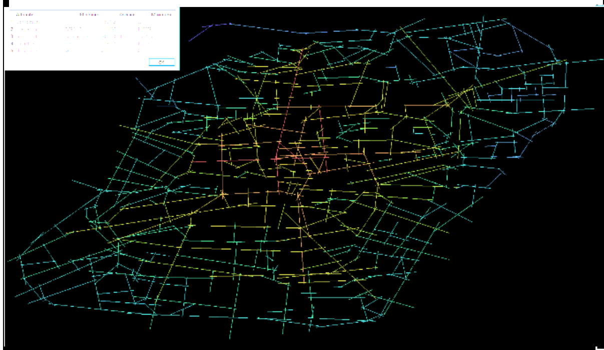
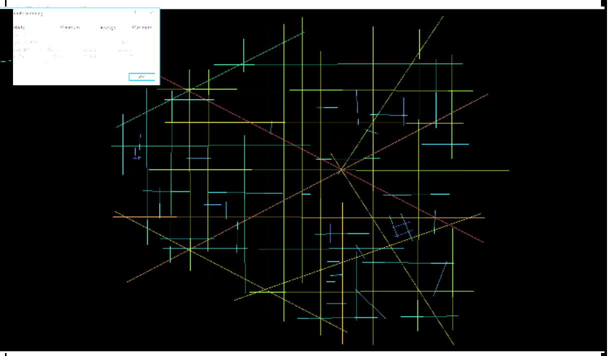
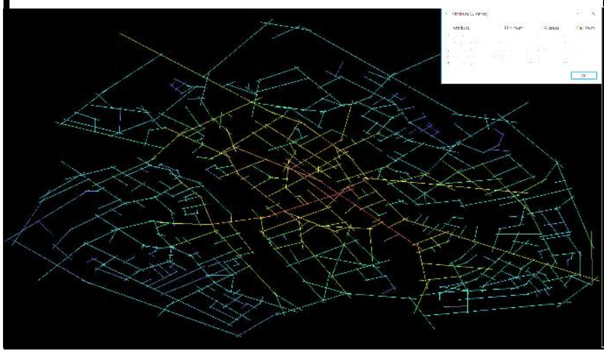
BOTTOM-UP cities	**TOP-DOWN cities**
Riomaggiore, Italy	**Moreshet, Israel**
	
Djenne, Mali	**Paris, Place de la Nation, France**
	
Avila, Old town, Spain	**Naarden, The Netherlands**
	
Zadar, Old town, Croatia	**Baracoa, Cuba**
	

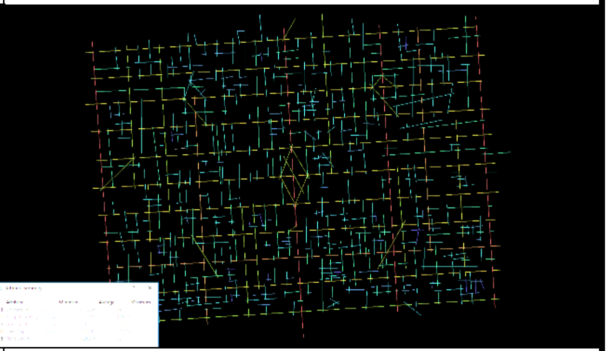
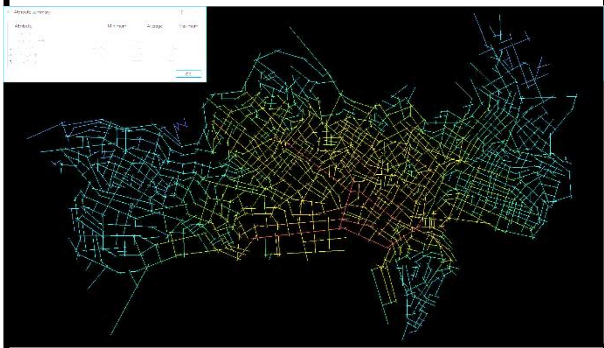
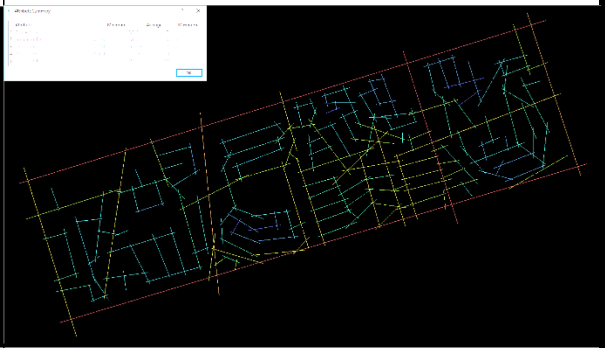
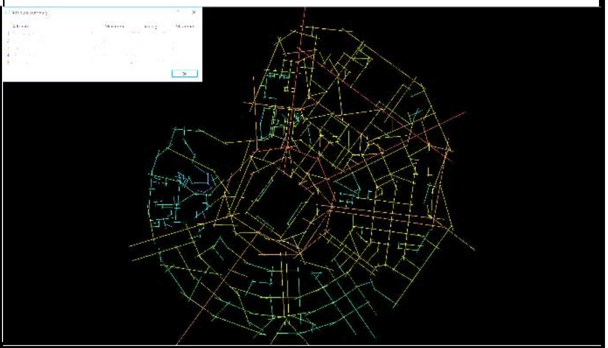
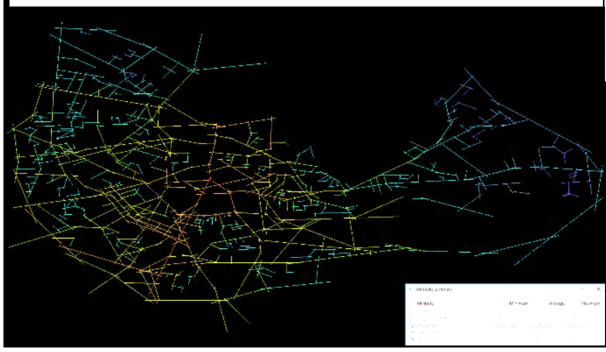
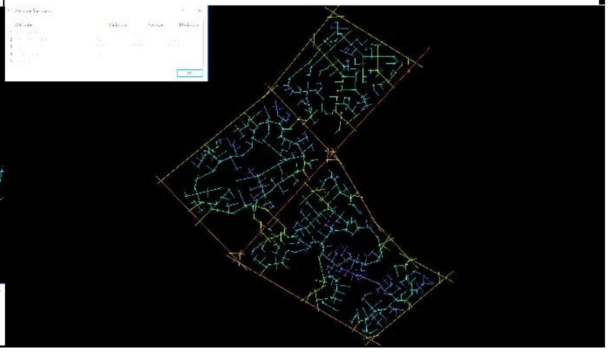
BOTTOM-UP cities	**TOP-DOWN cities**
Göreme, Turkey 	**Penang, city centre, Malaysia** 
Bucharest, Old town, Romania 	**Sibay, residential block, Russia** 
Rhodes, Old town, Greece 	**Pondbury, UK** 
Jerusalem, Old town, Israel 	**Katy, residential block, USA** 

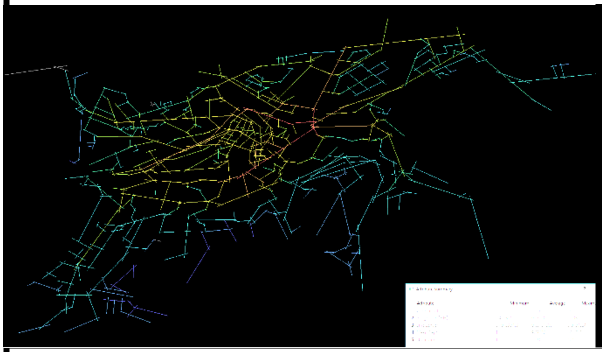
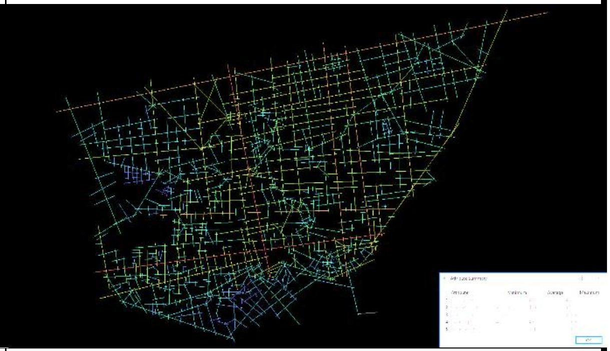
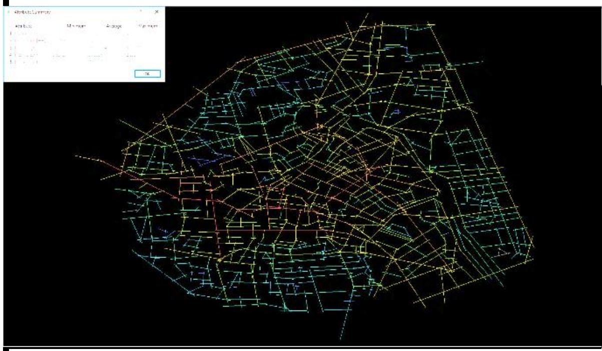
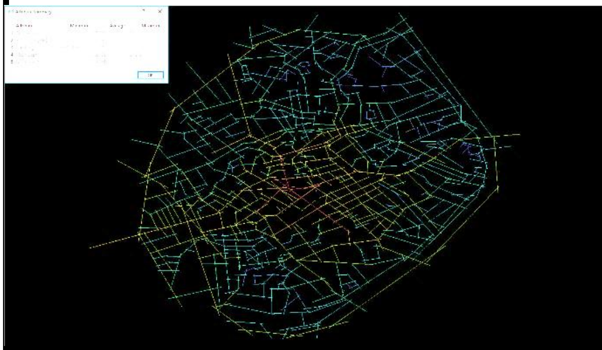
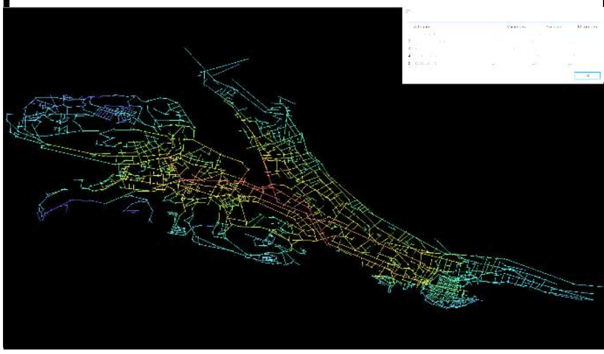
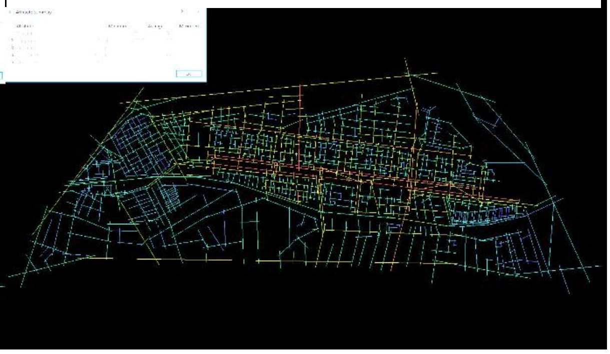
BOTTOM-UP cities	TOP-DOWN cities
Tunis, La Medina, Tunisia	**Radburn, residential block, USA**
	
Hanoi, Old quarter, Vietnam	**Houston, residential block, USA**
	
Cadiz, Barrio de la vina, Spain	**Budva, Montenegro**
	
Toledo, Old town, Spain	**Zurich, Old city centre, Switzerland**
	

BOTTOM-UP cities	TOP-DOWN cities
Bratislava, Old town, Slovakia	**Doesburg, The Netherlands**
	
Riga, Old town, Latvia	**Brazzaville, residential block, DR Congo**
	
Sibiu, Old town, Romania	**Alexandria, Karmouz, Egypt**
	
Old Damascus, Syria	**Los Angeles, residential block, USA**
	

BOTTOM-UP cities	**TOP-DOWN cities**
Nicosia, Old town, Cyprus	**Almere, Residential block, NL**
	
Valencia, Ciutat Vella, Spain	**Kiryat Gat, City centre, Israel**
	
Tallinn, Old town, Estonia	**Palmanova, italy**
	
Prague, Old town, Czech Republic	**Panchkula, Residential block, India**
	

BOTTOM-UP cities	**TOP-DOWN cities**
Mytilene, Greece	**El Salvador, Chile**
	
Siena, Old town, Italy	**The Woodlands, Panther Creek, USA**
	
Nuremberg, Old town, Germany	**Washington DC, Lincoln Park, USA**
	
York, Old town, UK	**Soledad, USA**
	

BOTTOM-UP cities	TOP-DOWN cities
Old Delhi, India	**Adelaide, City centre, Australia**
	
Kavala, Old town, Greece	**Ajax, Residential block, Canada**
	
Marrakesh, Medina, Morocco	**Canberra, City centre, Australia**
	
Vilnius, Old town, Lithuania	**Milton Keynes, Residential block, UK**
	

BOTTOM-UP cities	TOP-DOWN cities
Sighisoara, Romania	Catania, Italy
	
Ghent, Old city centre, Belgium	Brasilia, residential block, Brazil
	
Bruges, City centre, Belgium	Bet Shemeesh, Israel
	
Dubrovnik, Croatia	Brondby Strand, Resid. Block, Denmark
	

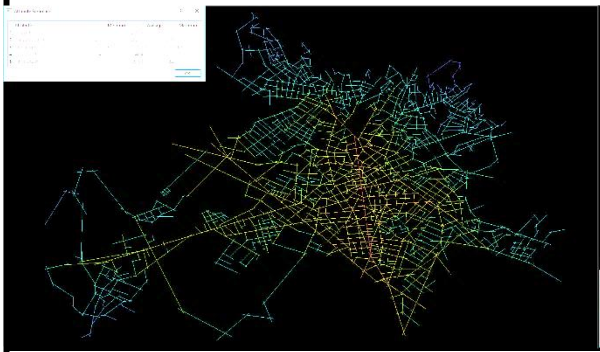
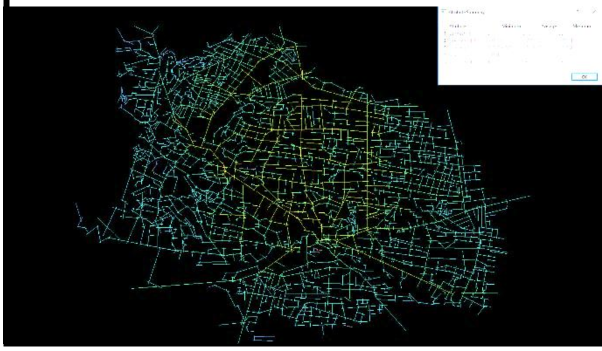
BOTTOM-UP cities	TOP-DOWN cities
Agrinio, Greece	**Abakan, City centre, Russia**
	
Jericho, Palestine	**Belconnen, Residential block, Australia**
	

Table 14 - 34 BU-TD city pairs presented with axial maps and integration HH levels

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