

Measuring Multifunctionality of Urban Area

Bekim Kajtazi
May, 2007

Measuring Multifunctionality of Urban Area

by

Bekim Kajtazi

Thesis submitted to the International Institute for Geo-information Science and Earth Observation in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation, Specialisation: Urban Planning Management

Thesis Assessment Board

Chairman:	Dr. R.V. (Richard) Sliuzas, Associate Professor
External examiner:	Dr. S.C.M. (Stan) Geertman, Associate Professor, University Utrecht
First supervisor:	Dr.Ir. L.G.J. (Luc) Boerboom, Assistant Professor
Second supervisor:	Ms. MSc. (Monika) Kuffer, Lecturer



**INTERNATIONAL INSTITUTE FOR GEO-INFORMATION SCIENCE AND EARTH OBSERVATION
ENSCHEDÉ, THE NETHERLANDS**

Disclaimer

This document describes work undertaken as part of a programme of study at the International Institute for Geo-information Science and Earth Observation. All views and opinions expressed therein remain the sole responsibility of the author, and do not necessarily represent those of the institute.

Abstract

Multifunctional land use planning has been introduced as a new planning concept in the late 1990s. It is of the newest concept and not all advantages and disadvantages are known. Therefore, many researches address the issue of multifunctionality with the objective to identify the possible causes and effects from it.

Multifunctional land use planning as a concept addresses the issues of inefficient use of space, dependency of people to travel by car and urban sprawl. However this is not the first concept that addresses these issues. Other planning concepts such as New urbanism, Smart Growth and Compact City are very similar to Multifunctional Land Use (MLU) planning. Therefore, there slightly older concepts can be used to help understand completely MLU.

For studying the possible advantages and disadvantages, a number of researches have addressed the problem of quantifying the MLU. However, only one research has made a real attempt to measure MLU spatially. This research addresses the problem of identifying the spatial indicators for measuring the multifunctionality of urban area. Furthermore, a new method for measuring the multifunctionality is introduced. The method is developed based on the MLU as a planning concept and as a empirical phenomenon of agglomeration of activities.

Spatial indicators *Distance*, *Density*, *Diversity* and *Time* are used to measure and visualize multifunctionality of urban area. In addition the patterns multifunctionality are visualized and the potential for further increase identified.

Acknowledgements

Finally I reached the end of a long road. A road that for me has been a difficult one. Being far from home for a long time, I missed a lot of things. But, I knew the importance and finally I am accomplishing something, for what there are many people I have to thank for.

First of all, I would like to express my gratitude to the Netherlands and in particular to the ITC as an institution for giving me the opportunity to come and study in one of the best places that one can wish for. For about 20 months of my stay here, I have transformed from a “knowing everything guy” to a very open minded, able to listen and learn person. I may have not become a scientist, but at least I learned how to become one in the future.

For all the skills and knowledge that I gained in ITC, I would like to thank to my lecturers Drs. Hofstee, Dr. McCall, Drs. de Meijere, Dr. Sliuzas and all staff of UPLA programme. For continues support and interest for my study and research I would like to thank from the bottom of my heart to programme director Drs. Emile Dopheide and Dr. Ali Sharifi.

While writing thesis I had faced many difficulties. Starting from reading an article, absorbing the required information and write about what I learned. And not to forget my scientific writing that was far from good. For all that I know its merits of my supervisors, Dr. Luc Boerboom and MSc. Monika Kuffer. Your support, understanding and guidance were beyond anything I could imagine, and only than'x to both you I managed to be where I am now.

During my stay in ITC i had met a lot of friends for all around the world. I would like to thank all of them for the friendship and joy they brought to me especially UPLA 2005 fellows, Thomas, Germain, Ginella, Javier and all of you wherever you are. I would like to give a special thanks to the friends that gave me a strong support during my research. Liton, your moral support, friendship and chatting has helped me during all time, I was missing your critiques during last weeks of my stay. How can I forget my Dutch friend who always expressed concerns and gave moral support to me, Yvet thank you very much for friendship and time. Also I would like to extend my thanks to Basak and Nesrin for strong support and friendship during my last months of stay in ITC.

Last but not least, I would like to thank my parents who always had faith on me. To my sisters and brother who I missed very much all this time. And to my dear grandfather and my best uncle who I will not find when I go back, I hope you are in the best place.

Table of contents

1.	Introduction	1
1.1.	Background	1
1.2.	Research Problem.....	4
1.3.	Research Objectives	5
1.4.	Research Questions	5
1.5.	Conceptual Framework	6
1.6.	Thesis Structure.....	6
2.	Multifunctional Urban Land Use	9
2.1.	Emergence of Multifunctional Urban Land Use as Planning Concept.....	9
2.1.1.	Multifunctional Urban Land Use Function, Activities and Accessibility	13
2.2.	Multifunctional Urban Land Use – Planning Concept and Empirical Phenomenon.....	14
2.3.	Displaying Multifunctional Urban Land Use	19
2.3.1.	Classification of activities	21
2.3.2.	Density of Activities.....	22
2.3.3.	Diversity of Activities	22
2.3.4.	Distance between Urban Activities	25
2.3.5.	Time interval of access to activities	25
2.4.	Conclusions	25
3.	Methodology	29
3.1.	GIS and Multifunctional land use planning.....	29
3.2.	Measuring Indicators of Multifunctional Urban Land Use	30
3.2.1.	Classification of Urban Activities	30
3.2.2.	Measuring Accessibility to Non-Residential Urban Activities	30
3.2.3.	Measuring Density of Urban Activities.....	31
3.2.4.	Measuring Diversity of Land Use Functions.....	32
3.2.5.	Time Indicator	35
3.3.	Agglomeration of Economic Activities.....	36
3.4.	Selection of Study Area.....	36
3.5.	Data Collection.....	37
3.5.1.	Primary Sources	38
3.5.2.	Secondary Sources	42

3.5.3.	Checklist of collected data.....	42
3.5.4.	Data processing	43
3.6.	Spatial Analysis	44
4.	Case Study	45
4.1.	Background of study area	45
4.2.	Study area in the context of multifunctional land use planning.....	46
5.	Spatial Analysis	49
5.1.	Uniform Service Areas	49
5.2.	Proximity of activities from residential areas.....	50
5.3.	Measuring the density of activities	51
5.4.	Measuring the diversity of Activities	55
5.4.1.	Richness.....	55
5.4.2.	Evenness	56
5.4.3.	Batty <i>et al.</i> Index of Density-Diversity.....	57
5.4.4.	Simpson’s Index of Diversity	59
5.4.5.	Shannon-Wiener Index of Diversity	60
5.5.	Measuring Multifunctionality over time.....	62
5.6.	Visualization of Diversity.....	64
5.7.	Conclusions	65
6.	Discussion and Conclusions	67
6.1.	Summary.....	67
6.2.	Discussion.....	68
6.3.	Conclusions	70
6.4.	Recommendations for further research.....	72
7.	References	73
8.	Appendices	75
8.1.	Appendix I - International Standard Industrial Classification of all Economic Activities	75
8.2.	Appendix II – Structure of ISIC for Education activity	77
8.3.	Appendix III - Questionare for Geodatabse.....	79
8.4.	Appendix IV – GIS model for measuring distance Indicator	83
8.5.	Appendix V – GIS Model for measuring Richness	85
8.6.	Appendix VI – GIS Model for measuring diversity	87

List of figures

Figure 1-1. Relationship between gasoline consumption and urban density (Dobbelsteen and Wilde, 2004)	2
Figure 1-2 Different forms of multifunctional land use (Dobbelsteen and Wilde, 2004)	3
Figure 1-3. Schematic representation of Conceptual Framework	6
Figure 2-1. Visual description of Land use, function and activity	14
Figure 2-2. Effect from clustering of economic activities.....	17
Figure 2-3. Relation between demand and supply factors, spatial functions	18
Figure 2-4. Model for measuring compactness and sustainability of cities with the relations between the variables.....	21
Figure 2-5. The difference between Richness and Evenness	23
Figure 2-6. Normalized values for Shannon-Wiener Index and Simpson's Index of diversity	24
Figure 2-7. Segregated Neighbourhood	26
Figure 2-8. Multifunctional Neighbourhood	26
Figure 2-9. The effects of changing the smoothing parameter (Batty et al., 2004)	27
Figure 2-10. Increase in degree of interweaving (Rodenburg and Nijkamp, 2004)	28
Figure 2-11. Decrease in degree of spatial heterogeneity (Rodenburg and Nijkamp, 2004)	28
Figure 2-12. Defined latent variables for the compact city and urban sustainability (Lin and Yang, 2006)	28
Figure 3-1. Fushë Kosova in Regional context (Not to scale)(Source: Urban+, 2003).....	36
Figure 3-2. Buildings on main street in 2003	37
Figure 3-3. Building in same location in 2006	37
Figure 3-4. Methods of data collection	38
Figure 3-5. Streetscape in location <i>Alpha</i>	38
Figure 3-6. Streetscape in location <i>X-ray</i>	38
Figure 3-7. Streetscape in location <i>Yankee</i>	38
Figure 3-8. Location where streetscape pictures were taken.....	39
Figure 3-9. Vision of future development in 3D	40
Figure 3-10. Data conversion flow	44
Figure 4-1. Satellite image of study area with surrounding	45
Figure 4-2. Aerial view of Fushë Kosova	46
Figure 4-3. Migration of population in Fushë Kosova (Urban+, 2003)	46
Figure 4-4. Reasons to move to Fushë Kosova (Urban+, 2003)	46
Figure 5-1. Activity with catchment area (Not to scale)	49
Figure 5-2. Intersection of catchments (Not to scale)	49
Figure 5-3. Activities and Catchment form USAs	50
Figure 5-4. Catchment of activities and buildings.....	50
Figure 5-5. Buildings in relation with catchment areas.....	50
Figure 5-6. Distribution and amount of activities over the urban area.....	51
Figure 5-7. The number of USA compared to the total area per division of activities	52
Figure 5-8. Patterns of Division A - Agriculture, hunting and forestry	53
Figure 5-9. Patterns of Division D - Manufacturing	53
Figure 5-10. Patterns of Division F - Construction	53

Figure 5-11. Patterns of Division G - Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	53
Figure 5-12. Patterns of Division H - Hotels and restaurants	53
Figure 5-13. Patterns of Division I - Transport, storage and communications	53
Figure 5-14. Patterns of Division K - Real estate, renting and business activities	54
Figure 5-15. Patterns of Division L - Public administration and defence; compulsory social security	54
Figure 5-16. Patterns of Division M - Education	54
Figure 5-17. Patterns of Division N - Health and social work	54
Figure 5-18. Patterns of Division O - Other community, social and personal service activities	54
Figure 5-19. Patterns of Division NA - No Activity	54
Figure 5-20. Richness of activities for urban area	56
Figure 5-21. Evenness of activities for urban area (Natural Breaks classification)	57
Figure 5-22. Diversity of urban area based on Batty et. al. method.	58
Figure 5-23. Diversity of urban area based on Batty et al by standard deviation.....	58
Figure 5-24. Diversity of urban based on Simpson's Index of diversity	59
Figure 5-25. Diversity of urban based on Simpson's Index of diversity by standard deviation.....	60
Figure 5-26. Diversity of urban area based on Shannon-Wiener Index	61
Figure 5-27. Diversity of urban area based on Shannon-Wiener Index by standard deviation	61
Figure 5-28. Diversity of evening activities with density-diversity index (Batty et al., 2004)	62
Figure 5-29. Diversity of evening activities with Simpson's index of diversity	63
Figure 5-30. Diversity of evening activities with Shannon-Wiener index of diversity	63
Figure 5-31. Distribution of Density values	65
Figure 5-32. Distribution of Batty et al. Index values	65
Figure 5-33. Distribution of Richness values	65
Figure 5-34. Distribution of Simpson's Index values.....	65
Figure 5-35. Distribution of Evenness values	65
Figure 5-36. Distribution of Shannon-Wiener Index values	65

List of tables

Table 1-1. Time of emerging of new planning concepts and their spatial level (based on Vreeker, 2004)	3
Table 2-1. Similarities and differences between various mixed and compact land use concepts (Vreeker et. al. 2004).....	12
Table 2-2. Possible advantages and disadvantages of mixed and compact land use (Vreeker, 2004). ..	16
Table 2-3. Hypothetical example for calculating Shannon-Wiener and Simpson's Index.....	24
Table 2-4. Similarities for measuring and representing multifunctional land use.....	27
Table 3-1. Classification of activity by ISIC – example of education	30
Table 3-2. Biology Taxonomy compared to ISIC structure	33
Table 3-3. Influence of rare activity in index of diversity.....	34
Table 3-4. List of interviewed persons with insight to the research.....	41
Table 3-5. List of collected non-spatial data and their sources	42
Table 3-6. List of collected spatial data and their sources	43
Table 4-1. Number of houses and population for Fushë Kosova (Urban+, 2003)	45
Table 5-1. Classification of activities in Divisions based on ISIC structuring list.....	52
Table 5-2. Comparison of spatial data visualizing methods in ArcGIS (Mitchell, 1999).....	64

List of equations

Equation 2-1. Density-Diversity Index (Batty et al., 2004)	23
Equation 2-2. Simpson's Index	23
Equation 2-3. Shannon-Wiener Index of Diversity	24
Equation 2-4. Maximum standardization. Benefit criteria (Sharifi et al., 2004)	24
Equation 3-1. Density-Diversity Index (Batty et al., 2004)	33
Equation 3-2. Simpson's Index	34
Equation 3-3. Contribution of an activity to diversity of area	34
Equation 3-4. Simpson's Index of Diversity	34
Equation 3-5. Shannon-Wiener Index of Diversity	34

1. Introduction

This chapter discusses the background of research, research problem, research objectives, research questions and research method. This research attempts to develop a method that would measure the multifunctionality of urban areas. This method describes the spatial indicators used to measuring and the methods for visualizing multifunctionality.

1.1. Background

In the last decades scholars around the world started to write about the problems that cities around the world face are result of planning concepts that does not serve its purpose. Many cities around the world suffer from traffic congestion, air pollution, uneconomic use of space, and so on. Among the first scholars to write about these problem of the cities was Jane Jacobs (Batty et al., 2004).

In the book “*The Death and Life of Great American Cities*” Jacobs (1961) criticize the concept developed in the early 20th century by architects of Congres International d’Architecture Moderne (CIAM) organization. The CIAM was established in 1928 by a group of architects who were lead by French architect Le Corbusier. The objective of CIAM was to address the issues of cities that were facing the problems of overcrowdings and poor living environment. The most important outcome was the drafting of the *Athens charter* in 1933 which served as the tool for planning and redevelopment of cities around the world. The document promoted urban planning that spatially separated the residential area, working and commercial areas from each other (Jacobs, 1961). Because of the distances that people needed to travel, the use of car became more popular. As a result the cities were big in size often occupying space with very low density (Batty et al., 2004).

While Jacobs (1961) mainly expressed concerns for North American cities and called for return to traditional form of urban development, in Europe the concerns were being raised about the urban sprawl and diseconomies of it (Batty et al., 2004; Torrens and Alberti, 2000). Many cities in Europe and around the world already realize that further sprawl results with social, economic, and environmental issues, or simply no longer physically possible (Dobbelsteen and Wilde, 2004). The low density development is directly connected with social and environmental problems of the cities (Kenworthy and Newman, 1987) (cited in Dobbelsteen and Wilde, 2004).

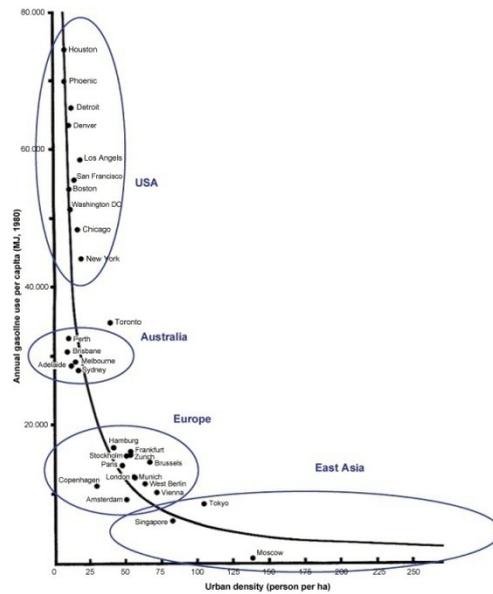


Figure 1-1. Relationship between gasoline consumption and urban density (Dobbelsteen and Wilde, 2004)

Last decades marked the development of new planning concepts which emerge mainly in North America and Europe. The concepts of mixed and compact land use development were introduced. In United States new planning concept called *New Urbanism* was used to improve quality of neighbourhoods which started in 1980. In Europe was published the Green Paper on the Urban Environment (EC, 1990) where issues of urban sprawl, traffic congestion, inadequate infrastructure, pollution were addressed.

Among the first planning concepts that addresses urban sprawl and mixed land use is *New Urbanism*. This mainly North American concept considers design and planning as essentials for high-quality development of neighbourhoods. Neighbourhoods are based on short walking distances and contain mix of housing, and work environments (CNU, 2001). Parallel to this planning concept, the *Smart Growth* concept emerged in 1990s. Smart Growth addresses three inter-related issues of the density of urban development, the spatial separation of land use functions, and the relation between land use, mobility patterns and transport mode choice. The proposed solutions include urban infill development, mixing land use functions and the creation of transit and pedestrian-friendly environments (APA, 1999). Both *New Urbanism* and *Smart Growth* are concepts that try to deal with problems of the cities by suggestion same or similar solution. The difference in the two is the scale they deal with. The *New Urbanism* is more focused in neighbourhood level, while *Smart Growth* concentrates in neighbourhood and city level.

The concerns of increasing urban sprawl and its negative effects were addressed in the European Council Green Paper published in 1990. This lead to a new planning concept known as *Compact City* which is similar to *Smart Growth* is planning concept (EC, 1990; van der Valk, 2002; Vreeker, 2004). The *Compact City* promotes urban infill development, mixing land use functions and the creation of pedestrian-friendly environments in neighbourhood, city and regional level. In addition to the *Compact City* a new planning concept that emerged in Europe is *Multifunctional Land Use* planning concept. Besides the similarities between these two European there are few differences. *Multifunctional Land Use* is focused in creation of synergies between the different land use functions and the spatial scale is based on building, neighbourhood and city level.

Table 1-1. Time of emerging of new planning concepts and their spatial level (based on Vreeker, 2004)

	New Urbanism	Smart Growth	Compact City	Multifunctional Land Use
Year	1980	1990	1990	1990
Spatial Level	Neighbourhood	Neighbourhood and City	Neighbourhood, City and Urban Region	Building, Neighbourhood, and City

Multifunctional land use combines different activities on the same area. The combination of different activities is possible in horizontal dimension by sharing the space for more than one function. In vertical dimension by building different functions one over the other, and fourth dimension by changing the function over time (Dobbelsteen and Wilde, 2004). The combination increases the density and diversity of activities within a building, neighbourhood and city (Batty et al., 2004). These combination of activities and multifunctional land use have been studied as an empirical phenomenon of clustering of commercial activities (Vreeker et al., 2004) and as a planning concept (Burton, 2001; Lin and Yang, 2006; Priemus and Hall, 2004; Rodenburg, 2006).

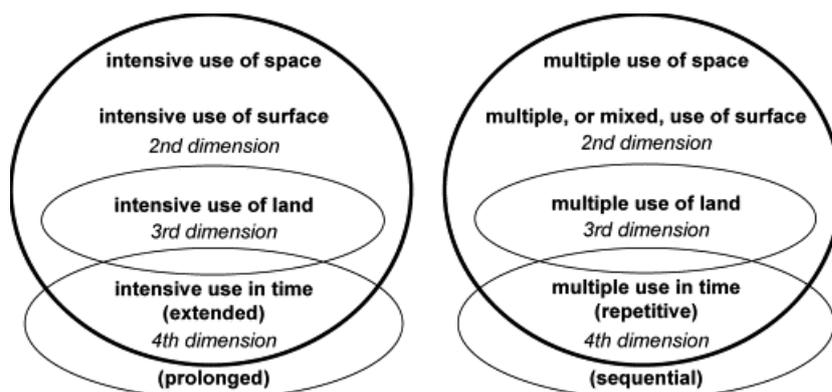


Figure 1-2 Different forms of multifunctional land use (Dobbelsteen and Wilde, 2004)

Multifunctional land use can be seen as an empirical phenomenon of agglomeration of economic activities within urban area (Vreeker et al., 2004). Economic activities cluster in space due to the benefits they have. The benefits are created as a result of knowledge spill over and share in price of infrastructure and other required services (Vreeker et al., 2004). It can, moreover, be used as a planning concept, which addresses the planning challenge to concentrate and combine several socio-economic functions (Housing, recreation, commerce, etc.) in the same area, to save scarce space and to exploit economies of synergy.

Multifunctional Land Use as a planning concept is relatively new. It aims to address issues like to minimize urban sprawl, minimize wasteful commuting and creation of synergy within urban areas by layering one on top the other. Recent studies such as the one done by Batty and others (2004), Burton (2001) and Rodenburg (2006) show the difficulties for representing and quantifying the multifunctionality of urban land use.

The degree of multifunctionality and its representations is dependent from the indicators and the spatial scale that is used (Batty et al., 2004). The indicators that could measure multifunctionality should represent the density and diversity if the functions that an urban area has (Batty et al., 2004;

Burton, 2001). Furthermore, the spatial scale and data requirement for each indicator is relevant since they have an effect on the multifunctionality. The spatial scale affects the multifunctionality since it is required to define the area where more than one activity can exist (Batty et al., 2004). That area could be on building, or a neighbourhood. Each will result in different degree of multifunctionality. The data that indicators would use to measure or represent multifunctionality could use the human activities such as work and living by recording the employment type and human density (Batty et al., 2004; Lin and Yang, 2006; Vreeker, 2004). Other data that indicators could use to measure the multifunctionality would be the activities with their characteristics by recording the type of activity such as, post office, grocery shop, etc. (Burton, 2001). Furthermore, the temporal dimension affects the multifunctionality since the activities can be operational in different time of the day (Dobbelsteen and Wilde, 2004). An activity can be operational during the first part of the day, and closed during the evening and night time, therefore not accessible.

1.2. Research Problem

The spatial separation of land use functions that accrued in the early part of 20th century caused sprawl of the cities into open areas and agricultural land. As a result of this form of development people living in the cities face the difficulties of accessing the services. Therefore new planning concepts that will deal with the issues were introduced in Northern America and Europe. One of the latest planning concept is Multifunctional land use planning. As a new planning concept and not all advantages and disadvantages are known to the planners (Vreeker, 2004).

The problem of measuring and representing the multifunctionality of urban area were introduced with by Burton (2002) and Batty and others (2004). Both studies identify the difficulties on the methods for measuring the multifunctionality. Furthermore, Rodenburg and Nijkamp (2004) define the difference between the urban land use spatial function and human activity which is relevant for defining the multifunctionality. However, there are discrepancies on the differences of urban activities and indicators for measuring the multifunctionality. Thus it is required to have a tool that would classify activities and a set of indicators that would measure the density and diversity of classified activities. Furthermore, the multifunctionality should be accessible to the people living in the urban area. Therefore the distance of residential areas from the diversity of the non-residential activities needs to be taken under consideration. While the urban activities are operational during just a part of the day, the diversity and access to also changes (Batty et al., 2004; Rodenburg and Nijkamp, 2004). Hence, in different time of the day density and diversity of urban non-residential activities will create different patterns.

The research problem of this thesis is how to how to measure the multifunctionality of urban land use based on urban non-residential activities. The measurement should reflect the access of people to the multifunctionality and the diversity in temporal dimension.

Thus, it is required to develop a method that would measure the density and diversity of urban multifunctionality that would integrate the distance of residential areas from this multifunctionality and the change of it during the different time of the day.

1.3. Research Objectives

The main objective of this research is to contribute on developing a method for measuring the multifunctionality of urban areas.

Multifunctionality can be achieved by increasing the density and diversity of the commercial activities in the city. But it is important to have this multifunctionality within reach the people living in that city. Since the multifunctional land use as planning concept promotes the pedestrian friendly streets, it is important to have a method that will measure the multifunctionality in relation with the walking distances.

The sub objectives of the research are as follows:

1. to define a concept for measuring the multifunctionality of urban area

This sub objective will describe the concept of multifunctional land use planning and difference between the land use, land use function and urban activity. Furthermore, it will identify the spatial indicators required for measuring the multifunctionality.

2. to analyze spatial distribution of urban activities

This sub objective will analyze the spatial distribution of activities based on a classification tool and the patterns of activities based on the density, diversity and change over time.

3. to visualise the multifunctionality of urban area

This sub objective will analyse the methods of data classification in visualizing the multifunctionality of urban area.

1.4. Research Questions

To address the sub objectives a number of questions shown here will be worked through.

1. to define a concept for measuring the multifunctionality of urban area

1.1. What is multifunctional land use?

In recent history new concepts of urban planning have been introduced in Northern America and Europe. What is multifunctional land use and will be addressed with this question.

1.2. What is the difference between the land use, land use function and urban activity?

In recent literature the land use, and use function and urban activity are often used as interchangeable term. Therefore this question will define the difference between the three.

1.3. Which GIS-based indicators can measure multifunctionality of urban area?

There are a number of different indicators introduced for measuring the multifunctionality of urban area. However, not all of them are GIS based therefore this question will identify which indicators could be used to measure the multifunctionality.

2. to analyze spatial distribution of urban activities

2.1. How to classify the urban activities?

Measuring the multifunctionality of urban area it is required to identify which activities contribute to the multifunctionality. For this identification and mapping of patterns it is required to classify activities. What tool should be used to classify them will be issue of this question.

2.2. Which activities contribute to multifunctionality?

The amount of activities in a defined area describes the density of it. However, based on classification it is possible to visualize which class or division of activity contributes and where is concentrated will help understand the spatial distribution of them.

2.3. How to measure diversity of urban activities?

There are different methods and indexes which can be used to measure the diversity. But for measuring the diversity of urban area there must be indexes that are simple and easy to use and interpret.

2.4. How to measure diversity over time?

The diversity of urban activities or rather the access to urban activities changes during the time of the day. How this effects diversity will be addressed with this question.

3. to visualise the multifunctionality of urban area

3.1. Which data classification method should be used for representing density and diversity of multifunctionality?

In data visualisation there are a number of classification methods that can be use. Which one/s is most suitable for visualization is addressed by this question.

3.2. How to compare different diversity indexes of multifunctionality?

Different indexes of diversity produce different values which can not directly be comparable. Thus, this question will address the methods that could be used for comparing these different results.

1.5. Conceptual Framework

Conceptual framework captures the steps of this research and phases, which will go through. The framework will address three main questions related to multifunctional land use in urban environment. Initially to clarify “What?” is the multifunctionality of urban area; “Where?” functions in space are and “How?” do we make them visible so that can be understandable.

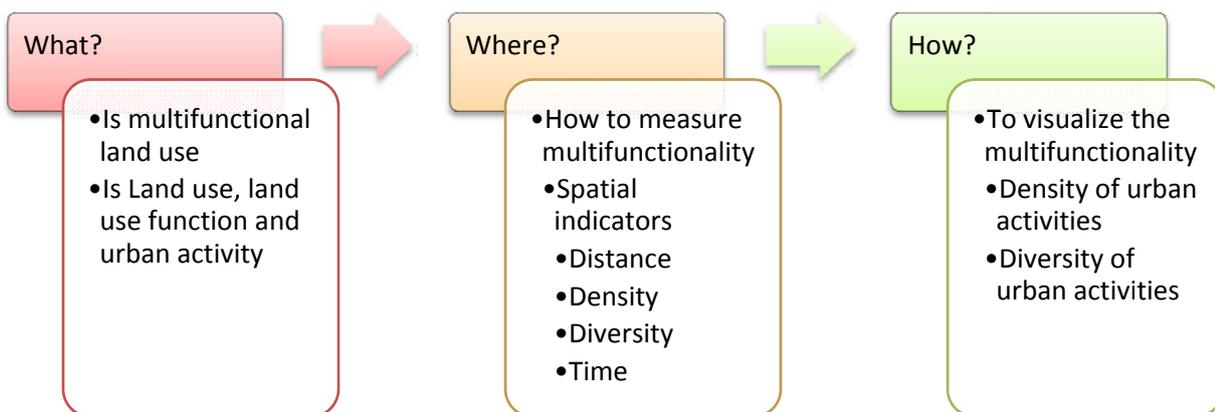


Figure 1-3. Schematic representation of Conceptual Framework.

1.6. Thesis Structure

This research explains the multifunctionality of urban area and explorers the methods of quantifying and visualizing it. To address the sub objectives and research questions the research is structured as follows:

The first chapter provides a general overview of study including research issues and justifications, research problem, objectives and research questions. Furthermore it gives a schematic representation of the conceptual framework.

Chapter two gives a comprehensive and critical review of literature on theory of Multifunctional Land Use as a planning concept. It gives a brief historic foray of planning concepts and recent trends. It defines the differences between the land use, land use function and urban activity. Furthermore, the challenges and indicator for measuring and visualizing the multifunctionality are discussed.

Chapter three will explain the methodology of the research. It includes research the process of applying the spatial indicators of multifunctionality, selection of study area, and data collection. Furthermore, it describes different processes of data analysis and method and methods of visualization.

Chapter four presents the study area of the research. It explains the challenges of the planning process and recent urban development. In addition, explains the study area in the context of the multifunctional land use planning and the need for this concept.

Chapter five presents spatial analyses accomplished during the research showing the measurements of multifunctionality and methods of visualizing it. In addition the methods of comparing and visualizing the differences from the diversity indices are provided.

Chapter six provides a discussion on the multifunctional urban planning concept and the shortcomings of previous researches based on reviewed literature. Recommendations for further research are given in the last part.

2. Multifunctional Urban Land Use

The purpose of this chapter is to critically review the literature for describing and measuring multifunctionality of cities. This is important because it can help to evaluate the distribution of the number and diversity of urban activities in the city..

In this research attempt is made to measure the multifunctionality of urban areas using vector based spatial data. Multifunctional Urban Land Use planning as a planning concept has emerged in the last decade of 20th century (Vreeker et al., 2004). However, this concept has not been long enough to understand fully the impact and implications for the future of the cities (Preuss and Vemuri, 2004). None the less, by developing a method that can measure the existing multifunctionality of cities can help predict the possible advantages and disadvantages it may have.

The measurement of multifunctionality is constituted with definition of what urban function is in relation to land use, and what urban activity is in relation to urban function. In this context, both urban function and urban activity can be measured through spatial indicators, which are identified in this chapter.

2.1. Emergence of Multifunctional Urban Land Use as Planning Concept

Multifunctional land use, as a planning concept, is relatively new, but the roots of multifunctional cities go far back in the history (Batty et al., 2004; Jacobs, 1961). In medieval times, European cities were relatively small comparing to the current ones. They were established in a form of multifunctional cities where people engaged in different activities. These activities were usually on the ground floors of buildings. The upper floors were used as living space (Batty et al., 2004). As the economies of urban areas became more diverse the potential for a better life and a more secure environment increased, thus leading to a progressive movement of people to the cities. The purpose of living in a city has remained very similar to present days (Priemus and Hall, 2004).

As cities started to grow, the core of urban centres started to change. The transformation accelerated during the industrial revolution. The new industries required more and more space, and concurrently more labour force. This, together with rapid growth of automobile use (Vreeker et al., 2004), resulted in a low density urban development or urban sprawl (Torrens and Alberti, 2000). The spatial separation of land use functions in planning started to emerge during the early 20th century and became more distinct after the Second World War (Batty et al., 2004; Vreeker et al., 2004). This form of development in literature is known as Single-Use zoning (Priemus and Hall, 2004; Vreeker et al., 2004). Large tracts of land are dedicated to the same type of development. Roads or other barriers segregate commercial, residential, and industrial areas from one another. Consequently, places where people live, work, shop, or recreate are situated in different parts of the city, resulting in extended walking distance and duration of travel (Duany et al., 2000).

This form of development became a doctrine for urban planning and a tool for policy making particularly after the Second World War. The concept of spatially separated zones originates from the

Modern Movement, which was led by the French architect, Charles-Edouard Jeanneret, known as *Le Corbusier*. The Modern Movement, also known as International Style, emerged in 1928 as an organisation and a series of meetings from the *Congrès International d'Architecture Moderne* (CIAM), the International Congress of Modern Architecture. In 1933, a meeting was held in Athens where the "*Athens Charter*" was drafted. The document was published in 1942. This charter constituted a fundamental basis for the development and redevelopment of many cities in the post-World War Europe. The city of Dresden in Germany makes an appropriate example for such a (re)development in Europe. CIAM IV (Fourth congress) laid out a 95-point programme for planning and construction of rational cities, addressing the topics such as the high-rise residential blocks, strict zoning, the separation of residential areas and transportation arteries, and the preservation of historic districts and buildings. The key underlying concept was the creation of the independent zones for the four key 'functions': living, working, recreation, and circulation, which were to be linked with transport networks.

Despite its achievements, the Athens Charter was widely criticized for its inflexible approach and its inhumane results. This criticism was initiated by the American activist Jane Jacobs in her book "*The Death and Life of Great American Cities*", published in 1961. The writer claimed that the International Style (Modern Movement) had promoted a development whereby cities became inhumane because they (cities) rejected living in a community characterized by "*layered complexity and seeming chaos*" (Jacobs, 1961, Page 228, 531). Jacobs was not alone in her criticism of the separation of land uses in urban areas (Handy et al., 2005). In particular, sprawling patterns of the development as a result of CIAM's concept of urban development was blamed for transforming cities into places where people were dependent on the automobile transport. Therefore, traffic congestions and poor air quality became some of the major problems in urban areas (Burchell and Mukherji, 2003). Snyder and Bird (1998) later undertook research on analysing the impact of uncontrolled urban expansion in the United States. They found that the urban sprawl led to a loss of open spaces, agricultural land, and a heavy dependency on automobiles for moving from one place of urban area to another (Burchell and Mukherji, 2003). Moreover, urban centres became blighted and less attractive, and the efficiency of using resources dropped significantly. Furthermore, cost of urban infrastructure is high and so are the charges for services.

The emergence of new planning concepts, such as New Urbanism, Smart Growth, Compact City, and Multifunctional Land Use planning (Vreeker et al., 2004), took place through the years of studying the cities and through the urban planning observations. In principle, there are not many differences among these concepts. As shown in the table below (Table 2-1), all four concepts of urban planning have been developed with the idea of improving the efficiency of space usage, creation of pedestrian areas and creation of synergies among the land use functions

However, the above four concepts are relatively new, and have not been around long enough for the public and the policy-makers to appreciate the long term effect and development patterns (Preuss and Vemuri, 2004). Nevertheless, it is widely accepted that the development of urban area can only be sustainable through diversifying functions and increasing density, through the infill development with transit oriented transport (Burton, 2001). One must, however, not be mistaken that any expansion or new development is urban sprawl. This is because the concepts of infill development and increased density development have certain physical limits. The new expansion simply needs to be in

accordance with the same conditions that are or will be put in place for every other part of the urban area, by promoting spatial, social and environmental quality.

The planning concepts such as New Urbanism, Smart Growth, Compact City and Multifunctional Land Use Planning will be briefly discussed below to provide a better insight.

New Urbanism is an urban planning concept that emerged in 1980s, and is mainly associated with the United States. As a planning concept, it is focused on the development of diverse housing forms and close proximity to jobs. Issues such as historic preservation, safe streets, green building, and the renovation of brown-field land are also the focus of New Urbanism. It is worth noting that many features that are associated with New Urbanism have their roots from a pre-automobile urban planning. Hence, this movement sometimes is presented as Traditional Neighbourhood Design (Talen, 2005).

The Smart Growth concept emerged in 1990s. Being mainly an North American concept it addresses three inter-related issues: 1) the density of the development, 2) the separation of land uses and different land uses, and 3) the mobility and transport mode choice (Vreeker et al., 2004). The features that distinguish Smart Growth in a community vary from place to place. Smart Growth promotes a character of the town centre. It is a transit and pedestrian oriented planning concept, and has a greater mix of housing with commercial and retail uses. It also preserves open space and many other environmental amenities.

The principles of Smart Growth are:

- Mix Land Uses
- Take Advantage of Compact Building Design
- Create a Range of Housing Opportunities and Choices
- Create Walk-able Neighbourhoods
- Foster Distinctive, Attractive Communities with a Strong Sense of Place
- Preserve Open Space, Farmland, Natural Beauty, and Critical Environmental Areas
- Strengthen and Direct Development Towards Existing Communities
- Provide a Variety of Transportation Choices
- Make Development Decisions Predictable, Fair, and Cost Effective
- Encourage Community and Stakeholder Collaboration in Development Decisions
(EPA, 2006)

Compact City concept emerged as a response to the occurrence of Urban Sprawl in European cities. The concept was first discussed in the publication of Green Paper on Urban Environment, which aimed at the improvement of the quality of life in relation to urban planning and sustainable development (Vreeker et al., 2004), while encouraging urban growth to take place within the existing boundaries of urban areas.

Three main attributes define the concept of Compact City: high densities, mixed uses, and intensification. This implies:

- conservation of the countryside
- lesser need to travel by car, thus reduced fuel emissions
- support for public transport

- walking and cycling
- better access to services and facilities
- more efficient utility and infrastructure provision
- and revitalisation and regeneration of inner urban areas (Burton, 2001; Jenks and Gerhardt, 2000)

Multifunctional Land Use as a concept emerged from the Dutch spatial planning in the late 1990s (Vreeker et al., 2004). As a planning concept, it promotes a sustainable form of land use by influencing the form of urban development. It endorses most of the principles of Smart Growth and Compact City, except that it encourages development in higher levels and subterranean levels. In addition, it achieves high density and makes it possible to mix different functions. Multifunctional Land Use (MLU) promotes activities of different users at different time in a mixed land use. One of the most important facts about MLU is that it concentrates specifically on the creation of synergies between various functions. This is one of the main principles that makes MLU distinct from Smart Growth and Compact City (Rodenburg, 2006; Vreeker et al., 2004).

The principles of Multifunctional Land Use are:

- Mix Land Uses and Compact Building
- Create a Range of Housing Opportunities and Choices
- Create Walk-able Neighbourhoods
- Increase Vertical Development (multi store buildings above and sub terrain)
- Strengthen and Direct Development Towards Existing Communities
- Provide a Variety of Transportation Choices

Table 2-1. Similarities and differences between various mixed and compact land use concepts (Vreeker et. al. 2004).

As new concepts emerged, starting from New Urbanism and all the way to Multifunctional Land Use planning, it is clear that they all contain overlapping principles. Yet, at the same time, one must appreciate that each concept goes a step further or deeper into the development, where less space is consumed for the purposes of greater development. This is deemed to be achieved through an increased density and mixed functions for increased diversity of functions and activities. The strongest common criteria for all four described concepts remain: space saving, reduced car mobility, and spatial scale in neighbourhood level.

This research will mainly focus on Multifunctional Land Use planning. Hence a more enhanced and elaborated description will be provided in order to demonstrate its different functions and activities.

	New Urbanism	Smart Growth	Compact City	MLU
<i>Characterization</i>	American planning concept aimed at the mixing of activities at neighbourhood level	American planning concept aimed at the protection of open space and farmland	European planning concept to improve the environmental and economic performance of cities	Planning concept aimed at the sustainable use of land. Especially focused on the creation of synergy between land use functions
<i>Time</i>	1980'	1990'	1990'	1990'
<i>Focus on urban revitalization</i>	Yes	Yes	Yes	Yes
<i>Attention to high density development</i>	No explicit attention	No explicit attention	Explicit attention	Explicit attention
<i>Spatial level</i>	Neighbourhood	Neighbourhood and city	Neighbourhood and urban regions	Building, neighbourhood, city
<i>Intended mobility effects</i>	Reduced (car) mobility	Reduced (car) mobility	Reduced (car) mobility	Reduced (car) mobility
<i>Transport mode favoured</i>	Pedestrian friendly	Pedestrian friendly	Pedestrian, bicycle, public transport	Public transport
<i>Space saving</i>	Yes	Yes	Yes	Yes
<i>Attention to resource use conservation</i>	Explicit attention	No explicit attention	No explicit attention	No explicit attention
<i>Creation of synergy</i>	No explicit attention	No explicit attention	Limited attention	Explicit attention

2.1.1. Multifunctional Urban Land Use Function, Activities and Accessibility

The understanding of Multifunctional Urban Land Use is based on the understanding of urban land use function and urban activity. Both are somewhat predetermined by urban land use plans, but by no means are the same. In order to understand their differences need to be defined.

In some literature land use and land use function are used as interchangeable terms (Batty et al., 2004). However, Rodenburg and Neijkamp (2004) differentiate them two by using a definition of spatial function from *Webster's Dictionary*: "a spatial duty or performance required of land in course of work or activity" (cited in Rodenburg and Nijkamp, 2004; Webster's, 1961). Furthermore, the authors differentiate urban land use function from human activity. Land use spatial function describes residential, commercial areas and alike, whereas human activities describe work, leisure and travel (Rodenburg and Nijkamp, page 279).

The above definitions and descriptions do not describe the urban environment adequately. For instance, a residential area, as a spatial land use function in the context of MLU, may contain commercial functions and combinations alike. Therefore, it is required to go a step further from land use spatial function in order to be able to identify and describe the functionalities that a land use may have. More detailed features of land use functions would be the activities that may exist within, such as different shops in a residential area. Hence, urban land use, land use function and activity could be defined as follows:

Urban Land Use

Is the method of organizing the use of lands and their resources to best meet people's needs over time, It defines the type of use such as, residential, commercial, industrial, recreational areas, etc.

Urban Land Use Function

Land use function describes the functions that are within a land use. Hence, function is described by the building that is constructed in a land use.

Urban Activity

Urban Activity is a location contained by urban land use function and that occurs over time. Hence, activity describes what building is used for.

To better understand the definitions a sketch is given below.

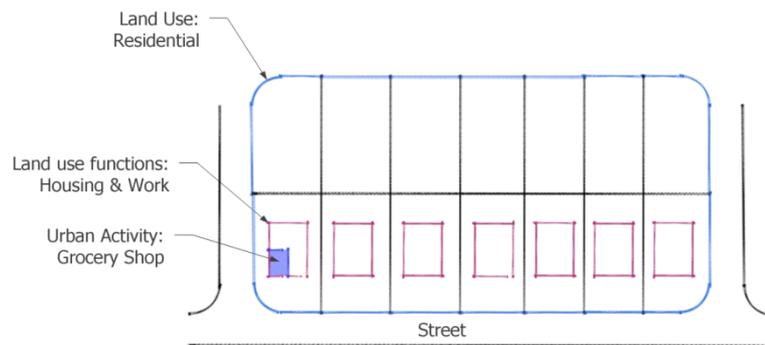


Figure 2-1. Visual description of Land use, function and activity

2.2. Multifunctional Urban Land Use – Planning Concept and Empirical Phenomenon

Multifunctional Land Use Planning is determined by the spatial scale or geographic extent and time dimension, over which activities take place. The spatial scale influences how multifunctionality of a city is percept. If a higher scale is chosen (e.g. city) it will result in a place that is more multifunctional. The same applies to the time dimension. Multifunctionality will be different if the time in question is a month instead of a week or a day (Batty et al., 2004; Rodenburg and Nijkamp, 2004). To clarify the definition of multifunctionality, two most recent definitions have been selected from a wide ranging literature:

“In talking of multifunctional cities, we make the assumption that more than one activity or function exists in the same location and/or at the same time, which only strictly holds if we consider a neighbourhood or time interval in which these activities exist together.” (Batty et al., 2004).

“A land use pattern is said to become more multifunctional when, in the same area considered, the number of functions, the degree of interweaving, or spatial heterogeneity increases. An increase of multifunctionality may therefore result from addition of functions to the same area (multifunctionality by diversity), from increase in dispersion of the number of functions over the area (multifunctionality by interweaving), or from an increase in the number of other functions touching a territory (multifunctionality by spatial heterogeneity).” (Rodenburg and Nijkamp, 2004).

Both definitions describe multifunctionality as a place where more than one activity or function exists. However, Batty (2004) emphasizes on a neighbourhood as a spatial scale, whereas Rodenburg and Nijkamp (2004) emphasize on a spatial distribution of functions.

The literature addresses Urban Multifunctional Land Use (MLU) as a planning concept (Rodenburg and Nijkamp, 2004) and an empirical phenomenon of agglomeration of business activities (Vreeker et al., 2004).

As a planning concept, Multifunctional Urban Land Use can be a useful tool of urban planning when saving scarce space. MLU encourages the increase of density and diversity through a development in vertical dimension, by layering different functions on top of each other. Moreover, MLU promotes non-automotive forms of transport in neighbourhood level.

Elaborating the principles in greater detail helps better understand the objectives of MLU as planning concept.

- **Mix Land Uses and Compact building.**
Increasing the number of different land use functions in less space will increase diversity of the neighbourhood. This will enrich neighbourhoods and make streets more attractive for people to walk rather than drive through.
- **Create a Range of Housing Opportunities and Choices.**
Planning different settings of housing for the people of different income level will enrich the town. Different social groups will most likely have different preferences for different services, and this demand can contribute to the diversity of different commercial services.
- **Create Walk-able Neighbourhoods.**
Creating opportunities for close proximity of services in residential areas can help reduce the need for the use of cars. Walking is the cheapest and environmentally friendliest mode of transport.
- **Increase Vertical Development (Multi store buildings above and sub terrain).**
Stimulating a development in vertical dimension for different functions can reduce the pressure for horizontal expansion of an urban area. This refers to the multifunction within a building or a building block on separate floors.
- **Strengthen and Direct Development Towards Existing Communities.**
Putting foremost attention to an existing community rather than creating new communities can help maintain compactness of the urban area, through an increase of the population of the density.
- **Provide a Variety of Transportation Choices.**
Offering different modes of transport can help reduce the use of personal cars. In fact, MLU promotes pedestrian and public transport modes. By offering good infrastructure for use of bicycle, or efficient public transport with the bus, tram or metro, can minimize dependency from cars.

Contrary to the possible positive effects that MLU may have for future spatial development of cities, it is difficult to know the extent of how mixed the neighbourhoods should be. The same applies to the diversity of business activities on the streets in order to achieve desired effects. A number of possible

environmental, social and economic positive and negative effects from compact and multifunctional planning are described (Vreeker (2004).

Table 2-2. Possible advantages and disadvantages of mixed and compact land use (Vreeker, 2004).

Advantages	Disadvantages
Environmental effects	
Protection of open space and farmland.	Lack of access to open and green spaces in urban environments.
Reduction in mobility (multi-purpose trips) resulting in reduced fuel consumption and emissions.	Concentration of environmental problems in one location.
Reduction in building energy consumption	
Social effects	
Increased overall accessibility.	Conflicts between activities (noise, congestion, parking problems, etc.).
Reduction in crime rates.	Reinforces the perception of overcrowding and loss of visual privacy.
Increased quality of life.	
Economic effects	
Increased diversity leading to an increased attractiveness and vitality of neighbourhoods. Increased population base for public services and amenities	May limit economic development in rural areas.
Efficient provision and re-use of infrastructure.	Higher wages paid to workers employed. Congestion costs resulting from suboptimal urban size.
Increased productivity in the form of economies of scale, density and diversity.	

The advantages of the multifunctional planning concept have put forward a solution to some of the major problems that cities face. There are a number of serious advantages in all three aspects: environmental, social and economical. However, one must not underestimate the disadvantages of this planning concept. For each advantage there is a price to be paid. It is difficult to measure the weight between the two. Therefore, a balance between the advantages and the disadvantages may be required to be pursued. Furthermore, it is plausible that an action or set of actions may be required to counter balance a negative impact that an advantage may have. In addition, the multifunctional land use may not be seen as a planning concept only but also as an empirical phenomenon of agglomeration of economic activities.

Another form of study of Urban Multifunctional Land Use is to observe the clustering of economic activities. By doing so many other aspects of MLU will not be considered, such as social and cultural advantages or disadvantages that may result. Nonetheless, it is the economic activities that provide the supply services, for which there is a demand, and at the same time bring the jobs, welfare and entertainment activities to urban areas.

Considering that businesses cluster in space (Vreeker et al., 2004) and that one of the main objectives of Multifunctional Land Use (see **Multifunctional Land Use** as a concept emerged from the Dutch spatial planning in the late 1990s (Vreeker et al., 2004). As a planning concept, it promotes a sustainable form of land use by influencing the form of urban development. It endorses most of the

principles of Smart Growth and Compact City, except that it encourages development in higher levels and subterranean levels. In addition, it achieves high density and makes it possible to mix different functions. Multifunctional Land Use (MLU) promotes activities of different users at different time in a mixed land use. One of the most important facts about MLU is that it concentrates specifically on the creation of synergies between various functions. This is one of the main principles that makes MLU distinct from Smart Growth and Compact City (Rodenburg, 2006; Vreeker et al., 2004).

The principles of Multifunctional Land Use are:

- Mix Land Uses and Compact Building
- Create a Range of Housing Opportunities and Choices
- Create Walk-able Neighbourhoods
- Increase Vertical Development (multi store buildings above and sub terrain)
- Strengthen and Direct Development Towards Existing Communities
- Provide a Variety of Transportation Choices

Table 2-1) is creation of synergies between various functions, (Rodenburg and Nijkamp, 2004) it is important to analyse this phenomenon closer. Even though this aspect of studying urban economy or micro economy originates from the economic literature, it can provide an insight towards the possible benefits that urban land use function diversity may have. Modern approaches to the agglomeration of economic activities are influenced by Information and Communication Technologies (ICT) with believe that ICT will overcome the barriers of space and time (Castells, 2000; Vreeker et al., 2004). However, it is maintained that physical concentration of economic activities will favour the cities even with (Linders et al., 2004). The reason why economic activities cluster is reflected by knowledge spill, over which results in increased productivity, in particular by firms in the office sector, but other sectors as well (Vreeker et al., 2004).

Looking from the perspective of urban planning, proximity of economic activities to the competitors and proximity to the clients create conditions for the firms to increase their competitiveness. Therefore, competitiveness is conditioned form higher density. The competitiveness to the firm should result in a higher quality services. Moreover, the supply is characterised by demand that exists. However, the demand is characterised by the need for a better, faster and low-cost service.

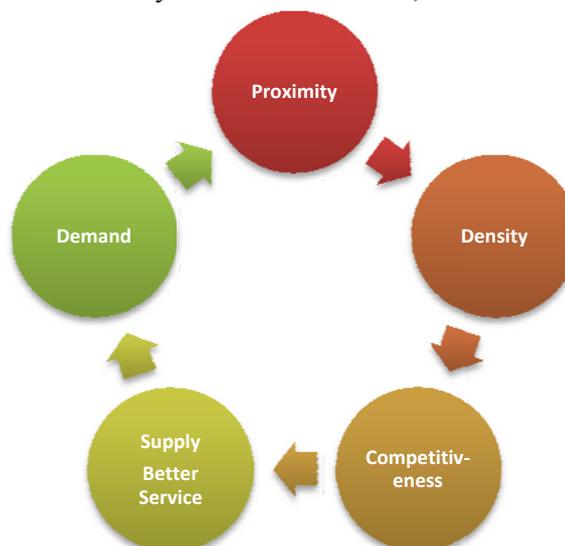


Figure 2-2. Effect from clustering of economic activities

Spatial distribution of business activities should be considered in terms of job opportunity and also as a location where a service is provided. On the other side, the travel distance from residential areas to the service location will determine the intensity of the travel and the mode of transport. With the help of compact urbanisation, densification and mix-use development it is plausible that the need to travel by car will be reduced (Maat et al., 2005). This is supported by the findings reached in the United States (Handy et al., 2005), where the residents living in the suburbs travel 18% more than the residents living in the traditional neighbourhoods. However, some studies show contrary findings. For example, (Badoe and Miller, 2000) have found that the impact of such variables is marginal at best. However, the mode of transport, individual preferences and accessibility to the services are also the factors that determine travel behaviour. Accessibility here is measured by how well connected a given location is with the land use of a given function. It is important to make access that requires less effort to reach services through a short walking distance or public transport. Hence, the focus cannot be only on the cost of travel but also on the benefits of the individuals who need to travel. By considering these factors it is plausible that desired results to reduce car traffic can be achievable.

A particular attention is given to the pedestrians, since one of the objectives of MLU is to create pedestrian areas. For this reason understanding the movement of people, such as an average walking speed, is very important. This would help analyse an approximate distance in time from a household to any given service in urban area. However, the average walking speed of a pedestrian varies depending on many different factors. Gender, age, mobility, group size, group gender, and hour of the day, are examples of significant factors. A recent research produced in England (Willis et al., 2004), covering all the above mentioned factors, showed that each factor leads to different results. Nonetheless, an overall mean walking speed of across a sample of 2613 individuals resulted to be 1.47 m/s.

The overall picture of Multifunctional Land Use seems to have become very complex. Multifunctionality, however, needs to be considered from two different perspectives. The first perspective is to expose the existing multifunctionality of an urban area. The second perspective is to discover the need for increasing multifunctionality from the people that live and work in that urban area. A combination of the two perspectives would ultimately lead to a possible sustainable implementation of MLU as a planning concept.

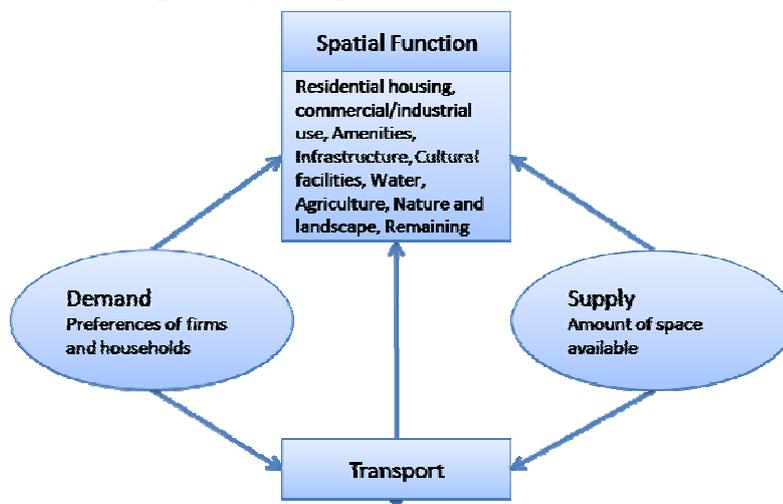


Figure 2-3. Relation between demand and supply factors, spatial functions and transport (Rodenburg and Nijkamp, 2004)

A comparison of two perspectives could be done through the spatial and non-spatial methods. The first method would require an input of a number of spatial and non-spatial data (Batty et al., 2004). The output of this method is the amount of activities that exist and that is desirable while showing where that demand is in space. The second method, however, can be performed through a statistical analysis or cost benefit analysis (CBA) (Lin and Yang, 2006; Rodenburg, 2006). The output of this method is the statistical analysis of the existing and desired multifunctionality in form of table, charts and diagrams.

While both perspectives, when analyzed with either method, could give a good insight into desired MLU, it is important to understand that the output may be different. Spatial planning without spatial data, such as CBA analysis, would most likely give only material benefit or the cost as an output, without seeing where what is. This drawback can be overcome through an application of the method with spatial data, with an application of the identified spatial indicators. Spatial indicators can map the urban activities and can represent the required information of each activity even if this information is non-spatial. Furthermore, spatial indicators can be used to show the existence of multifunctionality of a city. The indicators, however, need to be drawn in light of the definition of MLU as a planning concept.

2.3. Displaying Multifunctional Urban Land Use

Understanding the consequences that Multifunctional Land Use Planning may have on urban areas would help take necessary measure to prevent negative aspects of this planning concept. Certainly, one should note that not all the land use functions create synergies (Burton, 2002).

By addressing MLU as a planning concept and an empirical phenomenon of agglomeration of economic activities there is a possibility that new insights will appear. The planning concept will make it possible to study the density, diversity and proximity of urban land use functions that provide social and cultural services. The empirical phenomenon approach will make it possible to study the agglomeration of economic activities in urban areas. The balance among these two approaches on land allocation may lead to the interpretation of the degree of multifunctionality in urban area.

Land allocation can best be achieved through mapping. This allocation is spatially quantifiable, and therefore it is plausible that quantifying spatial functions of land use would also quantify multifunctionality. Recent literature shows that measuring multifunctionality is possible (Batty et al., 2004; Rodenburg and Nijkamp, 2004). One approach to identify the indicators (e.g. density, diversity) for measuring would be to start from the definition of multifunctionality.

Multifunctional land use is dependent from the increase of the density of activities. Therefore, a spatial indicator, that represents the location of activities that exist within each land use spatial function, would be required. However, having a high number of activities does not mean that a place has more than one function. Therefore, it is required to measure the diversity of those urban land use functions.

The diversity of activities will describe how many different activities are in the area. The diversity combined with the number of activities would visualize whether a particular type of the activity is clustered and where. These measurements of diversity could help understand the performance of

business activities. Furthermore, when combined with the travel behaviour, the measurements of diversity could help understand why some parts of the city are more overcrowded than others.

Both, the density and the diversity can be measured according to a defined area. Defining the size of the area can be arguable, since it is difficult to define the size of an area where more than one activity can exist. Furthermore, the area for which these indicators should be measured can also represent the proximity of the activities. The proximity can be identified by measuring Euclidian distance from each activity, or through a road network by creating a catchment area of each activity. The second option will produce a proximity measurement, which will represent accessibility to the activity. By measuring accessibility to the activities it is possible to gain an insight into the activities, in particular accessibility by the pedestrians.

Nevertheless, accessibility is characterised in terms of the time when activities are operational. Urban activities operate during different hours of the day. Some activities operate all day, and others operate only a few hours per day. These differences influence the number of activities that are accessible, which subsequently affects the diversity of the activities. This measurement can reflect the change on the spatial pattern of accessible activities of the city during the day.

The method for realizing these spatial measurements of density, diversity and operational time of activities can be different. It is possible to measure the urban activities or human activities. Urban activities will reflect the number of functions of the land use. Human activities will reflect the engagement of people in land use functions. Unfortunately, none of the researches found in recent literature (Batty et al., 2004; Burton, 2002; Lin and Yang, 2006) for measuring and representing urban multifunctionality, addresses the measurement of urban land use functions. On the contrary, they focus on measuring the human activities of working locations, living locations, such as employment density and population density. Another distinction of the measurements done so far is that only one research applies the spatial indicators for measuring the multifunctionality. In addition this measurement applies the GIS tools with raster data, which may have disadvantages in these measurements.

One of the first attempts to visually represent multifunctional land use has been done by Batty and others (2004). The objective of the research was to develop GIS techniques that would help understand the multifunctionality. However, the technique used was with spatial data in raster format which, as shown on paper, proved to have a major impact on how the multifunctionality is represented. The key issue with raster data is the size of cell of the raster layer. Even though the size of cell that was used complied with the postcode block size of the United Kingdom (50m resolution), the output was easily sensitive to this resolution (Batty et al., 2004). The change to the size of pixel from 50m to 250m changed the values of multifunctionality. This change makes questionable what is the real value of multifunctionality of the same location. Other than the postcode, the spatial resolution of the raster data was not based on anything else. Furthermore, the visualization of the multifunctionality was based on three different case studies. In each case population density and employment density were mapped in order to reach the ratio which helped to analyse wasteful commuting (Martin, 2001) cited in (Batty et al., 2004). Using the same technique, density-diversity of activities for the area of Amsterdam was used. Nevertheless, the result of these maps changed to higher or lower values, as the different smoothing factors were applied, which, as mentioned earlier, represented different results for the same areas.

Rodenburg and Nijkamp (2004) studied the possible combinations of different land uses by spatial function and human activities. The study gave an insight into how easy it is to combine the two, but it did not make any attempt to map those possible combinations. Similarly, Burton (2001) developed a method to measure the compactness of the UK cities. This method contained more than a dozen of indicators to measure the density, mix-of-use, and intensification of land use. However, it lacked the spatial component. The output contained a table for each indicator for 25 cities in the UK.

One of the latest studies of land use measurement has been done by Lin and Yang (2006). The authors measure the compactness of Taiwan cities by looking into the context of sustainability. The study does not, however, measure the compactness by using spatial tools, but by using statistical analysis instead. Therefore, the output is a diagram (Figure 2-4) with the relations between the variables considered for what the authors think constitutes a compact city and what constitutes an urban sustainability (Lin and Yang, 2006).

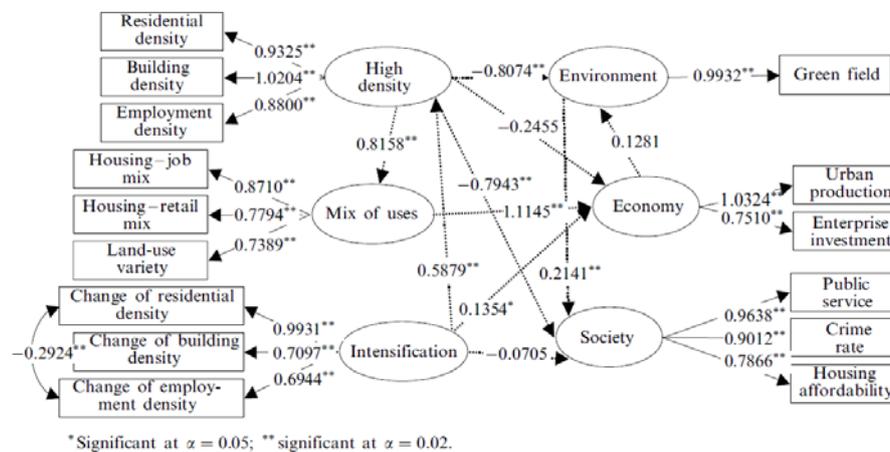


Figure 2-4. Model for measuring compactness and sustainability of cities with the relations between the variables.

The model represents the method of measurement of compactness with relations between the variables which are used to develop nine different hypotheses.

Nevertheless, neither of these researchers uses any method to classify in any way the urban land use functions or activities, except Batty and others who use a standard industrial classification of the employment. The classification helps state the difference between land use functions and the difference between the activities. Thus, the classification is deemed to be a vital factor when measuring the diversity of functions or activities.

2.3.1. Classification of activities

For measuring the multifunctionality recording all urban activities in space is required. The activity shows the number of functions that an area has. Since these activities may vary, to best describe this difference, it is necessary classify them with a structured classifying tool. The classification will help measure and describe the indicators of multifunctionality, in particular the diversity indicator.

In this context, it would be most appropriate to use a world standard classifying tool. This would allow comparative measurements in other places, or between the cities of different countries. More importantly, it will support the structuring of activities into classes in a consistent format. For this

reason and application of the International Standard Industrial Classification of all Economic Activities ISIC, which is developed by the United Nations Statistics Division, would be acceptable.

International Standard Industrial Classification of all Economic Activities groups all activities into the most detailed level, a Class, according to what is, in most countries, the customary combination of the activities described in statistical units. Complementary, the Groups and Divisions, are successively broader levels of classification that structure activities according to the character and technology. Despite the term "industrial", ISIC is not just a classification of industries. It also covers other activities (see appendix I).

When measuring the diversity overtime, this classification tool will enable us to see whether a particular class, group or division forms a pattern, and if so, during what part of the day. These patterns will help identify where the interest of people is focused and how these patterns change in comparison with the residential areas.

2.3.2. Density of Activities

With the objective to increase the density of functions in urban areas, MLU, as a planning concept, aims to achieve a higher number of urban land use functions. Looking from the perspective of economic agglomeration, the density of businesses is higher in areas where they make clusters. Identifying where the numbers of urban land use functions are higher would help compare the areas according to where some types of activities are grouped and what their spatial distribution is.

Density as a measurement simply takes a raw count of activities and divides that number per area measured. This would help the planners see the average number of spatial distribution of all, or of a specific land use function. Contrary to the planners, an average number of functions for an individual could be vague (i.e. 2.79 urban functions). It is plausible that the raw count of the activities that are accessible within a range would be understandable (i.e. there are 2 shopping centres within 5 minutes walking).

However, high density alone cannot determine the multifunctionality of urban area, since it does not give any indication of the types of functions that exist in that urban area. Therefore, measuring the diversity of land use functions would bring closer to visualize multifunctionality.

2.3.3. Diversity of Activities

The other identified indicator of urban multifunctionality is diversity. Conceptually, diversity is "*the number of different types of land use activities that exist in a specified area*". One can argue that every single shop is different from the other shop. One shop offers the products of another company, or targets a different group of people, etc. If one tries to measure the diversity as described above, he will face difficulties in developing a common procedure to measure that level of diversity. If the tools for measuring this level of diversity exist, it will take too long to record all the data of every single shop. By the time one reaches the end of data collection, the collected data at the beginning of the work will become obsolete, if not too old to be comparable with the new records.

To simplify the work, it would be useful to generalise data. In fact, one will assume that all the urban land use functions of the same class are equally important and are of the same quality. However, there are various ways introduced in measuring the diversity (Oindo, 2001).

The simplest way of measuring the diversity would be according to the richness and evenness of urban land use functions. Richness represents a total number of classes of activities that exist in each place. Evenness represents a relative contribution of each class to a total number of activities. The figure 2-5 gives two examples with different number of activities. On the left-hand is example “A” with four different classes of activities, each has different number of activities. On the right-hand is example “B” with four different classes, each has same number of activities. If measuring richness and evenness of both examples, the value of richness will be the same, that value is four. Evenness in example “A” is lower then on example “B” because the data are not evenly distributed. A perfect distribution gives vale of one, whereas value zero would be when data is least even.

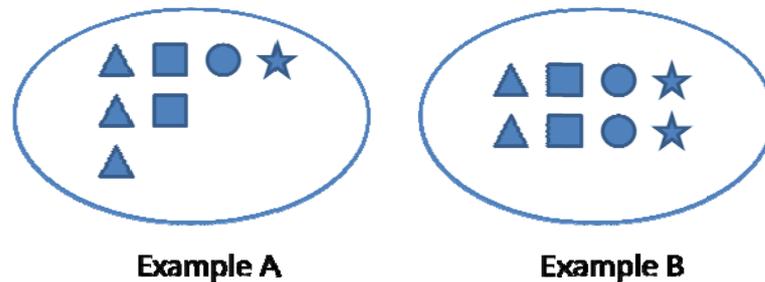


Figure 2-5. The difference between Richness and Evenness

One example of measuring the diversity of functions in urban area comes from the study of Batty and others (2004) for representing multifunctional cities. They do so by expressing the amount of the activity as a proportion of its maximum, and later accumulate these variables across all the activities, which exist in each place.

Equation 2-1. Density-Diversity Index (Batty et al., 2004)

Another way of measuring the diversity would be to probe the indices that are used in the natural science for measuring biodiversity. We could do so by grouping urban land use functions into classes. This could create a hierarchy of classes of urban land use functions similar to the hierarchy of species in the biodiversity. Grouping of urban land use functions could be done by using the United Nations Statistics Division (UNSD) International Standard Industrial Classification of all Economic Activities ISIC classification. See table 3-1.

Two most common used indices for measuring the diversity in ecology (Magurran, 1988) cited in (Oindo, 2001) are Simpson Index of Diversity and Shannon-Wiener Index of Diversity.

Simpson index of diversity is considered to be a dominance index, as it weighs more to the abundance of most common class. The formula for calculating the index is:

Equation 2-2. Simpson’s Index

The p_i is the proportion of activities found in i_{th} class (n/N). The n is a number of activities in i_{th} class, and N is a total number of activities in all classes.

The result of this index is heavily dependent on evenness. The increase of evenness in collected data significantly changes the result of the diversity. In addition, a size of collected data does not change the result of diversity; in short, the density is not calculated. This is because the richness and evenness do not measure the total number of activities. Since the result of this index is negatively related, then this index could be expressed as 1-D, which would reverse the value and also the definition of the index. The maximum value that this index can reach is equal to the maximum number of the classes of activities that exist in that place. For example, if there are five classes of activities found, then the maximum value of the diversity index would be 5 (Magurran, 1988) cited in (Oindo, 2001).

Shannon index of diversity is calculated from the relative abundances of data in each class and the richness of the activities a place has.

$$H = - \sum_{i=1}^s p_i \ln(p_i)$$

Equation 2-3. Shannon-Wiener Index of Diversity

The Shannon index assumes that all classes are represented in the collected data.

The p_i is a proportion of activities found in i_{th} class (n/N). The n is a number of the activities in i_{th} class, and N is a total number of the activities in all classes. Finally, \ln is a natural logarithm.

The result of this index is heavily dependent on the indicators: richness and evenness. The increase of one does not significantly change the result of the diversity. In addition, the size of collected data does not change the result of diversity therefore, the density is not calculated by Shannon-Wiener index.

To illustrate the difference between the calculations of index of diversity of Shannon-Wiener and Simpson’s Index a hypothetical example with four combinations of richness and evenness is taken. First combination has low richness and low evenness, second has high richness and low evenness, third has low richness and high evenness, and fourth sample has high richness and high evenness. The values are given in the table, and later are normalized with maximum standardisation in order to be able to compare the results from the two indexes.

$$\frac{\text{score}}{\text{highest score}}$$

Equation 2-4. Maximum standardization. Benefit criteria (Sharifi et al., 2004)

Table 2-3. Hypothetical example for calculating Shannon-Wiener and Simpson’s Index

Sample	Richness	Evenness	Shannon-Wiener Index		Simpson’s Index	
			Index value	Normalized value	Index value	Normalized value
1	5	0.1	0.918	0	0.196	0
2	15	0.1	0.870	0.0533	0.330	0.0557
3	5	1	0.2	0.5627	1.609	0.8433
4	15	1	0.067	1	2.708	1

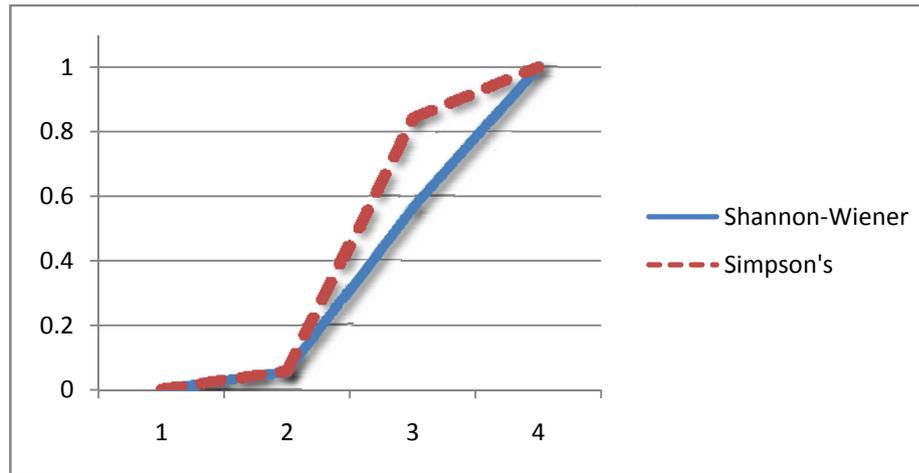


Figure 2-6. Normalized values for Shannon-Wiener Index and Simpson's Index of diversity

This example with four samples with four extreme values of richness and evenness shows that Simpson's index is more sensitive to richness. Therefore the Simpson's index will produce results with higher diversity for areas that have higher number of classes with less consideration to the relative contribution of each class to the total number of activities that exist in a place. Contrary to this, Shannon-Wiener index puts importance to both, richness and evenness for measuring diversity of an area.

Nevertheless, diversity of an area may be more of benefit if it is closer to the residential areas. This would create higher opportunity for people to access easier activities. Furthermore, it would encourage walking as more preferable mode of transport (Maat et al., 2005).

2.3.4. Distance between Urban Activities

The distance of land use functions from each other and in particular from residential areas describes the objective of MLU for creating pedestrian areas and minimizing dependency on travel by car (Priemus and Hall, 2004). By measuring this distance it would be possible to identify proximity of urban land use functions.

By emphasising pedestrian areas, it is possible to measure the accessibility of the functions. Since the pedestrians have their defined routes, the measurement of the distance should be conducted over these routes. To measure this distance it is also required to have an average walking speed of a pedestrian. Thus pedestrian routes and average walking speed of a pedestrian enable to generate catchment areas of each activity that exists within land use functions.

Accessibility to activities is not only defined by distance. An activity may be carried out close to the residential area, however it may not be operational, and therefore it would be of no use. Consequently, to measure accessibility to activities and to more diverse land use function it is required to consider the time when each activity is operational.

2.3.5. Time interval of access to activities

Measuring the time interval when activities are accessible would reflect the change into diversity of activities during the day.

Batty and others (2004) have explained multifunctionality of land use depending on how people engage in activities over space and time. This statement describes willingness of people to be active, but it does not describe the availability of functions for which people may have interest. Therefore, measuring the time interval when functions are accessible would show the opportunities for people to engage in different activities. This measurement will make possible to see different patterns of multifunctionality during different parts of the day.

Furthermore, identifying the activities that are accessible in the early part of the day and evening part of the day, beside pattern of diversity would also show which activities can be accessible.

2.4. Conclusions

Spatial planning has been a major interest of mankind for millenniums. The challenge to plan and build a city that fulfils the needs and offers good living environment has remained repeatedly. Throughout the history of urban planning many different concepts of how cities should be built were introduced. As people changed the way of living these concepts were changed to accommodate better living environment.

Unfortunately planning concepts were not always very successful (Hall, 1997; Jacobs, 1961; Snyder and Bird, 1998). The first half of 20th century was marked as an era of the Charter of Athens, which resulted in unsustainable use of space and environmental resources. The concept of urban development applied during that time created cities which now face many problems. The spatial segregation of land uses has created a living environment where everything is far from the residential areas, and the cities have to deal with traffic congestion and poor air quality.

Dealing with the problems of prior decades of urban development, new planning concepts emerged in the last decades of 20th century in Europe and the United States. The objective of these concepts is to reintegrate spatially segregated land use functions.

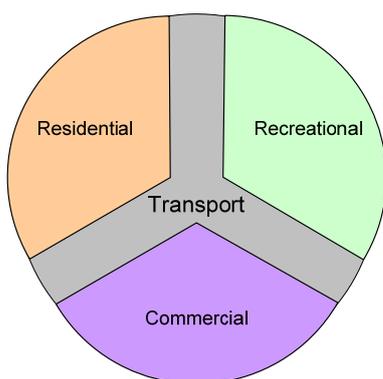


Figure 2-7. Segregated Neighbourhood

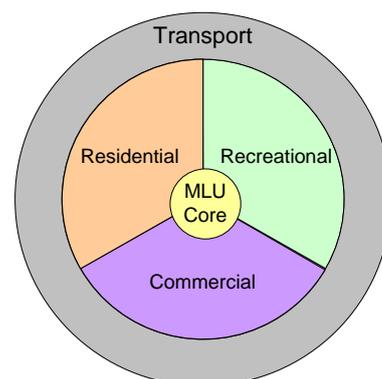


Figure 2-8. Multifunctional Neighbourhood

Nevertheless, the weaknesses of these concepts are not completely known yet. To foresee these weaknesses a number of studies have been done. However, the approaches are different varying from measuring multifunctionality based on human activities, cost benefit analysis, to the empirical phenomenon of business agglomeration.

The research of Burton (2001) measured compactness based on the services for which he developed a number of indicators to measure density, diversity and intensification. The intensification is the process of increasing the number of activities over the time. The main weakness of this research was that the data was collected from the “Yellow Pages” and did not contain any spatial data. Based on those data the comparison between 25 UK cities was done to show which ones are more and which less compact.

Table 2-4. Similarities for measuring and representing multifunctional land use

Approaches of representing MLU					
	Indicators	Measurement	Classification of land use & activities	GIS Method	
Authors	Burton (2002)	<ul style="list-style-type: none"> • Density • Mix of use • Intensification 	<ul style="list-style-type: none"> • Population density • Built form • Housing density • Number of facilities 	No classification (facilities taken from Yellow pages)	None spatial
	Batty at al. (2004)	<ul style="list-style-type: none"> • Density • Diversity • Time 	<ul style="list-style-type: none"> • Housing density • Population density • Employment type and density 	Standard Industrial Classification of employment	Raster data
	Rodenburg and Nijkamp (2004)	<ul style="list-style-type: none"> • Intensification • Interweaving 	<ul style="list-style-type: none"> • None 	Land use spatial function Human activities	None spatial
	Lin and Yang (2006)	<ul style="list-style-type: none"> • Density • Mix of use • Intensification 	<ul style="list-style-type: none"> • Residential density • Building density • Employment density 	NA	None Spatial
	This research	<ul style="list-style-type: none"> • Density • Diversity • Distance over the road network • Time 	<ul style="list-style-type: none"> • Number, diversity and distance of activities through pedestrian streets 	Land use function Urban Activity Based on ISIC classification	Vector data

Batty and others (2004) use GIS tools to measure the multifunctionality of urban area. The spatial indicators used are Density, Diversity and Time. All three indicators measure the employment type classified based on Standard Industrial Classification of employment and population density.

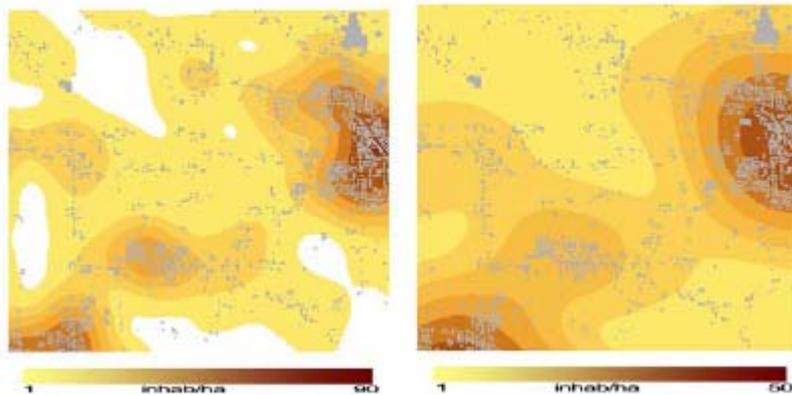


Figure 2-9. The effects of changing the smoothing parameter (Batty et al., 2004)

However, the research shows the disadvantages of measuring the multifunctionality with raster data. When applied the kernel density estimator (KDE) for smoothing the data for removing the discontinuities. The figure 2-9 shows an example of different smoothing parameters for visualizing the population density.

The research of Rodenburg and Nijkamp (2004) describes multifunctionality in details. Further it gives the possibilities of which activities and which functions could be combined and in which level. However, there is no spatial analysis to support or contradict the combinations they suggest. The indicators use to describe the multifunctionality are Intensification, Interweaving and spatial

heterogeneity. The explanation of intensification is given previously and the explanation of interweaving and heterogeneity given by authors is that both relate to diversity with some difference. Interweaving is the number of territories divided by the number of activities and spatial heterogeneity is the degree in which a given territory touches upon other different activities. The figures 2-10 and 2-11 visualize this difference.

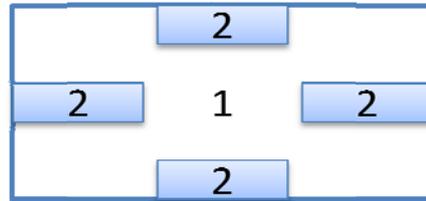


Figure 2-10. Increase in degree of interweaving (Rodenburg and Nijkamp, 2004)

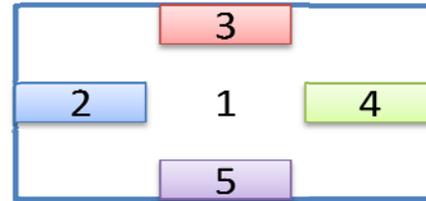


Figure 2-11. Decrease in degree of spatial heterogeneity (Rodenburg and Nijkamp, 2004)

Number 1 represent the territory which in fact is land use functions. And the number 2 to 5 represent different activities.

The research of Lin and Yang (2006) looks into compact cities and their sustainability. They take under consideration the density, mix of uses and intensification on one side for measuring compactness and environment, economy and society on the other side for the urban sustainability.

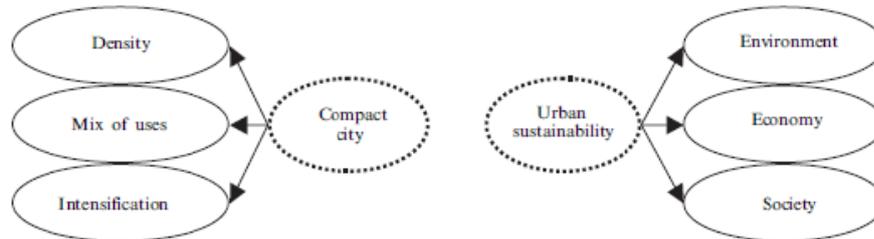


Figure 2-12. Defined latent variables for the compact city and urban sustainability (Lin and Yang, 2006)

Unfortunately, the research is not realized with spatial tools even though spatial data such as land use is used for analysis. This limits important information which would show where the advantage and disadvantage are.

In order to overcome the shortcoming of the previous researches new method with GIS based indicators is introduced for measuring the multifunctionality of urban area. The identified spatial indicators are Distance, Density, Diversity and Time. The distance will measure the proximity between the urban activities and will visualize the distance of residential areas from the patterns of multifunctionality. Furthermore, distance will be used to generate the catchment areas of each urban activity. Based on the catchments, uniform service areas will be generated which will serve to measure the density and diversity spatial indicators. Finally, the time indicator will show the change in patterns of density and diversity in different parts of the day.

In addition, the spatial analysis will be realized by using GIS tools with vector data. This should make possible to avoid the problems encountered on the research of Batty and others.

3. Methodology

The purpose of this chapter is to develop the method for measuring the multifunctionality of urban area based on the indicators identified from literature review.

For measuring the multifunctionality, the identified indicators need to be applied through a method that would represent the values of each indicator by using same spatial area. In order to achieve this, uniform service areas USAs will be defined. For generating the USAs three criteria's are taken under consideration. Firstly the location of each activity as a point, secondly the street network that is used by pedestrians, and thirdly the average walking speed of a pedestrian. Through this process first indicator of multifunctionality is already measured, and that indicator is Proximity. By using USAs, indicator of density and diversity are measured. Density is measured by counting the number of activities that cover each USA. The same is done for measuring diversity with the difference that classification of activities based on ISIC classification.

Furthermore, a short description of study area is given and methods of data collection are described together with the list of collected data.

3.1. GIS and Multifunctional land use planning

Spatial planning is not much comparable with other sciences where it is possible to have a trial and an error. The planners have only one chance and can not afford to make mistakes. This increases the need for using advanced tools that can help. The planners and planning department look for tools that can make data management and spatial analysis easier, due to the complexity of the problems they have to deal with. In particular, the advantage of Geo-Information (GI) tools shows to be very helpful in terms of managing a vast amount of different data that are required for the processes in spatial planning (Budic, 1994). A major part of such data is used in a spatial format. Thus the use of Geo-Information Technology (GIT) in the field of urban planning has been increasing each year.

The underlying principle of GIT tools has played a big role in analysing, visualising and measuring the use of space. Many studies have used GIT for conducting spatial analysis related to urban areas. In particular, Geographic Information Systems (GIS) are some of the most exploited tools when it comes to urban planning, land use allocation and measuring effects of a particular phenomenon such as urban sprawl or urban growth.

This research attempts to develop a conceptual framework based on which multifunctional urban land use can be identified and quantified. It is done by identifying spatial indicators that represent urban land use functions, and by measuring each one interrelated.

3.2. Measuring Indicators of Multifunctional Urban Land Use

Based on an extensive literature review, a number of indicators that represent multifunctional urban land use have been identified. These indicators are: density, diversity, distance and time. However, in order to measure multifunctionality, the sequence of these indicators needs to be altered.

Conceptually, before measuring the density and the diversity, a limit to the size of area should be defined. From the conceptual framework area is defined by a walking distance. These areas are identified as catchment areas of any service. A catchment area of a service is generated on the basis of measurements of an average walking speed of a pedestrian, a specified walking distance expressed in minutes and street network for pedestrians. Generated catchment areas are intersected and this generates a new spatial data that represents unified service area (USA). Unified service areas are used for measuring density and diversity indicators of multifunctionality. Density is the second indicator to be measured and is a raw count of the catchment of land use function that is overlapping the USA. After identifying the number of functions the next step will be to identify the type of functions they are. The type will help measure the diversity of functions for each USA. And finally, based on the time when certain functions are active during the day, it will help measure how the diversity changes.

3.2.1. Classification of Urban Activities

The classification of activities will help measure and describe the indicators of multifunctionality, in particular the diversity indicator. Furthermore, the indexes of Simpson and Shannon-Wiener measure the diversity based on the class, to which one activity belongs.

For this reason, application of the International Standard Industrial Classification of all Economic Activities ISIC, which is developed by the United Nations Statistics Division, groups all activities into Classes, Groups, Divisions and Section.

When measuring the diversity overtime, this classification tool will enable us to see whether a particular class, group or division forms a pattern, and if so, during what part of the day. These patterns will help identify where the interest of people is focused and how these patterns change in comparison with the residential areas.

Table 3-1. Classification of activity by ISIC – example of education

ISIC	Code	Classification
Activity	/	Primary school
Class	8010	Primary education
Group	801	Primary education
Division	80	Education
Section	M	Education

3.2.2. Measuring Accessibility to Non-Residential Urban Activities

Measuring the distance will reveal the proximity that urban activities will have between each other and, more importantly, from the residential areas. Urban activity will be used as a point location, which is within the land use functions.

A number of conditions must be fulfilled when measuring the distance of activities. All activities have to be recorded spatially throughout the urban area. This is done with point data, longitude and latitude

coordinates. This is followed with all streets and footpaths that serve the pedestrians for travelling, and together with an average walking speed of a pedestrian used as an input for conducting the measurement. Thus, having the point locations of all activities, street network and average walking speed, a geometric network should be built. The geometric network will serve to generate the catchment area of each activity.

The catchment areas will overlap in places where activities are closer to each other. Considering that the catchment of the activity is generated on the basis of a desired walking distance over the street network, the urban area will be insufficiently covered with service. This will show the areas where there is no service at all, in which case such areas can be interpreted as non-urban area. The overlapping catchment areas, on the contrary, will show where the service exists. Subsequently, the number of overlapping catchment areas will show the number of the activities that serve a place and that are accessible within a desired distance. However, this does not define precisely the size of the area for which the number of activities is overlapping. Therefore the intersection of the catchments will define these areas. The intersection will generate a unified polygon, which has the shape and size dependent on the number and shapes of overlapping catchments. This polygon is a unified service area or USA.

Later, USAs will be used to measure the density and diversity of activities.

3.2.3. Measuring Density of Urban Activities

Counting the number of activities and considering the distance factor can help identify two important pieces of information regarding urban multifunctionality. It can identify the number of activities that can be reached within a specified period of time. Therefore, a higher number of activities in a shorter distance represent the higher density.

Proximity of activities is an important factor for increasing the density in urban areas. However, it is rather complicated to define the desired level of density. This is dependent on the perception of people living in the area, and how they feel towards crowdedness (Vallance et al., 2004). Thus measuring the density could help understand this issue better. Moreover, the interpretation of density of activities can be done in two ways: 1) as an average number, or 2) as a raw count of land use functions per area. Either way the size of the area has to be defined before the measurement can be executed. The question that remains is: what is the correct size of the area for which the density is measured? Should that area be the same throughout the territory for which the measurement is done?

Assuming that density is measured taking the average number of activities of an area, the size will influence the result. Furthermore, it would be difficult to justify the size of polygon. On the second option, the raw count of land use functions per area will give more meaningful values (i.e. 7 functions) to the non-professionals. Nonetheless, the problem of the size of the area persists. Neither method describes the distance between the measured activities of a given location, or takes into consideration the road network, through which activities are accessible. For this reason, a new approach must be taken so that size, distance, and road network can be considered.

One possible approach to measure the number of activities would be to use USAs generated based on distance indicator. This would be a possible by counting the number of catchments that fall within

each USA. Therefore the results would be easier to interpret, and the size of the area for which the density is measured would not be defined by USA.

After measuring the distance, it is possible to proceed measuring the next indicator – measuring the density of urban activities.

3.2.4. Measuring Diversity of Land Use Functions

The simplest approach of measuring multifunctionality would be by the raw count of urban land use functions in the area. Yet, this will not satisfy the definition of Multifunctional Land Use Planning. The definition of multifunctionality calls for measuring the diversity of activities that exists in an area. For this reason supplementary methods have to be applied so that the diversity can be represented and measured. To be able to measure the diversity, a classification of the activities that exist within activities is required. One possible way of classifying the activities is to use the international classification system developed by the United Nations Statistical Division. This classification is known as International Standardisation of Industrial Activities ISIC (see appendix I). All known industrial activities are structured in a hierarchical manner, such as section, division, group and class, thus preventing a possible overlap of different activities.

The diversity of a place is dependent on the number of classes of activities that exist. Thus, the simplest method for measuring and visualizing the diversity is the raw count of classes. This method is known as richness. Richness will describe the difference between the two areas that have the same number of activities, but the area that has more different classes is more diverse than the other. Consequently, an area also will be interpreted as more rich, even in cases that have a smaller number of activities in total, but a higher number of classes of activities.

Even though richness as a measurement describes how rich an area is in terms of the number of classes, it does not take into account the distribution of the number activities among classes. Thus it does not completely satisfy the condition of describing the degree of diversity. Complementary to richness is the evenness measurement.

Evenness is a measure of the *relative* abundance of the different classes making up the richness of an area. An area is considered to be less diverse if it is dominated by one class. Therefore, a difference between two areas, which have the same number of classes of activities but the first is dominated by one class and the second area has evenly distributed number of activities among three classes is significant.

There are, however, limitations to both methods described above. Neither of them has been used to measure the diversity of functions in urban area (see page 28). Nonetheless, both methods can give fine information on spatial distribution of activities over the urban area. What they lack is the measure of the density for the area measured. Richness gives information on a number of classes of activities, but does not reflect the total number of activities. Complementary to this, evenness adds the information to richness by reflecting the contribution of each class of activity to the total number of activities. However, evenness will not differentiate between two areas that have as total a different number of activities.

There is, however, an example of measuring the diversity of activities in urban area. This method was developed by Batty and others (2004) for representing the density and diversity of the cities. The developed indicator tends to reduce the limitation of richness and evenness by taking into consideration not only the different activities, but also the density of activities of the area measured. The indicator first divides the areas that have one or more activities and areas that do not have any activity. Areas with no activity are excluded from further analysis.

For the areas that have one or more activities the diversity is measured first by calculating the difference between the activities that exist in the area and a total number of activities of the city. However, this measurement does not take into account the density. Therefore it is enhanced to meet this requirement. Consequently, the amount of activity in the area is expressed as a proportion of the maximum amount in the city, and then variables of all existing activities of an area are accumulated. This was called as density-diversity and the equation is as follows:

$$\delta(i) = \sum_k (a(i, k) / \max_k a(i, k))$$

Equation 3-1. Density-Diversity Index (Batty et al., 2004)

The variable i represents the area for which the measurement is done, K is the number of activities, and the amount of activities for a place is expressed as $a(i, k)$. The value of $\delta(i)$ varies from 0 to K , where if $\delta(i) = K$ then the volume and mix of activities in areas is maximum volume of each activity existing.

Another method for measuring diversity and that is applied in the context of urban diversity is Simpson's index of diversity. However, this index originates from natural science and is used to measure diversity of species of a natural environment. In natural science, diversity is measured based on specimens who belong to specie, genus, family, order, class, division, and kingdom respectively. Similarly, urban industrial activities are structured in a hierarchical order into, activity, class, group and division (see Appendix I).

Table 3-2. Biology Taxonomy compared to ISIC structure

Natural Science	Urban Activities
Specimen	Activity
Specie	Class
Genus	Group
Family	Division
Class	
Division	
Kingdom	

An illustration of biology taxonomy of natural science and International Standardisation of Industrial Classification (ISIC) of United Nations Statistics Division (UNSD) is given in table 3-1.

The Simpson's index of diversity has been applied in urban studies by department of urban planning of Illinois University, USA. The index was used to map the diversity of neighbourhoods in census block level by population race, age, income, and also for mapping mix of housing.

The rationale of using diversity index that is commonly used in natural science in order to measure diversity of functions in urban area is based on the common method of how they are structured. For

measuring the degree of diversity, Simpson’s index combines the measurement of Richness and Evenness. Therefore, measurement shows diversity based on hierarchical structure of measured unit. Hence, unit can represent a specimen in case of natural diversity, or activity in case of urban diversity of land use functions.

The formula for calculating diversity by Simpson’s index is:

$$D = \sum_{i=1}^s p_i^2$$

Equation 3-2. Simpson’s Index

The p_i variable represents the number n of activities of same class divided by the total number N of activities of the measured area, therefore also represents the evenness. The n variable represents the richness of area, since per each class there is one n .

$$p_i = \frac{n}{N}$$

Equation 3-3. Contribution of an activity to diversity of area

The index is influenced by evenness, however, as the diversity increases the value of D decreases. Thus it makes the reading of diversity more complex. In order to overcome this problem, a modification to the index is made by subtracting the value with one, which is known as Simpson’s Index of diversity.

$$1 - D$$

Equation 3-4. Simpson’s Index of Diversity

Similar to Simpson’s index is Shannon-Wiener index. Even though this index originates from information theory, it has wide use. It measures the order (disorder) of observed within a system. The first step is to measure the variable p_i of each class of activity and then multiply it with natural logarithm of the same number.

$$H = - \sum_{i=1}^s \ln(p_i)$$

Equation 3-5. Shannon-Wiener Index of Diversity

The result of this index is heavily dependent on both, richness and evenness indicators. The importance of activities that is rarer is higher from the activities that are common in the area for which the diversity is measured. This influence is due to the application of natural logarithm. The table below gives an example of an USA with only two classes of activities with different number of activities of each.

Table 3-3. Influence of rare activity in index of diversity

Class of Activates	Number	P_i Variable	\mathcal{LN} of P_i
Grocery Shop	9	0.9	-0.10536
Primary School	1	0.1	-2.30259
Total Abundance	10		

From the table it easy to understand also that by using logarithm the output is negative value. Since it is not logical to express diversity with negative value because there is no negative diversity, then the sum of values is multiplied with -1.

The rationale of applying the Shannon-Wiener index into urban diversity is based on method how index measures the diversity. The measurement shows diversity based on hierarchical structure of measured unit, which on this case will be urban activities. Furthermore, one can not expect that all activities will exist in same number in urban area. Here must be taken under account that services (activities) like secondary school, police station, post office and alike have larger catchment area than activities like grocery shop, fast food and alike. Therefore, this index will put more importance to these activities when diversity is measured.

All urban activities, however, do not operate 24 hours a day. There are number of activities that do, and there are activities that don't operate. These different operation times affect the diversity of urban area over the 24 hour frame time. Therefore, it is important to record the working hours for each activity and map the diversity as these activities are available.

3.2.5. Time Indicator

Whether a city is more diverse or less is also dependent on the availability of activities of land use functions in a particular urban area. The availability of activities where people can engage is dependent on the working hours that these activities have. The longer working hours result in greater possibilities for people to utilise the diversity of the activities that surround them.

There are many ways of recording the working hours of activities when measuring the diversity. One method would be to divide a day in three distinct times of eight hours each. This would be related with regular working hours of the institutional activities. The first time interval would be from 08:00 to 16:00, the second interval would be from 16:00 to 00:00, and the third interval would be from 00:00 to 08:00. This method would allow to see the number and the different classes of activities that operate. It would also make it possible to see the change of classes of activities from first, second and third interval. A reasonable conclusion could be drawn that during the first interval institutional activities would be one of the dominant classes, whereas the second interval would be more dominated by the recreational activities. Thus, a pattern of spatial distribution would be different.

Another method of measuring the diversity as it changes over the course of a day would be by applying a sequence of measurement in four hour interval starting from midnight. This would double the number of required observations as it doubles the number of outputs to visualise how the diversity of available activities changes over the time. Additional maps will help understand the dynamism of the urban area over the time and space. Furthermore, it will describe what happens in early morning hours before the institutional activities start to become operational, and what happens in the late hours of the evening.

The availability of activities over the urban area, and the influence of the same activities on the diversity of activities in the urban area will be more meaningful if they are put in the context of the calls of activities they fall into. Thus, it is required to have a method in place that will make this classification possible. The classification needs to be clear and comparable with the classes that can exist in different places. This would allow, if necessary, to compare different parts of the same city, or different cities as well.

3.3. Agglomeration of Economic Activities

Agglomeration of economic activities has been studied by Vreeker and others (Vreeker et al., 2004) as an important aspect of multifunctional land use.

The measurement of multifunctionality based on the density and diversity spatial indicators will help to visualize if this agglomeration exist. The density indicator will make possible to spatially identify areas where activities are concentrated. Furthermore, it is possible to measure the density of activities based on different class as classified by ISIC. This will identify the spatial pattern of which activities are clustered, and which area is this agglomeration

Furthermore, the diversity as spatial indicator for measuring the multifunctionality may play an important role to understand if clustering of economic activities. While the density could identify the cluster, diversity will visualise if this clustering is made of similar or different economic activities.

3.4. Selection of Study Area

Selecting a study area where it would be possible to measure MLU is one element of this research. The selected area is situated in a very strategic location in Kosovo. The town of Fushë Kosova is rather small but is located close to the capital city, Prishtina, and is surrounded with a number of industrial complexes and major infrastructure of national interest (see figure 3-1).

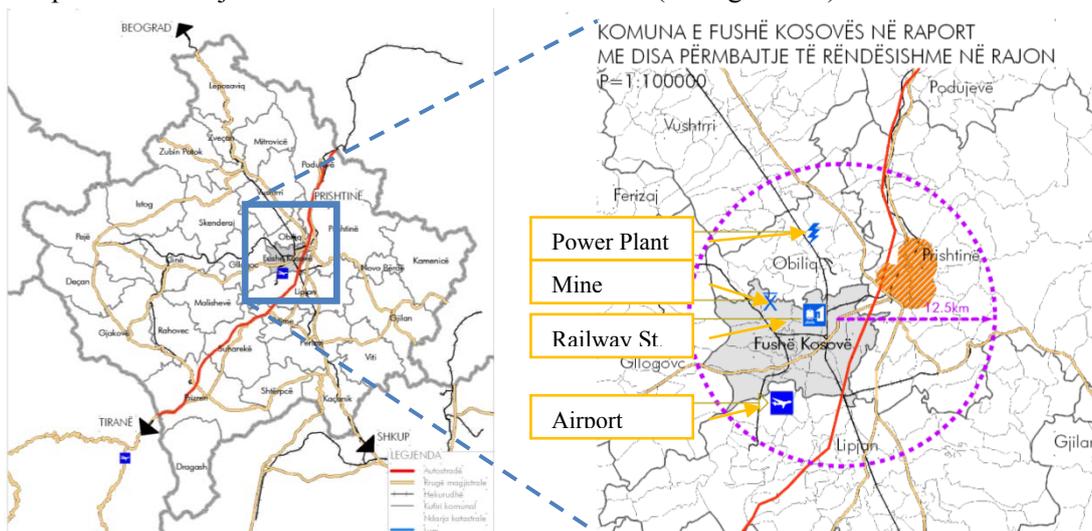


Figure 3-1. Fushë Kosova in Regional context (Not to scale)(Source: Urban+, 2003)

As the map shows, the capital city of Kosovo, Prishtina, is to the east of the town, and to the south there is Prishtina International Airport, with the main road connecting Prishtina and the Airport through the centre of Fushë Kosova. The town centre has a Central rail station, which is also the main rail station for Prishtina. Further west there is a major activity – surface coal mine that opened in mid 1960's, and today continues to grow. To the north-west lies a thermal power plant that employs a large number of people from Fushë Kosova. Another important part of the national transport infrastructure, a highway connecting the Albanian coast and Serbia through the centre of Kosovo, is expected to be constructed in the near future. All these factors contribute to an increase of pressure for more residential units to be constructed in Fushë Kosova.

The town was originally a small place with more than 90% of housing being detached houses. This is changing rapidly into multi-storey family housing, with usually commercial activities on the ground floors. Figures 3-2 and 3-3 show the same location within a three year period – large apartment blocks currently stand instead of two small detached houses.



Figure 3-2. Buildings on main street in 2003



Figure 3-3. Building in same location in 2006

The demand for housing is keeping the pressure for new developments. For this reason the local authorities are looking for a viable solution to have the development under control. Sustainability of these developments is the main concern for the authorities.

The area showed to be interesting enough to look into it from the multifunctionality perspective and see if and what can be learned from it. The area is not big in size, but due to the good location (see figure 3-1) it attracts people to move there for living. As a result, in last two years the population size has increased by more than 20%. As a result, the structure of the area is changing from the small detached houses to multifamily dwelling (see figures 3-2 and 3-3)

3.5. Data Collection

Before the field work was initiated, a list of required spatial and non-spatial data was prepared. The data collection was conducted using two methods, primary sources and secondary sources (see figure 3-4).

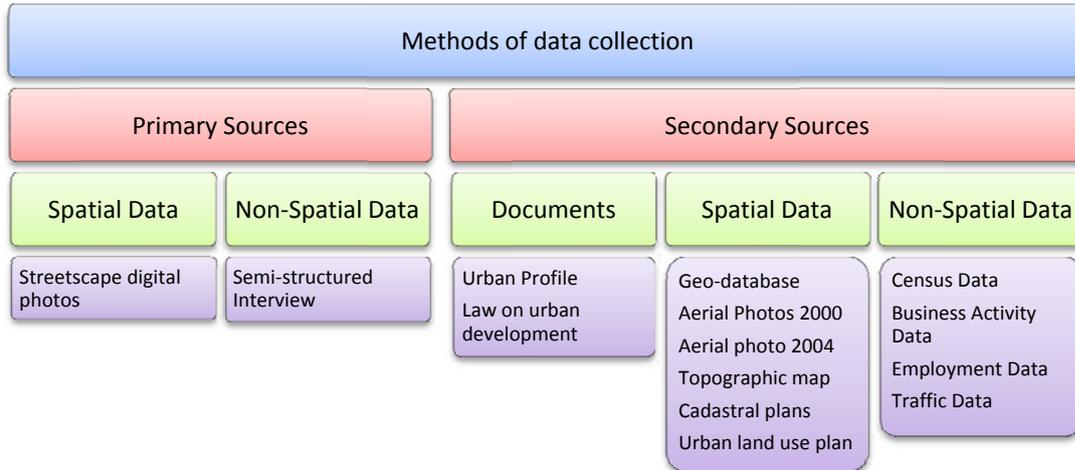


Figure 3-4. Methods of data collection

3.5.1. Primary Sources

The primary sources data include spatial data and non-spatial data. The spatial data are pictures of streetscape collected along the main street. These pictures were collected for the purpose of updating the geographic database (a secondary source) of all economic activities in Fushë Kosova (see figures 3-5, 3-6 and 3-7).



Figure 3-5. Streetscape in location *Alpha*



Figure 3-6. Streetscape in location *X-ray*



Figure 3-7. Streetscape in location *Yankee*

The location where the picture of streetscape were taken are located along the main road of the study area. This is the most important location since all the changes are happening along this road. The map indicating the 26 locations with three highlighted samples where the streetscape pictures are taking is shown in figure 3-8.

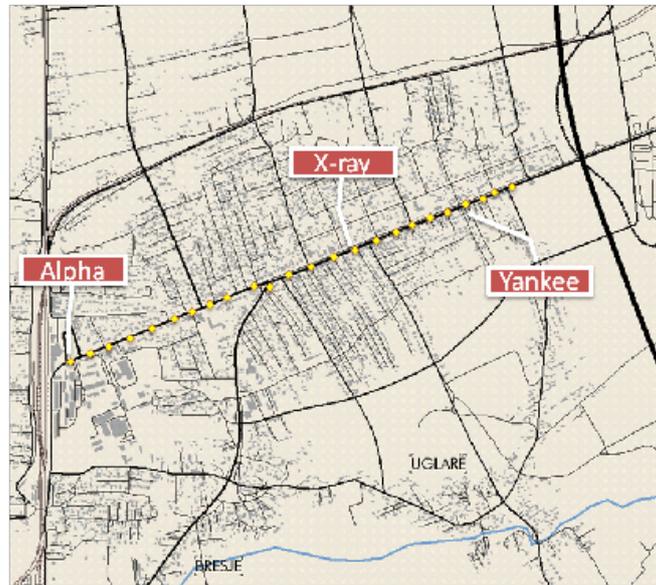


Figure 3-8. Location where streetscape pictures were taken

The primary sources included a number of semi-structured interviews with several organisations. Firstly, the interviews were conducted at the municipal authority of Fushë Kosova, with the head of Planning Department. Further interviews were conducted with three planning professionals working in the same department, who are directly involved with planning permits and the implementation of planning regulations. Secondly, an interview was carried out with the director of the Kosovar National Institute of Spatial Planning. The interest for this interview was based on the responsibilities that this Institute has for providing technical support on the implementation of laws, regulations and adopted urban plans to the municipal authorities. Thirdly, two additional interviews were conducted with two professionals of the company that, in cooperation with the municipality, developed Urban Strategic Development Plan (see figure 3.5 for a 3D model of the vision for future development).

All interviews were carried out on a face-to-face basis. Ample time was allocated for each interview so that the required information for the research is recorded. The interviews with the professionals of the municipality were conducted separately and in different locations to ensure that they are free of political pressure. A table with topics and insight from the interviews is given (see table 3-4).

The interviews with head of planning department and planners of the municipality of Fushë Kosova resulted with information relevant to multifunctional land use planning. The demand for new residential buildings, in particular along the main road is changing the structure of the town. This change is creating the single use areas to multifunctional land use, by changing from small detached houses to multifamily dwelling blocks. The change is creating the street into continues linear shopping area since all new constructions contain the ground floor and often first and second floor shops and office spaces. Unfortunately, planning authorities don't have resources to control all development which is in all cases realised by private sector. Therefore, planning authorities have serious concerns about the sustainability of the new development.

Considering the situation of local authorities in Fushë Kosova, which is similar with most of the towns in Kosovo, the National Spatial Planning Institute has come with policies that help local authorities. The policies promote the vertical development of urban areas, giving even more opportunity for multifunctional land use planning. This policy is based on the facts that new uncontrolled developments have caused to loss of open space and agricultural land that surround the town.

Furthermore, planning authorities have initiated the development of new strategic urban development plan, which was approved by local assembly in 2005. The new plan has made possible that new developments are brought under control. Through extensive analysis of existing situation, new plan of Fushë Kosova makes possible develop of high density areas with different functions along the main road (see figure 3-9).



Figure 3-9. Vision of future development in 3D

For complete list of collected data and their source see section 3.4.3.

Table 3-4. List of interviewed persons with insight to the research

Post of interviewed	Organization	Topics	Insights	Contexts
Head of Urban Planning Department	Local Government of Municipality	Planning processes Availability of data	<ul style="list-style-type: none"> • High demand for new development • Conversion of detached houses into residential building blocks • Concern for sustainability of current development • There are many data available in different formats, but unstructured and spread throughout different places 	<p>Current urban development and sustainability</p> <p>Availability of data</p>
Senior Urban Planner Urban Planner Urban Planner	Urban Planning Department	Planning procedures Building Permit Use permit Use of Plans (Land use, regulatory plan)	<ul style="list-style-type: none"> • Most of building permits are requested for multifamily housing along the main road • Most of new buildings contain at least one floor (ground floor) commercial activity, often also including first floor • All investments are realised by private sector 	Current urban development
Director	National Institute for Spatial Planning		<ul style="list-style-type: none"> • National policies favour vertical development with higher density 	Sustainability in current planning practices
Senior urban planner Senior urban planner	Urban+	Planning concept	<ul style="list-style-type: none"> • High density • Mix-use development (see figure 3-5) 	Vision for future urban development

3.5.2. Secondary Sources

The secondary sources data include spatial and non-spatial data for the town of Fushë Kosova. The spatial data include a geographic database which was built in 2003 and was developed for the purposes of collecting and storing data for the Strategic Development Plan that was approved by the Local Assembly in late 2005. The database contains information about the population, structured according to the size of the household, age groups, professional structure, travel mode preferences, employment, and so on. All the information was collected under the supervision of municipality and based on a questionnaire (see appendix III). The database includes information for some 3000 households, which represents approximately 80% of the total households. The database also includes data for all commercial and non-commercial activities located in the town. In addition, information regarding the employment and activities are included in the survey. Furthermore, aerial images of year 2000 and 2004 were provided by the company, which helped the municipal authorities develop the urban plans. Moreover, the cadastral plans were provided by the Property Department of the local authorities of Fushë Kosova. Finally, the Department of Urban Planning provided the land use plan, which was completed in 2005.

The non-spatial data were collected from the Department of Urban Planning. The data included information regarding the census, commercial activities, employment, traffic, and planning laws and regulations. The data, with the exception of planning laws and regulations, were collected as a supplement to the geographic database under the supervision and by contract of the Department of Urban Planning.

For an exhaustive list of data collected and their sources see section 3.4.3.

3.5.3. Checklist of collected data

Based on the objectives and research questions, a list of data and information was identified. The data were collected during the fieldwork and contain spatial and non-spatial data from various sources. Below, Table 3-6 provides the complete list of spatial data, whereas Table 3-5 provides a comprehensive list of non-spatial data.

Table 3-5. List of collected non-spatial data and their sources

Data	Source
Urban Profile Analysis of existing situation	Municipal Urban Planning Department
Law on Urban Planning	National Institute for Spatial Planning
Census data	Municipal Urban Planning Department
Business Activities	Municipal Urban Planning Department
Employment data	Municipal Urban Planning Department
Traffic	Urban+

Table 3-6. List of collected spatial data and their sources

Data	Type	Information	Q/A	Source
Land use	polygon	Residential Commercial, Industrial, Education, Green areas, Public Spaces, Cultural-Social, Health Service,	Will describe uses that are active, activities	Municipality Urban Development Plan, Urban Profile of Fushë Kosova
Parcel	Polygon	Area	Will be used for spatial analysis for pattern of function in parcel level	Municipality (Cadastral plans, aerial images)
Building	polygon	Use of building, Number of floors, Footprint area, Year of construction	Will answer the number of a within urban area.	Municipality (Cadastral plans, aerial images)
Building	point	Use type, Related uses,	Will answer the number of functions within urban area.	Municipality
Topographic map Scale 10k	Scanned	Update existing digital data	Quality control of function of major industry buildings	KFOR (NATO)
Aerial Photo Year 2000 20cm res.	Digital	Update existing digital data	Quality control and update of layers of buildings, functions	Kosovo Cadastral Agency
Oblique View pictures from helicopter	Digital	Update existing digital data	Update buildings layer	Personal Site visit
Side view pictures	Digital	Update function of buildings	Update business activities	Personal Site visit

* ArchiCAD¹ software that was used by the company to draw the plans

3.5.4. Data processing

Most of the data available were in a digital format. However, most of the spatial data were in a CAD format drawn using ArchiCAD software, which stores information in a PLN format, i.e. landuse.pln.

¹ ArchiCAD is a technical drawing and design software developed by GRAPHISOFT Company.
<http://www.graphisoft.com>

This format is not, however, supported by ArcGIS² that was used as the primary GIS software for spatial analysis during this research.

The process of data conversion was done by exporting layers from ArchiCAD to DXF³ file. FME⁴ software was used to convert data from DXF to shape file (SHP⁵), which is native ESRI spatial data format.

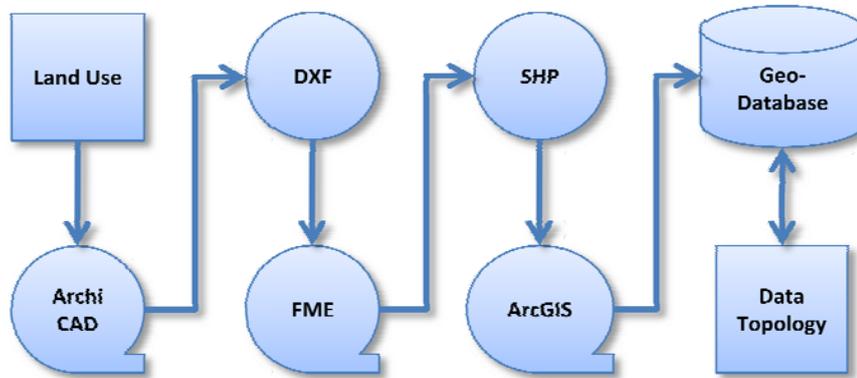


Figure 3-10. Data conversion flow

3.6. Spatial Analysis

For mapping the measurements of indicators of the multifunctional land use a number of spatial analyses should be realised. The developed methodology for each indicator should be applied to collected spatial and non-spatial data.

The identified indicators for measuring multifunctionality will produce maps which will visualize the measurement. It is of interest to map the contribution of each indicator to multifunctionality. Furthermore, classification of activities will make possible to map the contribution of each class, group or division of activity to the multifunctionality. In addition, the three methods for measuring diversity are to be applied to spatial data. The literature review suggests that each index of diversity will produce different results, thus visualisation will help to see these differences.

For the models and methods of reproducing the measurements see the appendices. For measuring distance, density, diversity and temporal diversity see appendix IV, V, VI and VII respectively.

² Geographic Information System developed by Environmental Systems Research Institute. <http://www.esri.com>

³ DXF is technology standard for CAD software's and stands for Data Exchange Format

⁴ Feature Manipulation Engine is software for spatial data conversion developed SAFE software vendor. <http://www.safe.com>

⁵ Shape file is native spatial data format for ESRI software products also support by major GIS softwares

4. Case Study

This chapter gives a brief historical background of the study area. Furthermore, it explains the geographic location and need for multifunctional land use planning.

4.1. Background of study area

The town of Fushë Kosova is located in geographic position that favours urban development. The town is located between important industrial and trade areas (see figure 3-1 and 4-1).

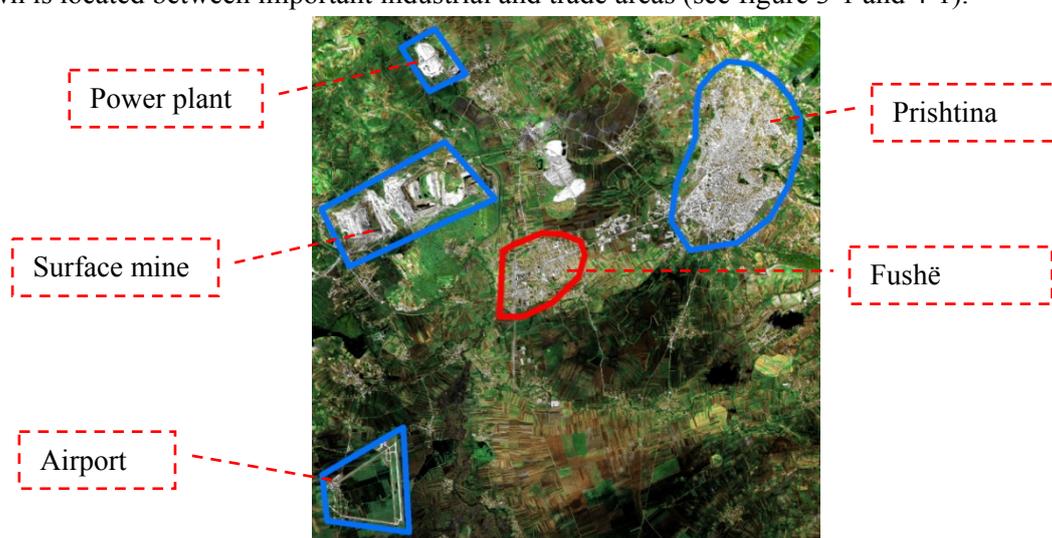


Figure 4-1. Satellite image of study area with surrounding

The town of Fushë Kosova until 1985 was part of the municipality of Prishtina, the capital city. However, with urban development and increasing number of people living there it was separated as a municipality. Since then, continuously the number of people that moved to live there increased.

Table 4-1. Number of houses and population for Fushë Kosova (Urban+, 2003)

	1948	1953	1961	1971	1981	1996	1999 para luf.	2001	2003
F.Kosova	203 847	339 1211	605 1413	1587 6992	2500 1248 0	---	1060 1000 0	1395 1400 0	--- 14000

The table 4-1 shows the increase of population and houses over the years. The first row shows the number of houses, and the second row shows and population. However, with the war in 1998 – 1999 most part of the urban area was burned and destroyed (Urban+, 2003).

In the post war time, the situation started to change due to the economic changes and redevelopment. This created a situation for new development which started to change the physical structure of the town. The most important part of the town for new urban development was along the main street. In land parcels where used to be small houses, started to emerge new buildings which are four to six floors while containing different commercial activities in the lower floors. This form of development matches with multifunctional land use planning, however, is not developed within the concepts of it.

4.2. Study area in the context of multifunctional land use planning

The town of Fushë Kosova in recent years has undergone through some dramatic changes. From the small community of mainly detached houses has changed to a town with many new residential apartment and commercial activities.



Figure 4-2. Aerial view of Fushë Kosova

The figure 4-2 shows an aerial view of the study area where new development can be seen. All big structures on the right hand of the main street are new residential apartments which are being built. This new development is driven by the opportunities for employment in the capital city and the industrial activities near by.

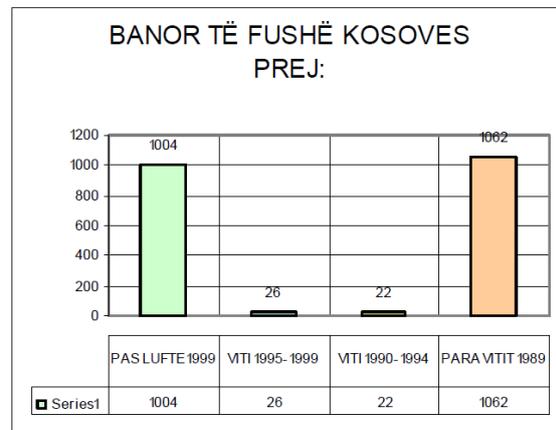


Figure 4-3. Migration of population in Fushë Kosova (Urban+, 2003)

A survey done in 2003 identifies the number of families that lived in Fushë Kosova before the war in 1999, and after the war. Figure 4-3 shows the results of the survey. The left bar of the graph (pas luftime 1999) shows the number of families that moved to live in Fushë Kosova, where the right bar (para luftime 1989) shows the number of families before the year 1989. Some of the main reasons for people to move there are employment, security and education (see figure 4-4).

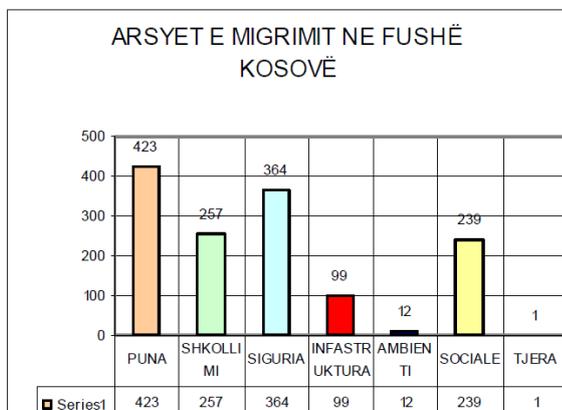


Figure 4-4. Reasons to move to Fushë Kosova (Urban+, 2003)

Brief explanation of the chart

<i>Albanian</i>	<i>English</i>
Puna	Work
Shkollimi	Education
Siguria	Security
Infrastruktura	Infrastructure
Ambienti	Environment
Sociale	Social
Tjera	Other

The recent data collected by the municipal urban planning department rise the number of population by more than 20% from the year 2003 to 2005. This signifies the pressure that planning authorities have and the need for new housing units and new jobs to be created within the town. Therefore planning authorities are making efforts to put under control the development by designing the new strategic urban development plan.

The new strategic urban development plan is design to make possible that all new development is done along the main road. This is done by involving the community and private sector and many other stakeholders in order to join efforts and bringing foreword the interest of people. However, all these efforts are done with the objective to increase the density and diversity of urban activities in the central part of the town (see figure 3-9). Furthermore, this form of development is supported by the planning law and policies drafted by the National Institute of Spatial Planning (ISP).

The interest of planning authorities and ISP is to prevent the expansion of urban area with low density housing by increasing the density and diversity of functions and urban activities within the town.

5. Spatial Analysis

The purpose of this chapter is to visualize the multifunctionality of urban area by using the developed method. By applying the method a number of maps are generated from which represent different indicators.

How each indicator is measured and what each map represent should result with meaningful output. The process of generating USAs is described and visualized. Furthermore, maps for each indicator are generated for representing which indicator how it measures and represents the multifunctionality. In addition, a visual comparison is made possible by putting maps side by side and visualising results by using standard deviation of their raw values.

5.1. Uniform Service Areas

For measuring the multifunctionality of urban area based on the identified spatial indicators it is required to have all location of urban activities. The activities are recorded as a point which is located within a land use, and as such it reflects the functionality that it may have. Furthermore, this functionality has an influence over the parts of urban area. This area is defined as catchment area of an activity. In addition, catchments represent the proximity of people to the activity. The catchment of an activity at the same time can be used to visualize the possible clustering of economic activities.

Considering the difficulties of measuring the multifunctionality of urban area with raster type of spatial data (see Batty et al., 2004), the approach in this research is to conduct the measurement with vector type data. The difference would be that instead of measuring multifunctionality per cell which has same size throughout entire layer, the polygons of vector layer will be used, which have different sizes and shapes. This is done by creating the polygon of catchment area for each activity and later intersecting them. The result of intersection is an area polygon that is covered by different number of activity catchments from all its neighbouring polygons. This we call uniform service area USA. The catchment polygon contains the information of the activity that belongs to. Therefore, it is possible to map the number and the class of activities for each USA.



Figure 5-1. Activity with catchment area (Not to scale)



Figure 5-2. Intersection of catchments (Not to scale)

The process of creating catchment areas requires minimum three parameters. The first parameter is the location of activity in space, because it is required to have a centre point of polygon. The second parameter is the road network. In this case we measure the access to activity for pedestrian, therefore only pedestrian paths are considered. And the third parameter is the travelling speed. This parameter is more difficult to define because of different characteristics of walking. However, based on literature, it is suggested that the average walking speed of pedestrian is 1.47m/s (Willis et al., 2004). This result was based on observation of people of different ages, genders and groups.

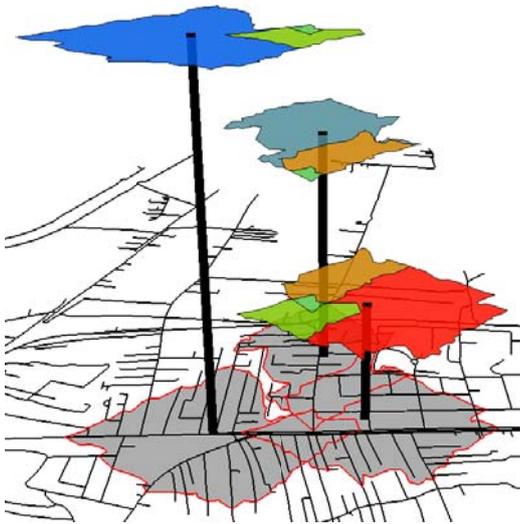


Figure 5-3. Activities and Catchment form USAs

The figures 5-1, 5-2 and 5-3 show the method how the USAs are created. From three activities (represented with cross in fig. 5-2) catchment areas are created for each one. The intersection of the catchments generates six USAs shown in 3D in fig. 5-3. Each USA is represented with the same colour in the all catchments.

For further spatial analysis, USAs are used to measure the density, diversity, and diversity during the day.

5.2. Proximity of activities from residential areas

When generating catchments of activities we identify in space the distance that needs to be covered to reach the activity. In this case the distance is not directly expressed in meters, but in time of minutes. Therefore, it is possible to identify for a given activity how many houses are within reach of 5 minutes walking. By merging together catchments of all activities it is created the total catchment area of all activities. This overall catchment visualizes very important information. Which houses are within the catchment, and how many of them.

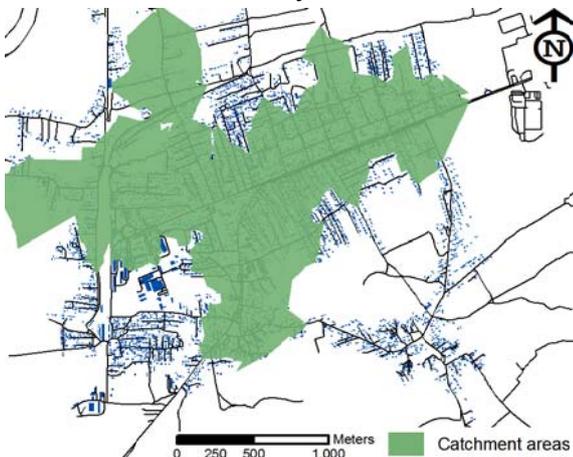


Figure 5-4. Catchment of activities and buildings

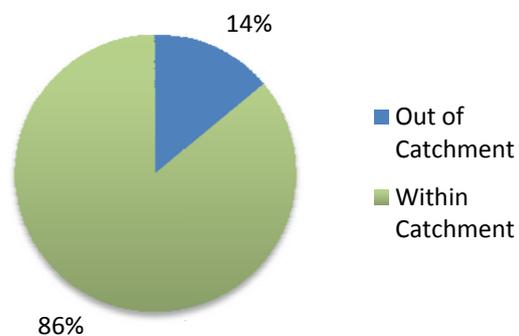


Figure 5-5. Buildings in relation with catchment areas

The overall catchment shown in figure 5-4 is measured based on 5 minutes walking distance from non-residential activities. This means that all people that live in the area that is not covered with overall catchment need more than 5 minutes walking to reach to any activity. The overall catchment does not measure the number of activities, thus density is not measured in this process.

5.3. Measuring the density of activities

The density of activities is measured using the USAs. But, the size of USAs is not the same therefore, there are USAs with area ranging from less than a meter square to thousands of meters. As a result, measuring the average number of activities that cover USAs, causes the values to be extrapolated. Hence, the raw count is taken to represent the density.

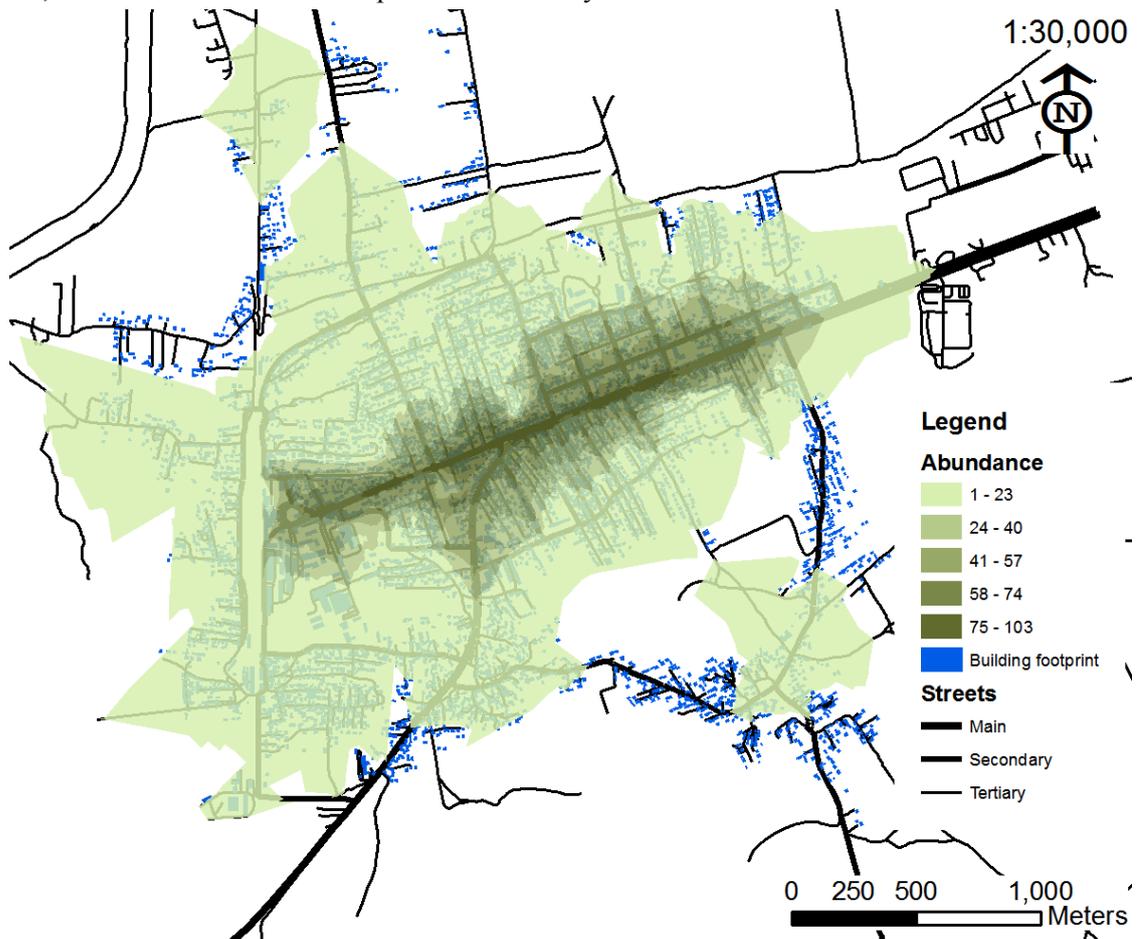


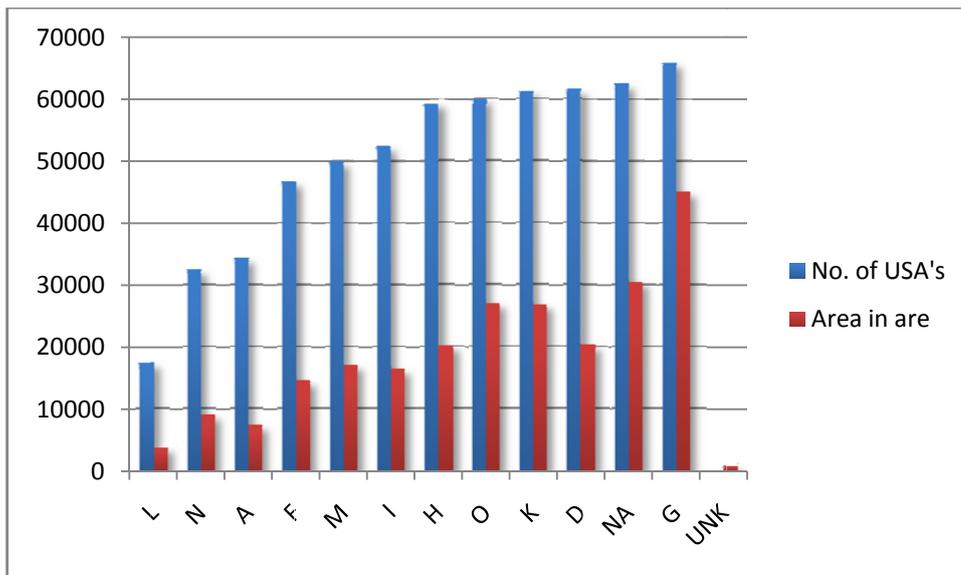
Figure 5-6. Distribution and amount of activities over the urban area

The map in figure 5-6 shows the amount of activities without considering to which class, group or division they belong. The spatial distribution of activities follows the main road and is following the secondary roads. This distribution shows that activities are mainly concentrated along the better road infrastructure which makes access easier. Furthermore, the density of activities is concentrated around the area that has higher density of housing.

For identifying which activity is contributing more to overall density, classification is applied and map for each division is produced.

Table 5-1. Classification of activities in Divisions based on ISIC structuring list

Description	Division Code
Agriculture, hunting and forestry	A
Manufacturing	D
Construction	F
Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	G
Hotels and restaurants	H
Transport, storage and communications	I
Real estate, renting and business activities	K
Public administration and defence; compulsory social security	L
Education	M
Health and social work	N
Other community, social and personal service activities	O
No Activity	NA
Unknown	UNK


Figure 5-7. The number of USA compared to the total area per division of activities

To understand better the distribution of activities of each division a chart shown in figure 5-7 is prepared. Two information's are compared, first is the number of USAs and the second is area in are (are is measuring unit for 100 meter square). Each division covers different number of USAs, starting with division L “*Public administration and defence; compulsory social security*” which has the least number of USAs to the division G “*Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods*” covering highest number of USAs.

However, the size of USAs is not same. Hence the total area of each division shown in are is does not increased with higher number of USAs. To compare this difference we could show the difference between the division K – “*Real estate, renting and business activities*” and division D – “*Manufacturing*”. Both have almost same number of USAs, but the total area of division D is smaller.

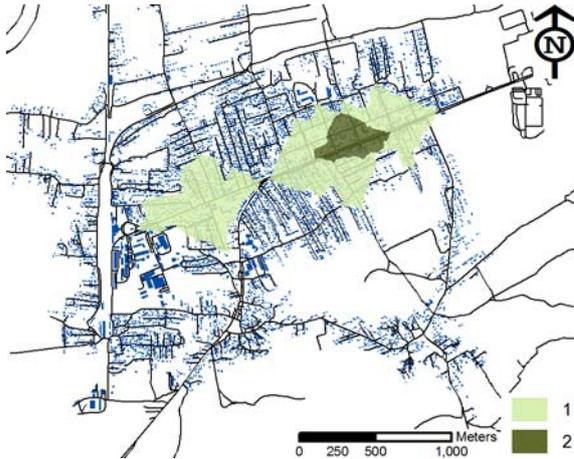


Figure 5-8. Patterns of Division A - Agriculture, hunting and forestry

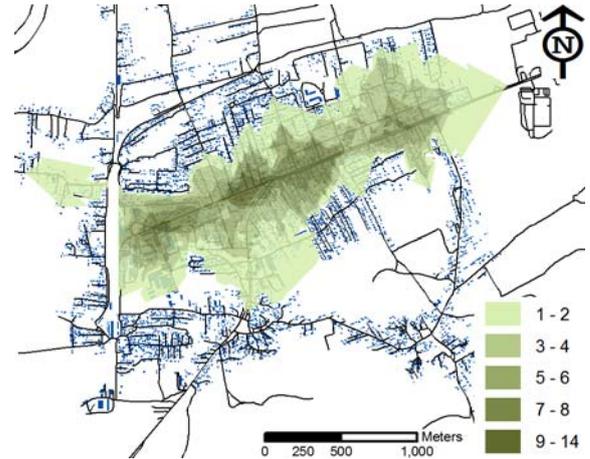


Figure 5-9. Patterns of Division D - Manufacturing

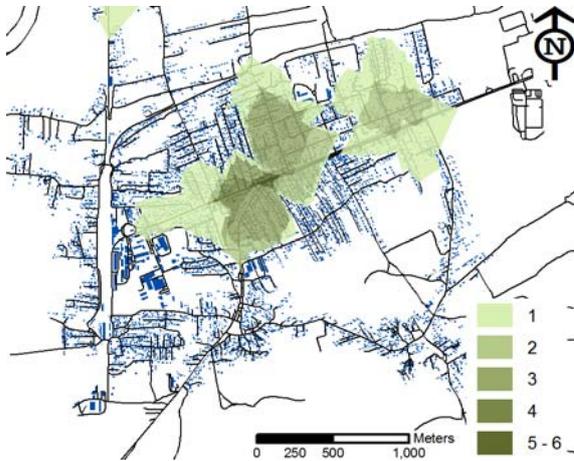


Figure 5-10. Patterns of Division F - Construction

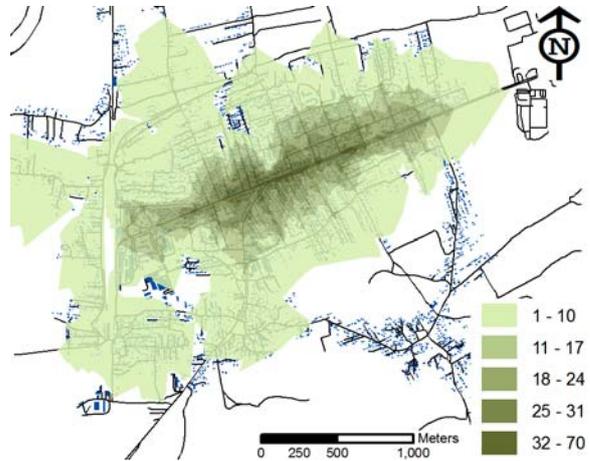


Figure 5-11. Patterns of Division G - Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods

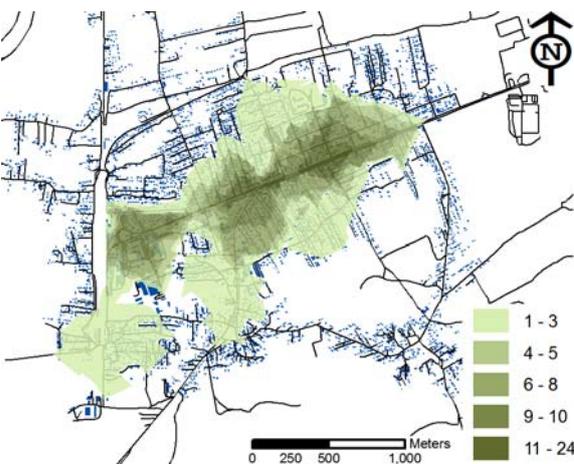


Figure 5-12. Patterns of Division H - Hotels and restaurants

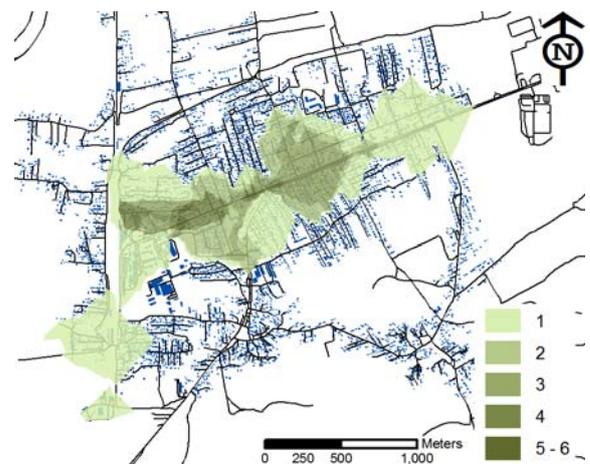


Figure 5-13. Patterns of Division I - Transport, storage and communications

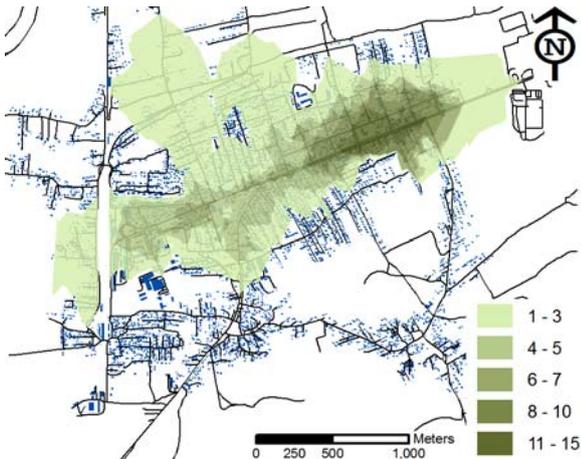


Figure 5-14. Patterns of Division K - Real estate, renting and business activities

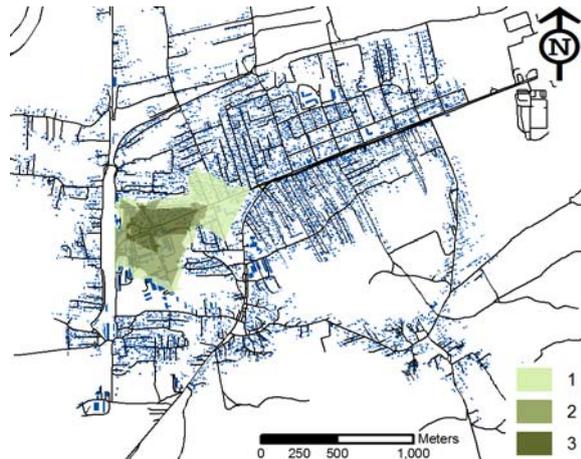


Figure 5-15. Patterns of Division L - Public administration and defence; compulsory social security

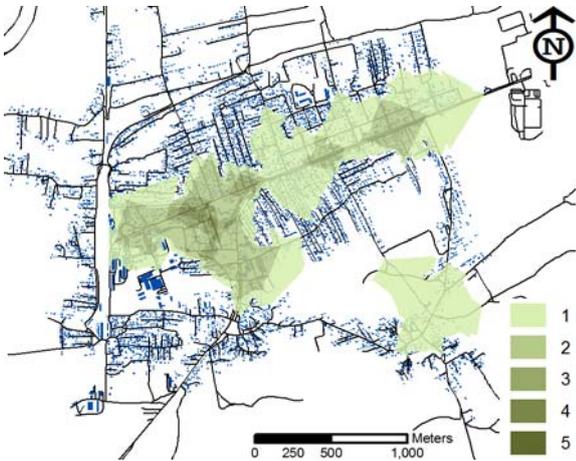


Figure 5-16. Patterns of Division M - Education

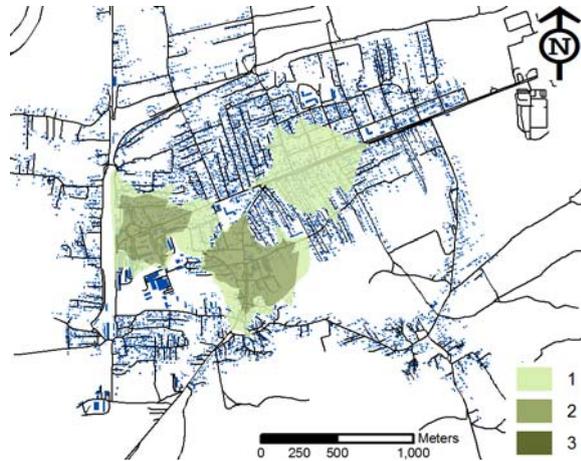


Figure 5-17. Patterns of Division N - Health and social work

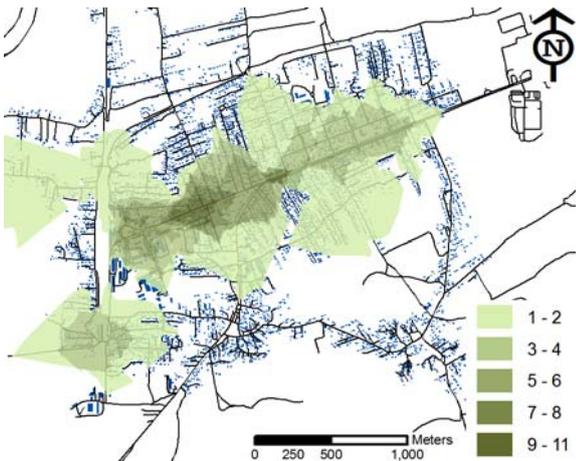


Figure 5-18. Patterns of Division O - Other community, social and personal service activities

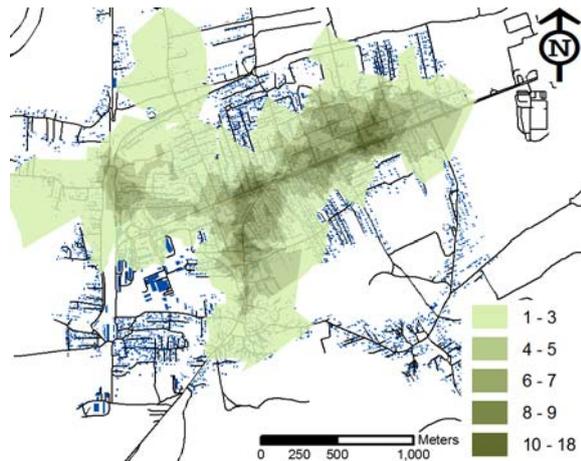


Figure 5-19. Patterns of Division NA - No Activity

The division of activities that contribute most to the density of urban area is division G “Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods”. It is spread over most part of urban area with up to 70 activities per USA.

While each division has different pattern of spatial distribution, the pattern of density is stronger along the main road for all division. One of the interesting patterns is the division D – “*Manufacturing*” which would be more logical to be distributed in the fringe of urban area due to the noise and waste they create. However, this pattern is also much denser in the central part of the town, along the main road.

Furthermore, the patterns of division M – “*Education*” and N – “*Health and social work*” do not show very high density. But the significant information is their concentration instead of balanced spatial distribution. As a result the residential areas that are out of the catchment are identified.

In the context of multifunctionality attention would draw the pattern generated from the locations that are vacant (figure 5-19). Even though the density is higher along the main road, the pattern is distributed in most parts of urban area. This information reveals the potential that exist inside the urban area for increasing the multifunctionality.

5.4. Measuring the diversity of Activities

The diversity of urban area is determined by the diversity of activities that exists. This diversity is measured for each USA. The more different activities cover the same USA the more diverse will show. For measuring the diversity per USA it is required to apply the indexes of diversity identified from literature review.

5.4.1. Richness

Richness as method of measuring the diversity shows how many classes of activities contribute to diversity. However, the richness does not take under the consideration the total number of activities. This method for measuring diversity of urban area may be important information. Because the urban activities have different duty to perform, it is not possible to have all activities cover entire urban area.

An example of this difference could be to compare the grocery shop with a school. Grocery shop is commercial activity which can vary in number and size within one street or neighbourhood. Contrary to this, school is activity which is expected to be more spatially distributed in urban area, and usually serves to more than one neighbourhood.

The map showing patterns of richness measurement (figure 5-20) seems very similar with the patterns of density of activities. The pattern of high richness consists with the central part of urban area showing, on this case, that high density is somewhat balanced with diverse richness.

But, having the high richness does not completely explain diversity. The diversity is dependent from the classes of activities, and from the distribution of activities per class. The distribution of activities per class can be measured with evenness.

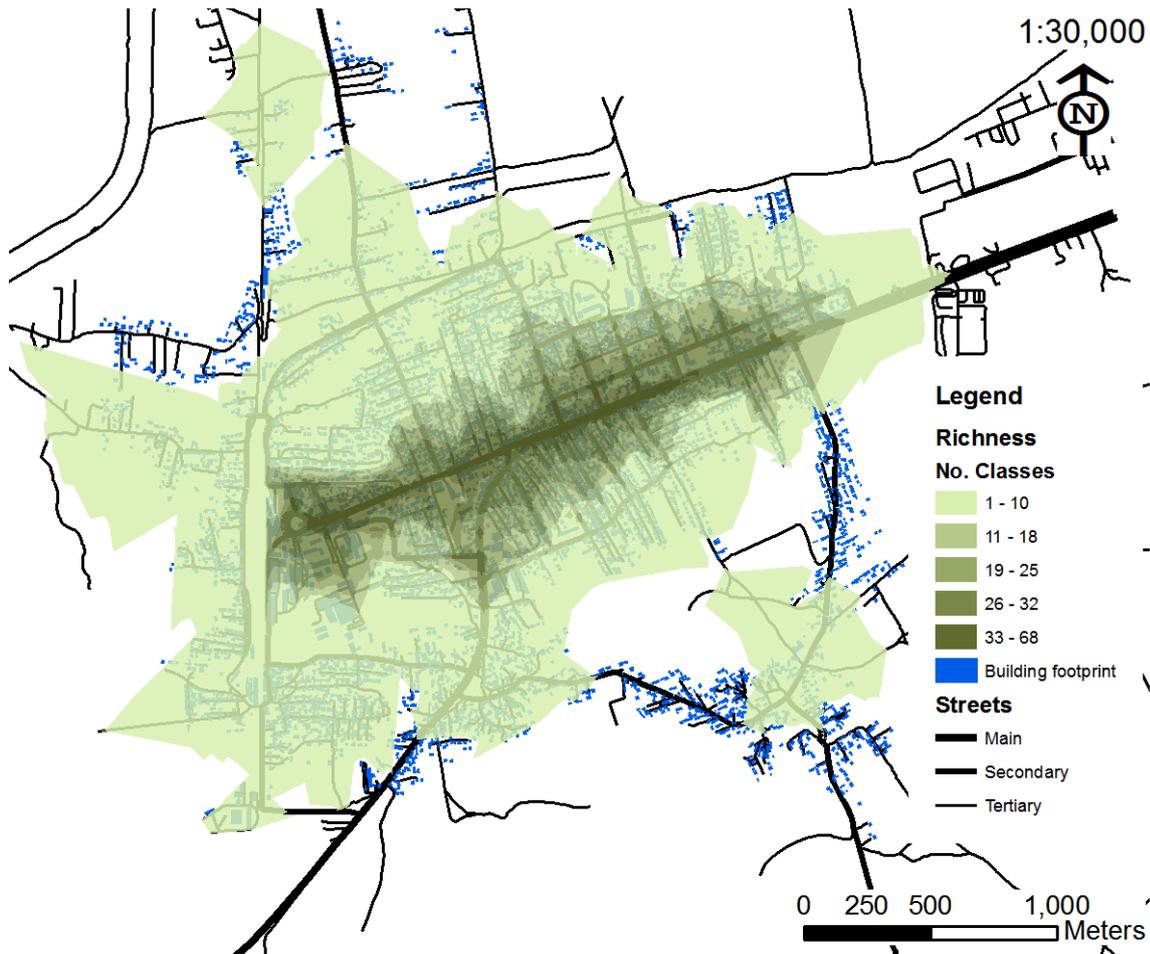


Figure 5-20. Richness of activities for urban area

5.4.2. Evenness

The measurement of evenness represents how the activities are distributed per class. It measures the number of each activity in proportion to the total number of activities per USA. The value of evenness ranges from zero to one, where zero represents no evenness. The value one represents close to perfect distribution of activities within USA.

The evenness generates somewhat different pattern from richness. Even though the pattern of high evenness is visible to be stronger in the central part of the urban area, it is more distributed than the patterns of richness. This pattern shows that just having high number of activities nearby, and different classes of activities is not necessarily more diversity. Moreover, it is important that these activities are evenly distributed within the area, hence making the area more diverse.

However, to measure diversity more accurately, richness and evenness should be combined. Thus, additional three methods were used. The first is the method developed by Batty and others, and two other methods are borrowed from natural and science.

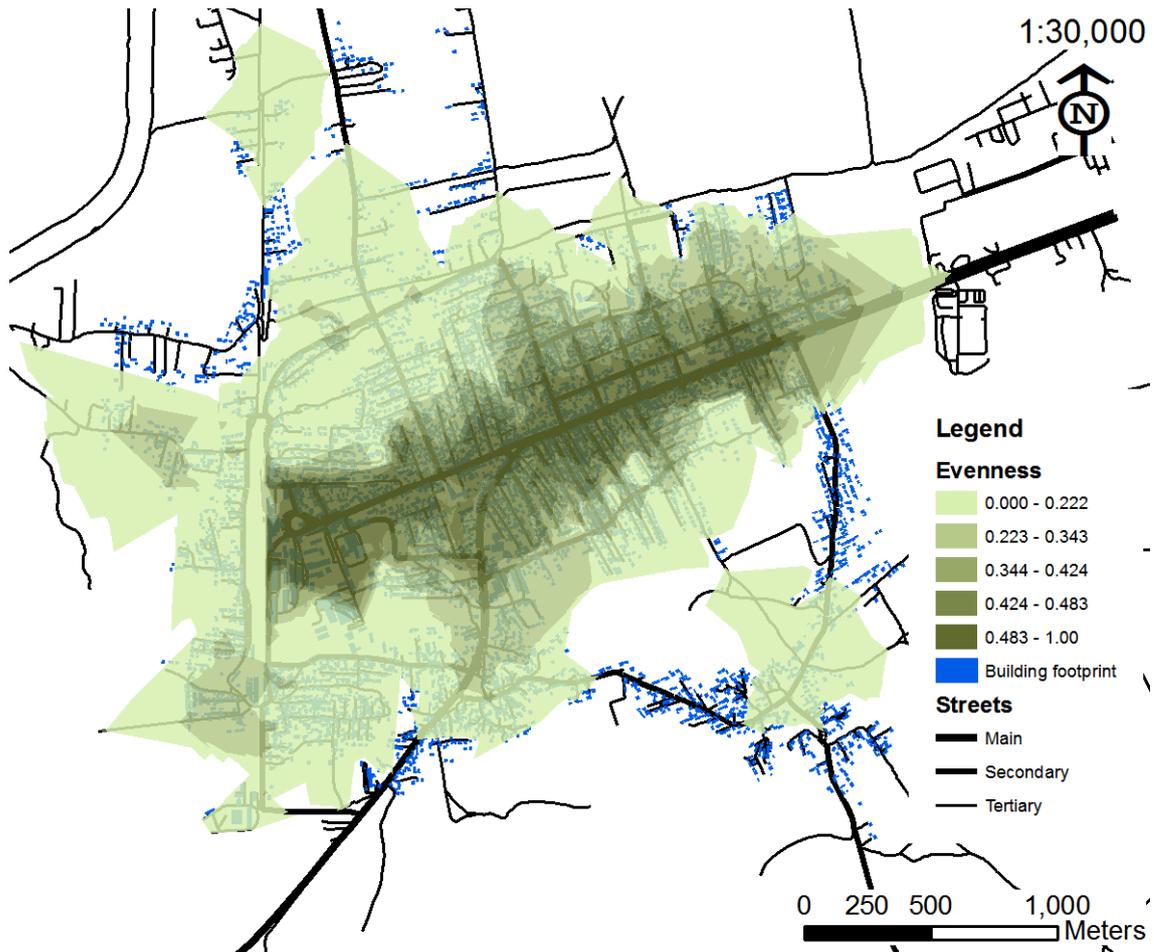


Figure 5-21. Evenness of activities for urban area (Natural Breaks classification)

5.4.3. Batty *et al.* Index of Density-Diversity

Even though Batty used the developed method to measure the diversity by using raster data, the same principles were applied so that diversity is measured per USA. First step is to identify each activity in all USAs. The index measures the ration of each activity in a USA from its total amount in urban area. Later, in each USA the ratios of activities are summed to get the value of index.

The patterns of diversity based on density-diversity index of Batty and others, is shown on figures 5-22 and 5-23. The first one is visualizing the diversity with raw values. The second is visualizing the diversity by using standard deviation method for data classification. The values of this index are in a range from zero (0) to thirty eight (38) showing high difference between the areas. This index will give higher values in the areas where more rare activities are located. This is proved with the pattern of high diversity shown on both maps, which compared with the map of density of division M “Education” share common centre of high values.

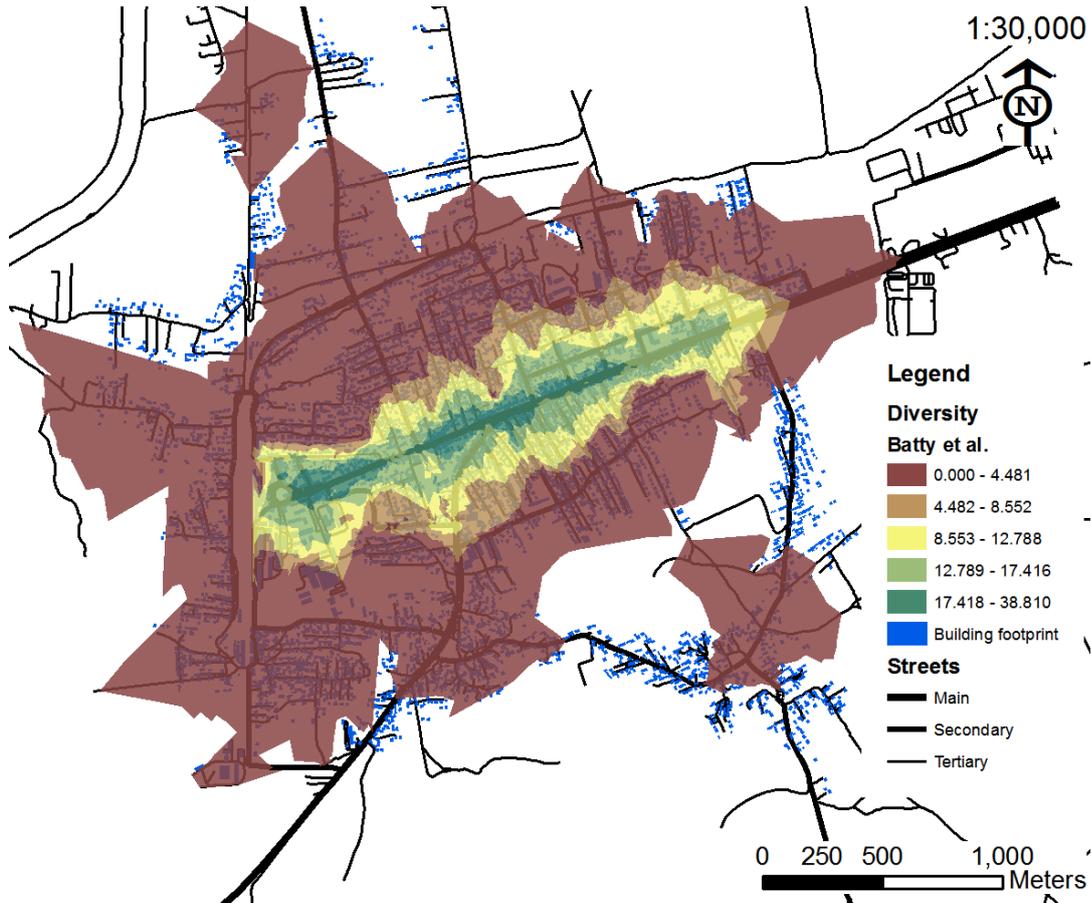


Figure 5-22. Diversity of urban area based on Batty et. al. method.

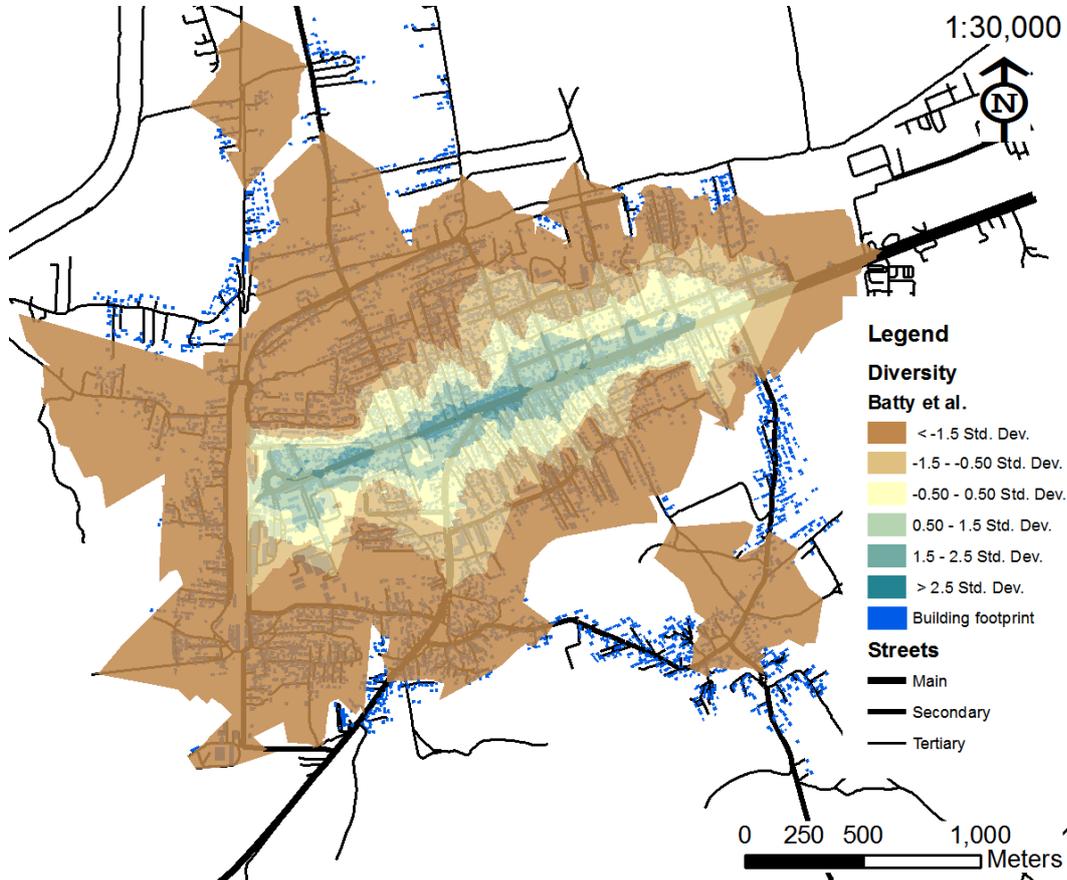


Figure 5-23. Diversity of urban area based on Batty et al by standard deviation

The purpose of visualizing the index based on standard deviation is to compare the values of index from its mean value. Furthermore, it will help to compare the patterns with other indices of diversity. Standard deviation shows that in this index the area of low diversity dominates the pattern, and only small part in the centre is high above the mean value of diversity.

The second method used for measuring diversity of activities in urban area is Simpson's index of diversity.

5.4.4. Simpson's Index of Diversity

The Simpson's index for measuring diversity is applied to each USA. The index generates values where higher diversity is represented with lower values. Thus, the reverse diversity index is applied where all values are subtracted by one (1).

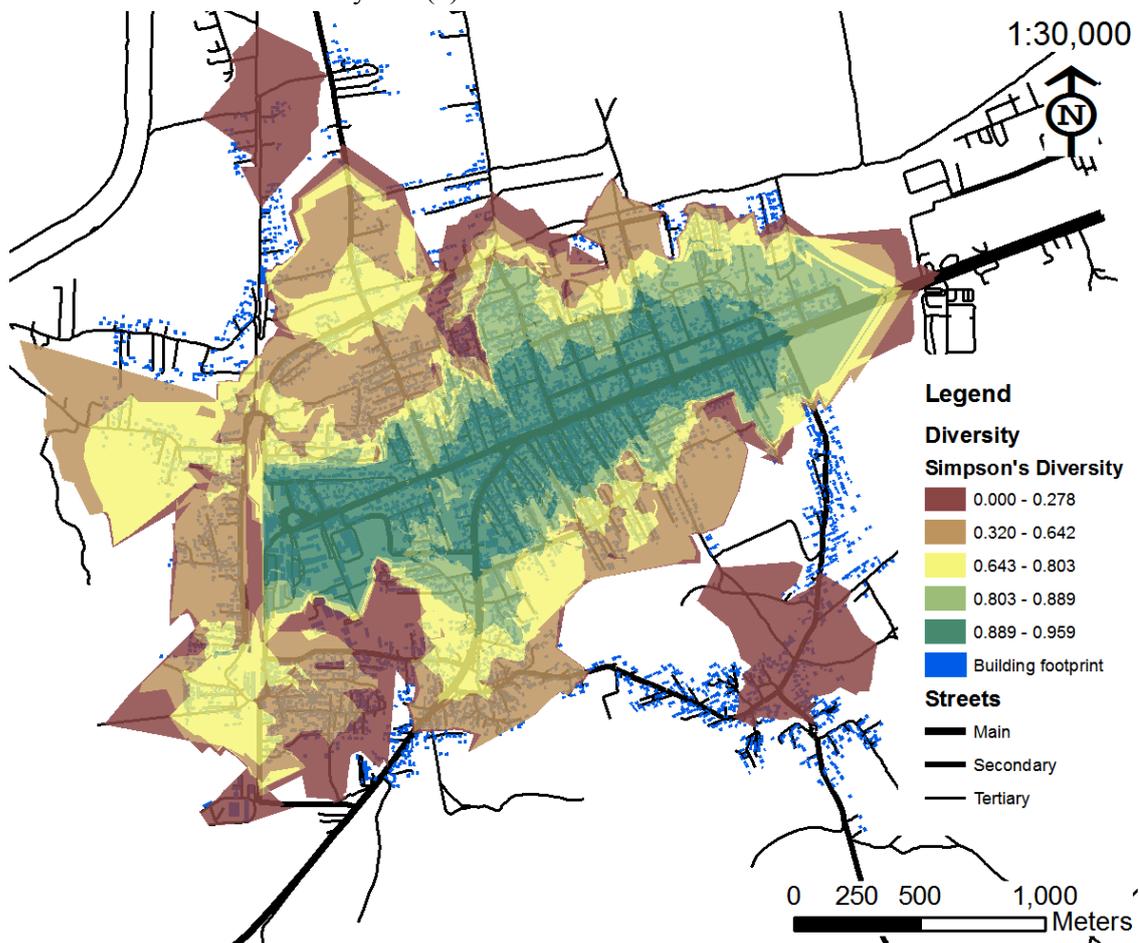


Figure 5-24. Diversity of urban based on Simpson's Index of diversity

The index takes under consideration the richness and evenness. However, since it is influenced by richness more than evenness the result is that the urban area seems to be of high diversity. The pattern of diversity, as expected, is dominant along the main road. However, the northern part of the study area, even though is further from the main road, seems to have moderate diversity, which was not the case with Batty's density-diversity index. The areas of low diversity are hardly visible, with exception of the two detached areas, one in the north and the other on the southern part of the study area.

However, by applying the standard deviation to the values (see figure 5-25), the patterns change significantly. The areas that have highest value above the average occupy much less space from what

looked in figure 5-24. However, the values above the mean value of index still dominate the central part of the study area, along the main road.

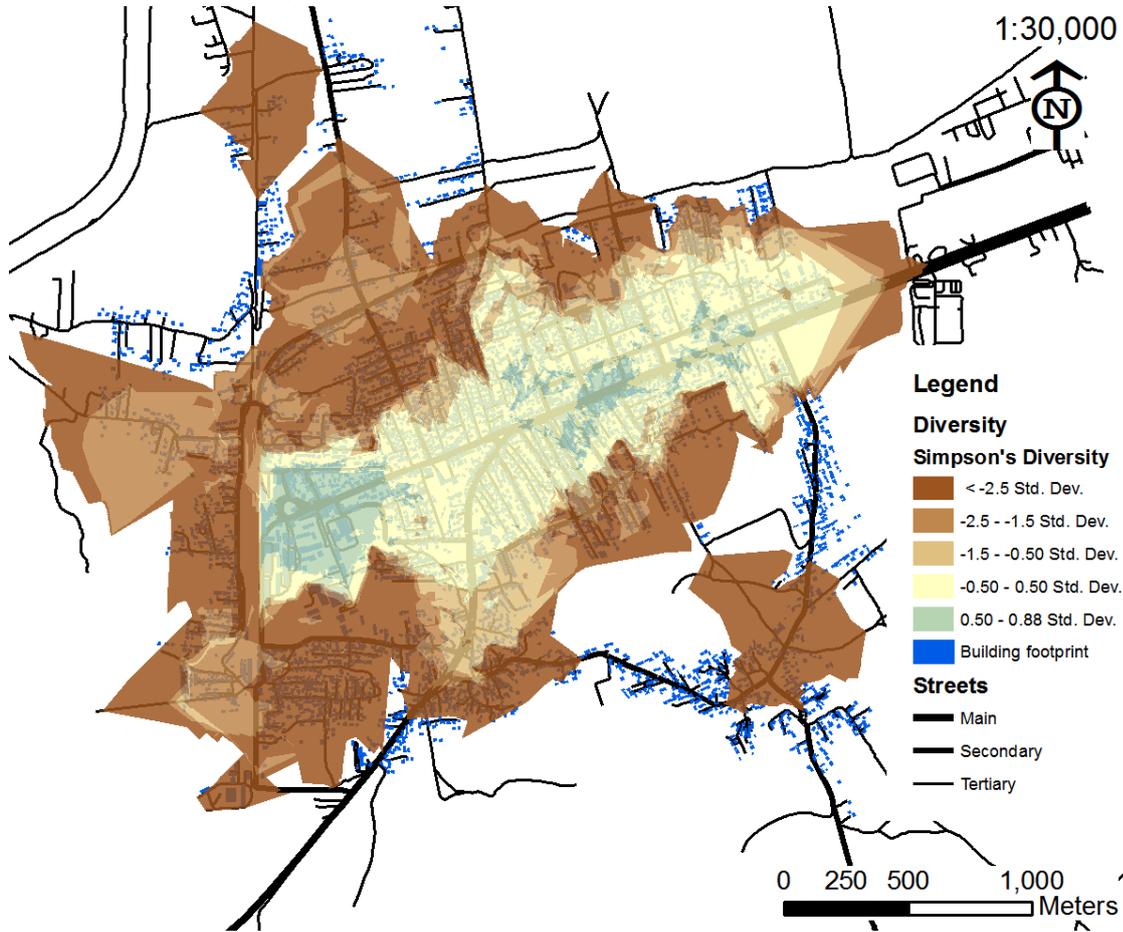


Figure 5-25. Diversity of urban based on Simpson's Index of diversity by standard deviation

Since this index is more influenced by richness, the next index of diversity puts importance to richness and evenness.

5.4.5. Shannon-Wiener Index of Diversity

The Shannon-Wiener index of diversity is measure through same method as the previous two indices of diversity. The diversity is calculated per USA and visualized which gives the patterns of diversity.

The initial view of the map (figure 5-26) shows that diversity measured by Shannon-Wiener index is higher in central part of the study area. This result was expected since the richness and evenness of urban area was also concentrated in the same area. The values of diversity seem to be between the values of Batty et al. and Simpson's indices of diversity. This indicates that the index is more balanced between the richness and evenness the other two indices.

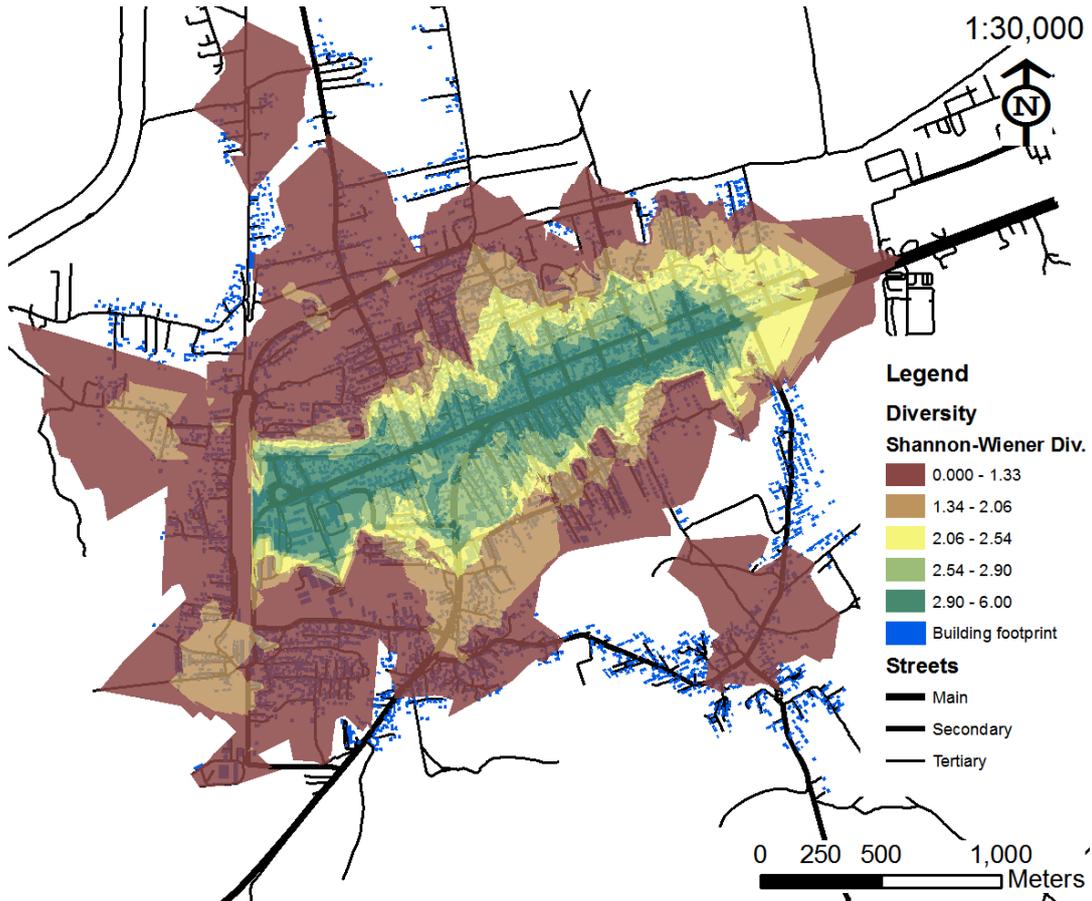


Figure 5-26. Diversity of urban area based on Shannon-Wiener Index

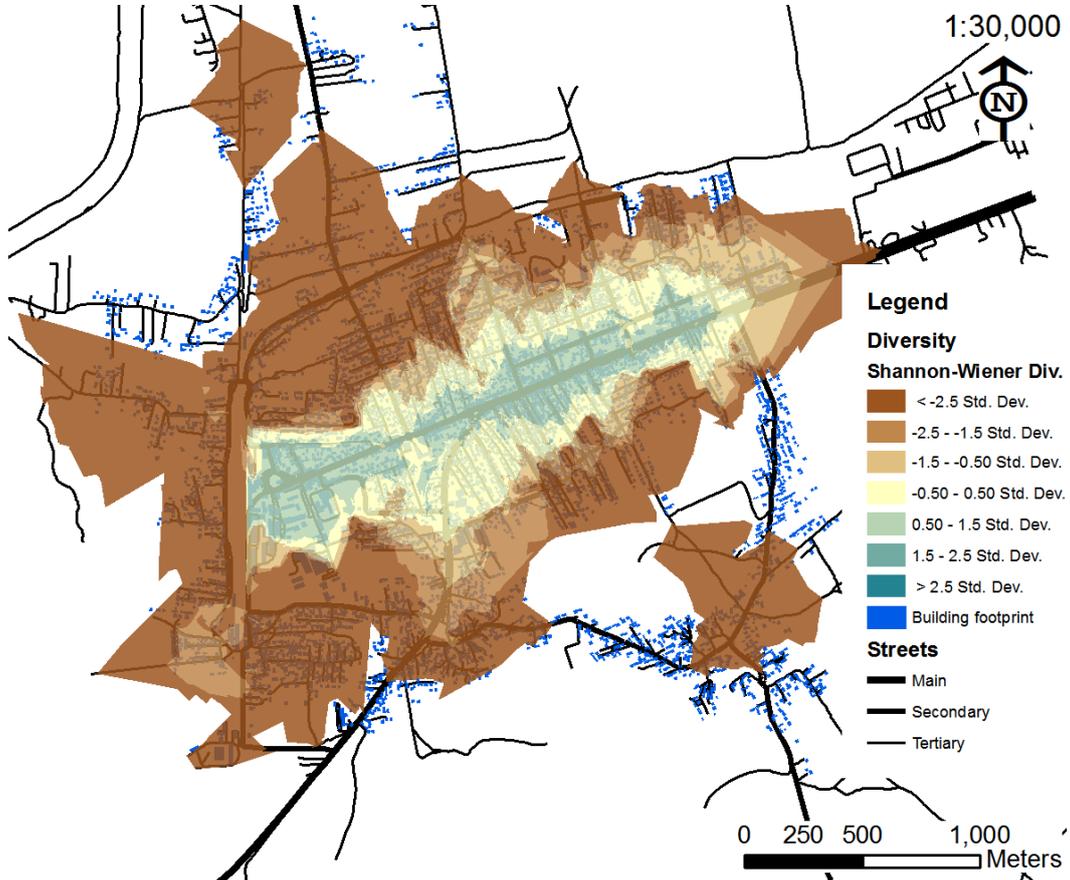


Figure 5-27. Diversity of urban area based on Shannon-Wiener Index by standard deviation

Visualization based on standard deviation (figure 5-27) reveals that the area that shows to be of high diversity (figure 5-26) is somewhat balanced between the values that are closer and values that are higher from the mean value of index.

5.5. Measuring Multifunctionality over time

The diversity of activities changes in different part of the day. This change is as a result of operational time of activities during different part of the day. For measuring this diversity, activities should contain the information of operationally. The mapping of diversity in this method will reveal the activities where people can engage. Hence, a connection between the people's interests for activities and the activities that are accessible can be made. In the study area, there are a number of activities that are operational during the evening hours. However, considering that it is a small town, there are not many attractive locations where people like to spend evening. Most of urban activities are operational until 20:00 of the evening. However there are some activities that continue until 24:00 hours. Thus, the mapping of diversity for the evening is done for activities that are accessible between the 20:00 and 24:00 hours. In the entire town, there is only on activity that operates 24 hour a day, but that activity is police station. Therefore diversity of activities does not exist after midnight and it will not be mapped.

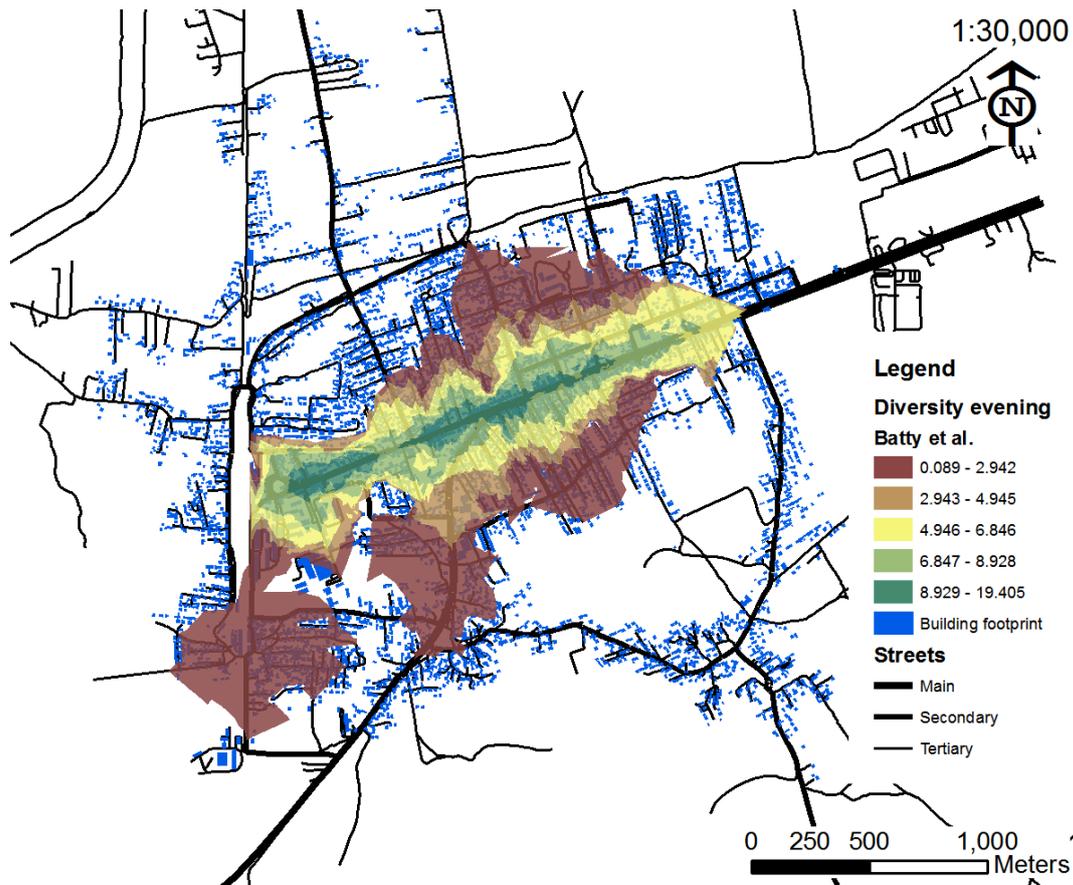


Figure 5-28. Diversity of evening activities with density-diversity index (Batty et al., 2004)

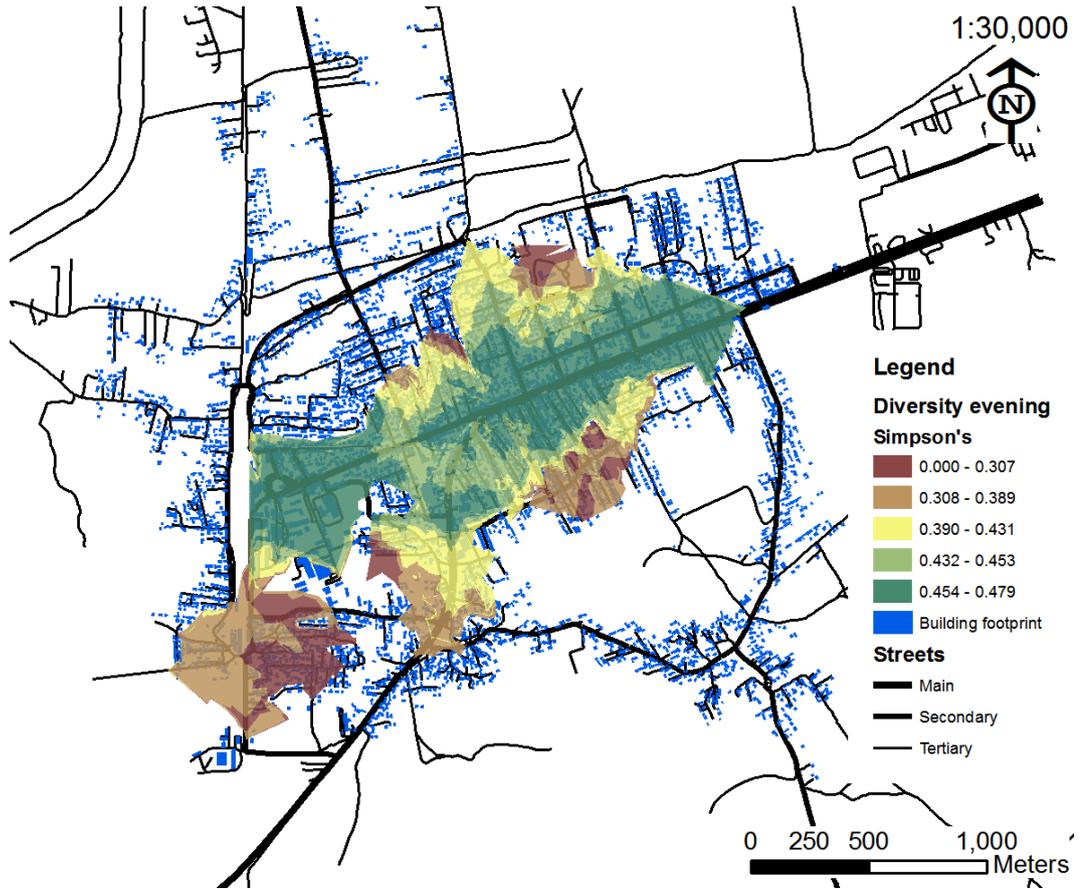


Figure 5-29. Diversity of evening activities with Simpson's index of diversity

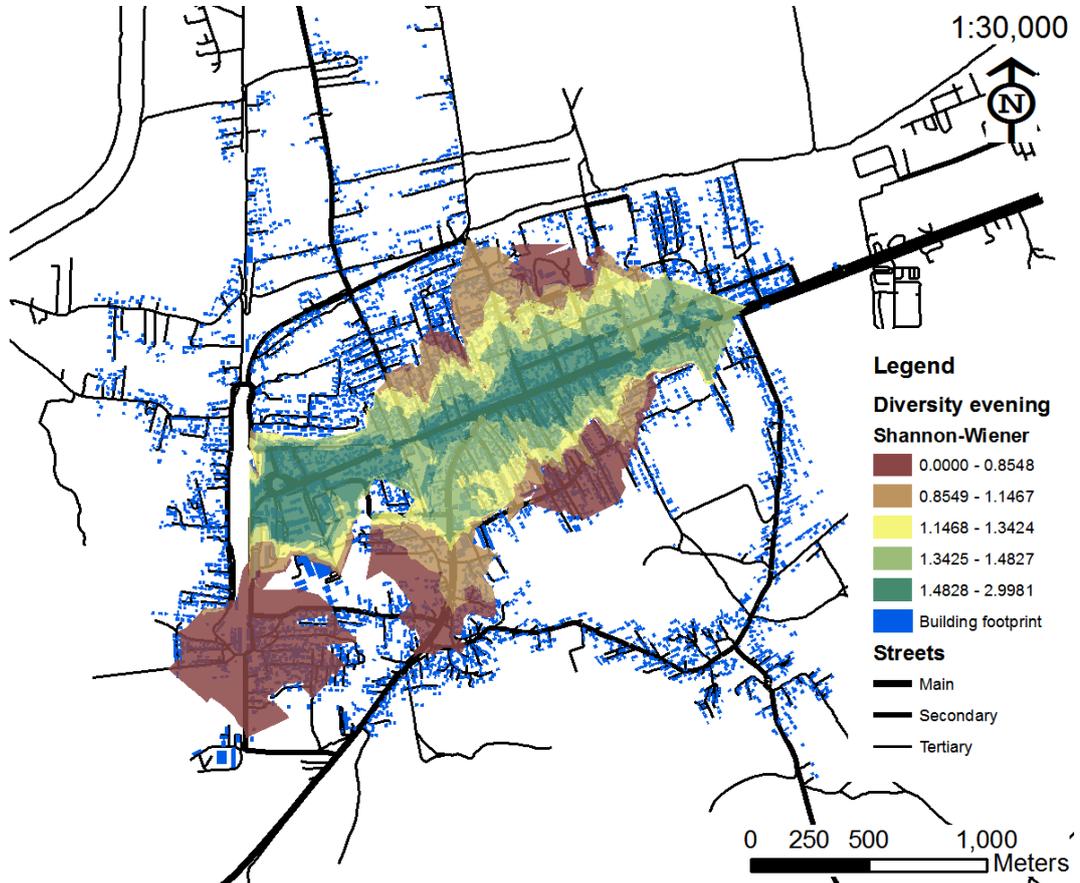


Figure 5-30. Diversity of evening activities with Shannon-Wiener index of diversity

All three indices used for measuring the diversity of activities in the evening hours of the day show the degree of diversity in the central part of the town. The patterns of diversity are comparable between the indices similar to comparability of overall diversity of urban area. The main difference is the spatial extend of diversity which shows the decrease of diversity compared to the daytime diversity. Another difference of diversity in the evening hours from the overall diversity is the dominance of activities of the division H – “Hotels and Restaurants” (see figure 5-12).

5.6. Visualization of Diversity

Visualizing the multifunctionality of urban activities may be a complex task. There can be two purposes for such visualization. The first purpose is exploring the data to see what patterns could be found in the study area and what questions can come up from those patterns. The second purpose is to show a map that shows patterns that give a specific answer (Mitchell, 1999).

For this research the interest is to explore the data and visualize the possible patterns of distance, density, diversity and change of diversity during the day. The characteristics of the data that were mapped require the methods for mapping the amount, as amount of density and diversity. Therefore, classification methods for spatial data visualization are applied.

ArcGIS was used as GIS tool to realize spatial analysis for this research. Methods for data visualization that are available with the package satisfy the requirements for this research. In ArcGIS there are five methods for spatial data classification. These methods are: Natural Breaks (Jenk’s), Quintile, Equal Interval, Standard Deviation and Manual defining intervals.

Table 5-2. Comparison of spatial data visualizing methods in ArcGIS (Mitchell, 1999)

	Natural Breaks	Quintile	Equal Interval	Standard Deviation
How it works	The GIS automatically determines classes by grouping data with similar values	The GIS divides the classes by same number of features	The GIS divides classes with equal range of values	The GIS divides each class from the mean value of all the features
What is good for	Mapping data values that are not evenly distributed	Mapping data in which values are evenly distributed	Presenting information to a non-technical audience	Seeing which features are above and below average value
Disadvantages	Difficult to compare the map to other maps	Features with close values can end up in different classes	If data is not evenly distributed, there may be many features in one class and only few in some classes	The map does not show the actual value of the features

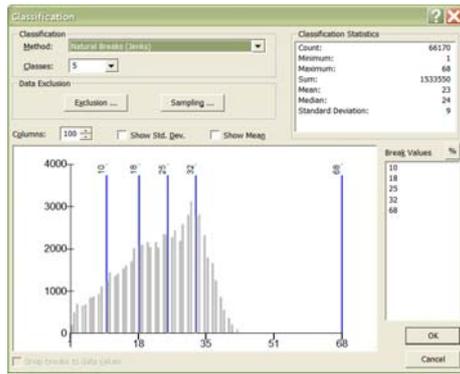


Figure 5-31. Distribution of Density values

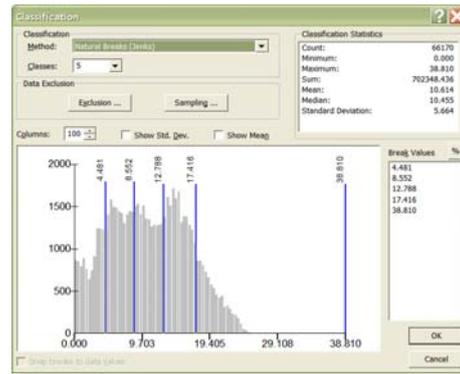


Figure 5-32. Distribution of Batty et al. Index values

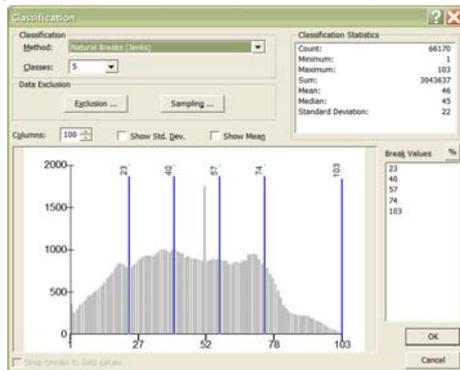


Figure 5-33. Distribution of Richness values

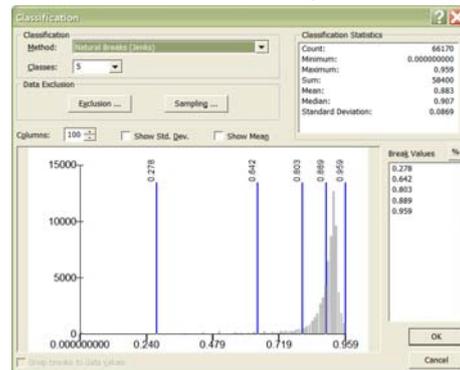


Figure 5-34. Distribution of Simpson's Index values

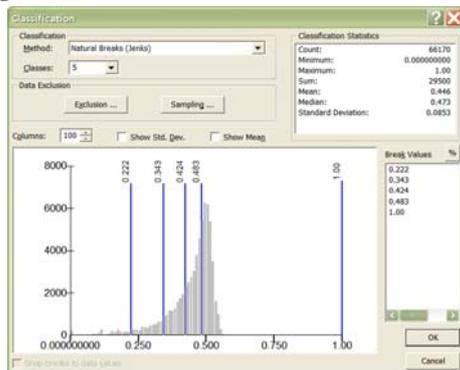


Figure 5-35. Distribution of Evenness values

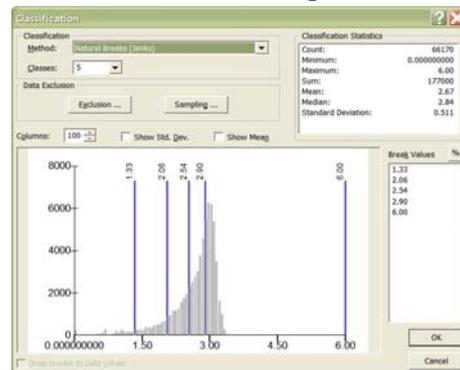


Figure 5-36. Distribution of Shannon-Wiener Index values

The spatial data for measuring indicators of multifunctionality of urban area are not much evenly distributed. The figures 5-31 to 5-36 shows the distribution of values for density indicator and all five different methods for measuring the diversity.

Except for the richness, all other data are not evenly distributed. Therefore in all measurements Natural Breaks was used to summarize the data for visualization. In addition, Standard Deviation was used to show the difference of data from the mean value.

5.7. Conclusions

Measuring multifunctionality of urban land use based on activities seems to make possible to visualize the location of activities and their proximity. The developed methodology helps to measure the proximity of activities to residential area of the city. Consequently the polygons based on which the measurement of density and diversity are generated. These polygons represent an area that is covered

by different number of activities from all its neighbours, thus name “uniform service area” (USA) was given. USAs were used as defined area for which the density and diversity of activities was measured. The spatial layer containing all USAs is of vector data type. However, in practice behaved as a raster type layer with the difference that USA layer had polygons of different sizes. This difference helped to avoid the problem of cell size that raster data imposes.

The method of measuring the density of activities based on the classification of ISIC list makes possible to visualize the spatial distribution of each division of activity. Thus, the amount of each division and the difference in patterns reveal the contribution of each division to the total number and spatial distribution of activities.

The diversity of activities is dependable on two indicators. These indicators are richness and evenness. While the first measures the number of classes, groups or divisions of activities, the second measures the distribution of activities per each class. The combination of these two indicators is possible with the Simpson’s index and Shannon-Wiener index of diversity. Different from these indexes, Batty’s density-diversity index measures the contribution of an activity to the diversity based on the ratios from its total amount in the entire city. All three indexes produce results with values of different scale, therefore the comparison of the maps is difficult to make. In addition the data are not distributed evenly (see figures 5-31, 32, 33, 34, 35, 36). For this matter the natural break classification of visualisation is used. For comparing the values of the indexes with their raw values, the standard deviation method of visualisation was applied. This method made possible to map the difference of the value of diversity from its mean. Hence the hotspot diversity of pattern was spatially identified. Further more, the areas resulted with minimum or no diversity at all shows the potential for increasing the diversity over the urban area

Based on the operation time of activities and their catchment, the diversity in time was also measured. This method of measurement made possible to visualize the change in diversity and the change in pattern as well as identifying which classes of activities are accessible in what part of the day.

Measuring multifunctionality urban area reveals major information. Measuring not only identifies where higher or lower multifunctionality is, but also the areas where it can be increased. Considering the distance to the multifunctionality also help to identify in space areas that are outside the measured multifunctionality.

6. Discussion and Conclusions

This chapter provides a brief summary of the part of literature review for multifunctional land use planning. In addition, the critical discussion is provided on previous researches and which weaknesses were covered by this research. Finally, recommendations for further research are given to improve the shortcoming from this research.

6.1. Summary

Multifunctional land use planning is relatively new planning concept which originates from the country that has a very long history of planning and housing, the Netherlands. One may think that the reason why this concept originates from this country may be the fact that Netherlands is one of the most densely populated countries in the world. Hence, the pressure for more efficient use of space influences planners to come with new ideas. These ideas have to satisfy many stakeholders of the planning processes, such as planning authorities, developers, people, and environmental issues and so on. However, multifunctional land use planning is strongly connected with other planning concepts of mixed land use, the new urbanism, smart growth and compact city.

All three mentioned planning concepts and MLU emerged in late 1980 and 1990. They are as a response to the misperception in urban planning of the CIAM organization. The CIAM was established in 1928 from a group of architects with Le Corbusier as head of the organization. The main objective was to develop a new planning concept for functional city and preservation of cities. The CIAM organization held ten meetings around the world of which the fourth one, CIAM IV, was the most significant. On this meeting was written the Athens charter which listed some 95 points on how the cities should be planned and built in order to solve the problems that existed at that time. The idea of a functional city based on CIAM "ideology" was to spatially separate functions of living, working and recreation from each other. This was thought to be a method of urban development which would create cities with high-rise residential buildings from where you travel to your work or you drive to a place where one can be entertained and so on. There are no doubts that the CIAM has the best intentions on making a planning concept based on which cities will be a wonderful place to live. How far the organization would go it could be described by the action of the leader of the organization, Le Corbusier, who rejected to have a CIAM meeting in Moscow. He claimed that Russia has rejected the urban development based on functionality. Instead the CIAM meeting was held in a cruiser travelling from France to Greece. However, what CIAM missed to take under consideration was the saving of land as a resource, environmental pollution created from the car traffic within the cities, the transport infrastructure in terms of cost and division it created between neighbourhoods. All these missed points created an environment where cities became scattered and urban sprawl came to be a major problem in present days.

The criticism towards the CIAM started not long after the organization was dismembered in 1956. Among the first planners that wrote about the problems of spatial separation of functions was Jane Jacobs. With her book "The death and life of great American cities" she initiated a long debate on planning, practices in urban development and returning to the old style cities. In the mean time, the air

pollution, traffic congestion, lack of space and many other problems started to become major issues for the mega cities. The need for action became very strong.

The new concepts of urban planning such as new urbanism, smart growth and compact city were inspired from the debate for change and even more forced from the need to manage the above mentioned problems of the cities. The issue was not to go back to the “old city” for of development. Instead, the multidisciplinary approach to address the problems was how to find better solutions to save space, use it in more efficient and sustainable form. In addition, buy using land more efficiently it is necessary to search for incorporating the methods of development for more compact and mixed activities. Multifunctional land use planning is very similar with new urbanism, smart growth and compact city planning concepts. All four planning concepts have strong ties in their characteristics as listed on the table of Vreeker and others (table 2.1). All four concepts promote on urban revitalization, mixed land uses, reduction of car traffic, space saving and so on.

The only characteristic differentiating MLU from other three concepts is addressing the creation of synergies among the land uses. In this context, Vreeker studied the agglomeration of commercial activities from the economic perspective. There are a number of benefits for business activities when they are grouped in cluster. However, it is not clear which type of business activity benefits more and which less. This agglomeration, however, was not put on the perspective of the diversity of activities. Even though the paper concludes that the benefits for commercial activities benefit from knowledge spill over, creation of competitiveness and share of price for infrastructure, not much attention was put into the interest of the people that would use those commercial activities. The question that remains is how much the clustering of commercial activities would improve service to the people living nearby or over the whole city. In addition to commercial activities, other services such as social and cultural activities contribute to the multifunctionality of a city.

6.2. Discussion

The benefits of MLU as a planning concept for urban planning sounds to be very high, at least based on the objective it has. Minimising the use of space for more functions, minimising car traffic by promoting public transport and pedestrian friendly streets tend to create an idea of a green city with no or less air pollution. However, this does not coincide very often with reality. In many cases high dense development areas suffer from lack of green parks for example. In addition a study done in New Zealand (Vallance et al., 2004) show that people are not very pleased to have denser neighbourhood due to the loss of privacy and feeling of overcrowdings. The same findings have also the study of Vreeker (2004) where he identifies the environmental, social and economic negative effects.

In the recent literature different methods for measuring the compactness and multifunctionality of urban areas were introduced. Among the first researches to measure the compactness of urban area is the research of Burton (2001). Author measured compactness based on the services for which he developed a number of indicators to measure density, diversity and intensification. Later Rodenburg and Nijkamp (2004) describes multifunctionality in details. Further it gives the possibilities of which activities and which functions could be combined and in which level. However, there is no spatial analysis to support or contradict the combinations they suggest. To address the issues of sustainability of the compact cities Lin and Yang (2006) take under consideration the density, mix of uses and intensification on one side for measuring compactness and environment, economy and society on the

other side for the sustainability. However, the only research the spatially measured and visualized multifunctionality of the cities is the one of Batty and other (2004). The spatial indicators that were used to measure and visualize multifunctionality are density and diversity. Furthermore, the spatial analyses were realized with raster data which resulted with the question: What should be the size of the area for measuring multifunctionality?

Even though previous researches have contributed to understanding and visualizing the compact city and leading to multifunctionality, there are many shortcomings. Firstly, only the research of Batty and others measured multifunctionality with spatial indicators and GIS tools. The most common feature of all researches is the indicators of density and diversity. However, the indicators were not completely based on the concept of multifunctional land use planning. Density and diversity of urban area do not describe all objectives of MLU as a planning concept. They do, however, visualize the agglomeration of economic activities which was topic of Vreeker and others (Vreeker et al., 2004).

The measurements of Batty and other (2004) and of the Lin and Yang (2006) are focused on measuring the human activities. This form of measurement reflected the density and diversity of employment by type and the density of population. Through the measurement of employment by type it is gained a good insight for the functions of urban area. However the high density of employment shows only the average number of people working in a city. When compared with population density not necessarily shows multifunctionality. This may be often the case in developing countries where usually only one member of family is working. Furthermore, the spatial measurements (Batty et al., 2004) with raster data shows the disadvantages of measuring and visualising the multifunctionality. The cell size of the raster is dependent from the size of the area where more then one function exists. Since it is difficult to define this area, it becomes even more difficult to justify the size of the cell of the raster data based on which multifunctionality is measured.

The focus of this research was to develop a method which based on spatial indicators will measure and visualize the multifunctionality of urban area. The approach was from the MLU as a planning concept and from the agglomeration of economic activities as empirical phenomenon. The planning concept was used to identify the spatial indicators and agglomeration of economic activities was used to observe the economic functions and their spatial distribution.

For measuring the multifunctionality of urban area four spatial indicators where identified. These indicators also try to address the shortcomings of previous researches. Furthermore, a classification tool was used which was important for measuring spatial indicators. But before all, the difference between the land use, land use function and urban activity was defined. The definition was necessary since these terms often are used interchangeable.

The multifunctionality of urban area was measured through the urban activities. This was done because is the most detailed level of urban environment. After identifying spatially all urban activities classification was made based on United Nation Statistical Department classification of ISIC. The ISIC was used since it is a tool that is used as a standard in most countries. Furthermore, this was lacking in all previous researches and measuring the spatial indicators in particular diversity requires that activities are classified in a hierarchical structure.

The spatial indicator for distance was measured to address the objective of multifunctional land use as a planning concept, which promotes the pedestrian streets and public transport. This measurement made possible to measure the proximity between the urban activities based on what the agglomeration of economic activities was mapped as a density indicator. But before that, the issue of size for which the multifunctionality can be measured need to be addressed. For the issue the USA was introduced based on what density and diversity were measured.

Measuring the density of urban activities was made for two purposes. The first purpose was to visualize the density of all urban activities in urban area. The second purpose was, to explore spatially agglomeration of urban activities, in particular economic activities. This was done by measuring the density of activities based on classification of ISIC. The division as level of classification was used.

Further, diversity was measured by using five different methods. This was necessary since previous researches did not have a standard index for measuring the diversity of urban activities. And at the end, the diversity was measured in the evening part of the day for the purpose of visualizing the urban dynamic during the day. Diversity of urban activities measured through spatial indicator helped to visualize the higher diverse areas of the town, where the low or no density areas were interpreted as a potential for increasing the multifunctionality.

However, this research also has some weaknesses. One of the weak points is the catchment area which is dependent from the walking distance for pedestrians. While here is used distance of 5 minutes walking, it can be argued that this distance should be different. However, this may not be true for all urban activities since some of them have defined the catchment size based on standards. Therefore, applying the standards of the country where the measurement is done should help to avoid the weakness. However, the problem remains if there are two cities from two different countries to be compared which one is more multifunctional.

6.3. Conclusions

- ***Measuring multifunctionality based on USAs and vector data has advantages for measuring diversity but has disadvantages for data handling***

The use of vector data helps to measure multifunctionality in a method that avoids the falsity in distribution of values of density and diversity. Uniform service area is very useful for defining an area that is covered by activities and later to measure density and diversity based on that area.

However, the amount of data created is very large and it makes difficult to realize calculations for measurement. Furthermore, there are USAs that are very small in area that could be easily considered as insignificant for representing multifunctionality.

- ***The classification of activities helps to measure the multifunctionality***

For multifunctionality it is required to classify activities. The classification done based on ISIC classification list provides a good basis for realizing the measurements that can be reproducible in different cities and countries. Furthermore, classification helps to identify which division of activities contributes to the density and diversity of urban area.

- Classifying activities into highest level of ISIC is useful to map the patterns of activities based on the division they belong to. These patterns reveal the concentration or distraction of activities. The patterns of each division can give an insight on identifying the problems that exists in parts of urban area, such as comparing the division of activates that causes pollution and the division that is most vulnerable to that problem.
- For measuring diversity the classification if a necessity. Diversity can only be measured if the difference between activates is clear and discrete. Therefore, the ISIC classification could be used since it provides a comprehensive classification which is developed based on the input of most of the countries and it covers all business activities that exist.
- ***Use of catchment areas helps to measure multifunctionality that is closer to residential areas***

By measuring the time and distance which needs to be covered by a pedestrian to reach the activity reveals the multifunctionality that is relevant to the surrounding residential area. The multifunctionality in some parts of the city is higher and some other parts less. However, the catchment puts on first place the importance of the multifunctionality that is easy accessible and that does not require travelling by car.

- ***Diversity of activities shows the patterns of distribution of activities***

By measuring diversity of urban activities it is possible to map the spatial distribution of activities based on the class, group or division they belong. The visualization reveals patterns that show which parts of the city have more mixed activities and which parts of the city have no activities at all. Furthermore, different methods to measure diversity produce different results which can be used for identifying how activities are distributed.

- *Richness* as method for measuring diversity identifies spatially the distribution and delineation of patterns of activities based on the classification.
 - *Evenness* visualizes the patterns of spatial distribution of mixed activates that are more balanced and mixed activities that are dominated by one activity.
 - *Batty et al.* index of *density-diversity* index measures the diversity of a location in the city by measuring relation activity in relation to the overall amount of same activity in the city.
 - *Simpson's index* measures diversity by putting importance to richness and evenness. The importance is higher on the richness rather then evenness. Therefore the measured diversity of the area tends to show more diverse.
 - *Shannon-Wiener index* measures diversity similarly with Simpson's index. However, the importance for richness and evenness is equally distributed.
 - The City seems to be most diverse when measured with Simpson's index then Shannon-Wiener and Batty et al. However, Shannon-Wiener index shows the city as less diverse then other indexes when calculated with the same data.
 - ***The diversity over time changes as people change interest for activities***
- During the day people engage in different activities in different locations. By mapping the diversity over the time the patterns of diversity change revealing the locations where different

activities are of more interest. Furthermore, measurement over time shows also the class of activity that is more required and at which part of the day.

6.4. Recommendations for further research

During the research progress, I came to understand that some of the following topics need further research for the multifunctional land use planning.

Developing composite index for MLU

While different indicators were introduced for measuring the multifunctionality of urban area and compactness, there are differences between them. This research has identified four different indicator based on which the multifunctionality can be measured. However, it is useful to have an index which could spatially visualise the multifunctionality.

The identified indicators of distance, density, diversity and time each individually visualize and measure one aspect of multifunctionality. However, the possibility that these indicators could be combined for representing degree of multifunctionality remains very high. The challenge would be to identify if all indicators are of same importance or if not, which one is more important and why.

Developing a method to measure the desired multifunctionality

Multifunctionality of urban area can be described in three different forms. First is the existing multifunctionality, second is the potential multifunctionality and third is desired multifunctionality. While this research has made an attempt to visualize the existing and potential one, the possibility for comparing the existing and potential with desired multifunctionality remains open. The three different measurements could make a good tool for more sustainable multifunctional urban planning.

Can multifunctionality be measured and visualised with real 3D GIS data

Multifunctional land use planning promotes the development in vertical dimension. This form of development leads to increased multifunctionality of urban area. In this research all measurements and visualization are done with 2D data.

However, the new technology and new GIS tools make possible that urban area are represented in 3D virtual environment. The combination of these tools with spatial indicators of multifunctionality could lead to possibilities to develop a methods that can measure and visualize the multifunctional and compact cities in 3D virtual environment which can help to study even further the multifunctionality.

7. References

- APA, A.P.A., 1999. Principles of Smart Growth. American Planning Association Press, Chicago.
- Badoe, D.A. and Miller, E.J., 2000. Transportation-land-use interaction: empirical findings in North America, and their implications for modelling. *Transportation Research Part D: Transport and Environment*, 5(4): 235-263.
- Batty, M., Besussi, E., Maat, K. and Harts, J.J., 2004. Representing Multifunctional Cities: Density and Diversity in Space and Time. *Built Environment*, 30(4): 324 - 337.
- Budic, Z.D., 1994. Effectiveness of geographic information systems in local planning. *Journal of the American Planning Association*, 60(2): 244.
- Burchell, R.W. and Mukherji, S., 2003. Conventional development versus managed growth: the costs of sprawl. *American Journal Of Public Health*, 93(9): 1534-1540.
- Burton, E., 2001. The Compact City and Social Justice, Housing Studies Association Spring Conference, Housing, Environment and Sustainability. University of York, York, UK.
- Burton, E., 2002. Measuring urban compactness in UK towns and cities. *Environment and Planning B: Planning and Design*, 29(2): 219-250.
- Castells, M., 2000. The Rise of the Network Society. The Information Age: Economy, Society and Culture, 1. Blackwell Publishing, 566 pp.
- CNU, 2001. Principles for Inner-City Neighborhood Design: Part II, Congress for the new urbanism, Washington.
- Dobbelsteen, A.v.d. and Wilde, S.d., 2004. Space use optimisation and sustainability--environmental assessment of space use concepts. *Journal of Environmental Management*, 73(2): 81-89.
- Duany, Andrés, Plater-Zyberk, Elizabeth and Speck, J., 2000. Suburban Nation: The Rise of Sprawl and the Decline of the American Dream. North Point Press, New York.
- EC, 1990. Green paper on the urban environment, Communication from the Commission to the Council and Parliament. COMMISSION OF THE EUROPEAN COMVIUNITIES, Brussels.
- EPA, U.S.E.P.A., 2006. About Smart Growth. EPA, Washington DC, pp. US government Agency.
- Hall, P., 1997. Modelling the post-industrial city. *Futures*, 29(4-5): 311-322.
- Handy, S., Cao, X. and Mokhtarian, P., 2005. Correlation or causality between the built environment and travel behaviour? Evidence from Northern California. *Transportation Research Part D: Transport and Environment*, 10(6): 427-444.
- Jacobs, J., 1961. The Death and Life of Great American Cities. Vintage Books, New York.
- Jenks, M. and Gerhardt, W., 2000. Urban intensification: The potential of decision support for assessing brownfield sites. *Urban Design International*, 5(3-4): 233-243.
- Kenworthy, J.R. and Newman, P.W.G., 1987. Gasoline consumption and cities—a comparison of U.S. cities with a global survey and some implications. Murdoch University, Murdoch.
- Lin, J.J. and Yang, A.T., 2006. Does the compact-city paradigm foster sustainability? An empirical study in Taiwan. *Environment and Planning B-Planning & Design*, 33(3): 365-380.
- Linders, G.J.M., Groot, H.L.F.d. and Nijkamp, P. (Editors), 2004. Locality Matters: myths and Facts on the New Economy. Edwards Elgar, 27-48 pp.
- Maat, K., Wee, B.v. and Stead, D., 2005. Land use and travel behaviour: Expected effects from the perspective of utility theory and activity-based theories. *Environment and Planning B: Planning and Design*, 32(1): 33-46.
- Magurran, A., 1988. Ecological Diversity and its Measurements. Croom Helm, London.
- Martin, R.W., 2001. Spatial Mismatch and Costly Suburban Commutes: Can Commuting Subsidies Help? *Urban Studies*, 38(8): 1305 - 1318.
- Mitchell, A., 1999. The ESRI Guide to GIS Analysis, Volume 1: Geographical Patterns & Relationships, 1. Environmental Systems Research Institute, Inc., Redlands, California, 188 pp.

- Oindo, B.O., 2001. Spatial patterns of species diversity in Kenya. Wageningen University, Enschede.
- Preuss, I. and Vemuri, A.W., 2004. "Smart growth" and dynamic modelling: implications for quality of life in Montgomery County, Maryland. *Ecological Modelling*, 171(4): 415-432.
- Priemus, H. and Hall, P., 2004. Multifunctional Urban Planning of Mega-City-Regions. *Built Environment*, 30(4): 338 - 349.
- Rodenburg, C.A., 2006. Quantification of economic benefits of multifunctional land use - An empirical analysis among employees. *Journal of Housing and the Built Environment*, 21(1): 69-81.
- Rodenburg, C.A. and Nijkamp, P., 2004. Multifunctional Land Use in the City: A Typological Overview. *Built Environment*, 30(4): 274-288.
- Sharifi, A., Herwijnen, M.v. and Toorn, W.v.d., 2004. Spatial Decision Support Systems. ITC, Enschede.
- Snyder, K. and Bird, L., 1998. Paying the Costs of Sprawl: Using Fair-Share Costing to Control Sprawl, U.S. Department of Energy's Center of Excellence for Sustainable Development.
- Talen, E., 2005. Conclusions: The Survival of New Urbanism, *New Urbanism & American Planning: The Conflict of Cultures*. Routledge, New York, pp. 309.
- Torrens, P.M. and Alberti, M., 2000. Measuring Sprawl. *CASA Working Papers*(27): 43.
- Urban+, 2003. Municipal Strategic Development Plan of Fushe Kosova, Municipal Planning Department, Fushe Kosove.
- Vallance, S., Perkins, H.C. and Moore, K., 2004. The results of making a city more compact: neighbours' interpretation of urban infill. *Environment and Planning B: Planning and Design*, 32(5): 715 - 733.
- van der Valk, A., 2002. The Dutch planning experience. *Landscape and Urban Planning*, 58(2-4): 201-210.
- Vreeker, R., 2004. Urban Multifunctional Land Use and Externalities, ERSA conference. ERSA conference papers, Vienna, Austria.
- Vreeker, R., Groot, H.L.F.d. and Verhoef, E.T., 2004. Urban Multifunctional Land Use: Theoretical and Empirical Insights on Economies of Scale, Scope and Diversity. *Built Environment*, 30(4): 289-307.
- Webster's, 1961. Webster's New Twentieth Century Dictionary of English Language. World Publishing Company, New York.
- Willis, A., Gjersoe, N., Havard, C., Kerridge, J. and Kukla, R., 2004. Human movement behaviour in urban spaces: implications for the design and modelling of effective pedestrian environments. *Environment and Planning B: Planning and Design* 31(6): 805 – 828.

8. Appendices

8.1. Appendix I - International Standard Industrial Classification of all Economic Activities

- A - Agriculture, hunting and forestry
 - 01 - Agriculture, hunting and related service activities
 - 02 - Forestry, logging and related service activities
- B - Fishing
 - 05 - Fishing, aquaculture and service activities incidental to fishing
- C - Mining and quarrying
 - 10 - Mining of coal and lignite; extraction of peat
 - 11 - Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction, excluding surveying
 - 12 - Mining of uranium and thorium ores
 - 13 - Mining of metal ores
 - 14 - Other mining and quarrying
- D - Manufacturing
 - 15 - Manufacture of food products and beverages
 - 16 - Manufacture of tobacco products
 - 17 - Manufacture of textiles
 - 18 - Manufacture of wearing apparel; dressing and dyeing of fur
 - 19 - Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
 - 20 - Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
 - 21 - Manufacture of paper and paper products
 - 22 - Publishing, printing and reproduction of recorded media
 - 23 - Manufacture of coke, refined petroleum products and nuclear fuel
 - 24 - Manufacture of chemicals and chemical products
 - 25 - Manufacture of rubber and plastics products
 - 26 - Manufacture of other non-metallic mineral products
 - 27 - Manufacture of basic metals
 - 28 - Manufacture of fabricated metal products, except machinery and equipment
 - 29 - Manufacture of machinery and equipment n.e.c.
 - 30 - Manufacture of office, accounting and computing machinery
 - 31 - Manufacture of electrical machinery and apparatus n.e.c.
 - 32 - Manufacture of radio, television and communication equipment and apparatus
 - 33 - Manufacture of medical, precision and optical instruments, watches and clocks
 - 34 - Manufacture of motor vehicles, trailers and semi-trailers
 - 35 - Manufacture of other transport equipment
 - 36 - Manufacture of furniture; manufacturing n.e.c.
 - 37 - Recycling
- E - Electricity, gas and water supply
 - 40 - Electricity, gas, steam and hot water supply
 - 41 - Collection, purification and distribution of water
- F - Construction
 - 45 - Construction

- G - Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods
 - 50 - Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel
 - 51 - Wholesale trade and commission trade, except of motor vehicles and motorcycles
 - 52 - Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods
- H - Hotels and restaurants
 - 55 - Hotels and restaurants
- I - Transport, storage and communications
 - 60 - Land transport; transport via pipelines
 - 61 - Water transport
 - 62 - Air transport
 - 63 - Supporting and auxiliary transport activities; activities of travel agencies
 - 64 - Post and telecommunications
- J - Financial intermediation
 - 65 - Financial intermediation, except insurance and pension funding
 - 66 - Insurance and pension funding, except compulsory social security
 - 67 - Activities auxiliary to financial intermediation
- K - Real estate, renting and business activities
 - 70 - Real estate activities
 - 71 - Renting of machinery and equipment without operator and of personal and household goods
 - 72 - Computer and related activities
 - 73 - Research and development
 - 74 - Other business activities
- L - Public administration and defence; compulsory social security
 - 75 - Public administration and defence; compulsory social security
- M - Education
 - 80 - Education
- N - Health and social work
 - 85 - Health and social work
- O - Other community, social and personal service activities
 - 90 - Sewage and refuse disposal, sanitation and similar activities
 - 91 - Activities of membership organizations n.e.c.
 - 92 - Recreational, cultural and sporting activities
 - 93 - Other service activities
- P - Activities of private households as employers and undifferentiated production activities of private households
 - 95 - Activities of private households as employers of domestic staff
 - 96 - Undifferentiated goods-producing activities of private households for own use
 - 97 - Undifferentiated service-producing activities of private households for own use
- Q - Extraterritorial organizations and bodies
 - 99 - Extraterritorial organizations and bodies

8.2. Appendix II – Structure of ISIC for Education activity

Source: United Nations statistics Division

<http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=17&Lg=1>

Hierarchy				
Section	Division	Group	Class	Explanatory note
M Education	80 Education	801 Primary education	8010 Primary Education	<p>This class includes:</p> <ul style="list-style-type: none"> - pre-primary education (education preceding the first level) - primary education (education at the first level) <p>Education can be provided in classrooms or through radio, television broadcast, Internet or correspondence.</p> <p>This class also includes:</p> <ul style="list-style-type: none"> - special education for handicapped students at this level - provision of literacy programmes for adults <p>This class excludes:</p> <ul style="list-style-type: none"> - child day-care activities, see 8532
		802 Secondary education	8021 General secondary education	<p>This class includes:</p> <ul style="list-style-type: none"> - general school education in the first stage of the secondary level corresponding more or less to the period of compulsory school attendance - general school education in the second stage of the secondary level giving, in principle, access to higher education <p>Education can be provided in classrooms or through radio, television broadcast, Internet or correspondence.</p> <p>Subject specialization at this level often begins to have some influence even on the educational experience of those pursuing a general programme. Such programmes are designated to qualify students either for technical and vocational education or for entrance to higher education without any special subject prerequisite.</p> <p>This class also includes:</p> <ul style="list-style-type: none"> - special education for handicapped students at this level <p>This class excludes:</p> <ul style="list-style-type: none"> - adult education as defined in 8090

			<p style="text-align: center;">8022</p> <p style="text-align: center;">Technical and vocational secondary education</p>	<p>This class includes:</p> <ul style="list-style-type: none"> - technical and vocational education below the level of higher education as defined in 8030 <p>Typically, the programmes emphasize subject-matter specialization and instruction in both theoretical background and practical skills generally associated with present or prospective employment. The aim of a programme can vary from preparation for a general field of employment to a very specific job. Education can be provided in classrooms or through radio, television broadcast, Internet or correspondence.</p> <p>This class also includes:</p> <ul style="list-style-type: none"> - special education for handicapped students at this level <p>This class excludes:</p> <ul style="list-style-type: none"> - technical and vocational education at post-secondary and university levels, see 8030
		<p style="text-align: center;">803 Higher education</p>	<p style="text-align: center;">8030 – Higher education</p>	<p>This class includes:</p> <ul style="list-style-type: none"> - first, second and third stages of higher education: · post-secondary education not leading to a university degree or equivalent · post-secondary education leading to a university degree or equivalent <p>A great variety of subject-matter programmes are offered at this level, some emphasizing more theoretical instruction and others, more practical instruction. Education can be provided in classrooms or through radio, television broadcast, Internet or correspondence.</p> <p>This class also includes:</p> <ul style="list-style-type: none"> - special education for handicapped students at this level
		<p style="text-align: center;">809 Other Education</p>	<p style="text-align: center;">8090 – Other Education</p>	<p>This class is reserved for specialized training, generally for adults, not comparable to the general education in groups 801-803.</p> <p>This class includes:</p> <ul style="list-style-type: none"> - adult education, i.e. education for people who are not in the regular school and university system. Instruction may be given in day or evening classes in schools or in special institutions providing for adults: driving schools, flying schools, art schools, cooking schools etc. - instructions on general and vocational subjects - education that is not definable by level <p>Education can be provided in classrooms or through radio, television broadcast, Internet or correspondence.</p> <p>This class excludes:</p> <ul style="list-style-type: none"> - higher education, see 8030 - activities of dance schools, see 9219 - instruction in sport and games, see 9241

8.3. Appendix III - Questionare for Geodatabase

PYETESOR

kodi i shtepise

Emri dhe mbiemri I te intervistuarit _____

Emri dhe mbiemri i pronarit_(pronareve) _____

Emri dhe mbiemri I Kryefamiljarit _____

INFORMATA THEMELORE PER PRONEN

- **tipi i banimit**

Individual shumebanesore

- **shfrytezimi**

e banuar e pabanuar

- **pronesia**

Pronar Me qira shoqerore Jo e poseduar E zaptuar Paguese qiraje zaptuesit

-

Siperfaqja e shtepise ne baze _____m²

Siperfaqja e ngastres _____ar

Etazhiteti i objektit _____

Viti i ndertimit _____

Prone tjeter te patundeshme po jo

KARAKTERISTIKAT SOCIALE TE FAMILJES

- **perkatesia kombetare**

shqiptare serbe R.A.E malazeze boshnjake turq te tjere te padeklaruar

- **vendbanimi**

-banore te Fushe Kosoves prej vitit _____

-vendbanimi I mehershem _____

-arsyet e migrimit _____

- a mendoni te jetoni ne F.K. edhe ne te ardhmen po jo nuk e di

- nese jo per cfare arsye _____

punes shkollimit sigurise infrastruktures ndotjes se ambientit te tjera

- **struktura e moshes** (te shenohet numri)

Numri I anetareve te familjes _____

deri 5 vjet 6-17 vjet 18-65vjet mbi 65vjet

- **struktura gjinore** (te shenohet numri)

meshkuj femra

- **struktura arsimore** (te shenohet numri)

Pa shkollim shkollim fillor shkollim te mesem
shkollim te larte

- **struktura profesionale** (te shenohet numri) _____

- **te ardhurat financiare**

pa te ardhura me ndihme sociale pensioni nga shtetet e jashtme
nga anetaret e punesuar perkohesisht nga anetaret e punesuar te tjera

anetaret e punesuar (te shenohet numri)

-te punesuar ne sektorin publik meshkuj femra
-te punesuar ne sektorin privat meshkuj femra

- **vendi i punes**

Fushe Kosove Prishtine komune tjeter

INFRASTRUKTURA

- **Furnizimi me uje te pijshem**

Nga ujesjellesi nga bunari (pusi) nga cisternat te tjera
-nese nga bunari ose burimi tjetër ____ uji I testuar po jo nuk e di
I pishem po jo nuk e di
Sasi e mjaftueshme p jo

- **Kanalizimi i ujerave te zeza dhe fekale**

Me kanalizim te qytetit ne grope septik ne lum (perrock te tje

- **Furnizimi me energji elektrike**

Formal joformal s'ka kycje

- **Ngrohja e objektit**

qendrore me gas me dru apo thengjill me rryme

- **Lidhje telefonike** p j

nr. I telefonit _____

SHERBIMET

- **A ka sherbime te mjaftueshme ne lagjen e juaj?**

po jo nuk e di

Sherbimet qe mungojne ne lagje _____

shitore zeje sherbyese ente parashkollore klube shoqerore

AMBIENTI

- **Hudhja e mbeturinave**

E organizuar (sherbimi komunal) e organizuar nga lagja e pa organizuar

- **Vendi dhe menytrat e largimit te mbeturinave**

kontejner deponi joformale ambient perreth ne lum(perrocke) digjet

- **Te rrezikuar nga ndotja e ambientit**

ndotja e ajrit ndotja e ujit ndotja e siperfaqes se tokes zhurma

- **Te rrezikuar nga vershimet** po jo nuk e di

- **Numri I automjeteve ne familje**_____

udhetimi per pune/shkolle me

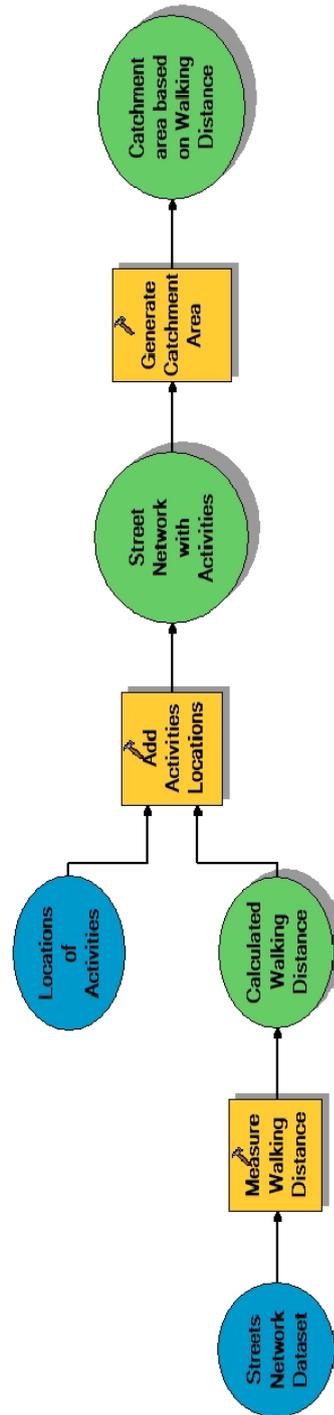
veture private tren autobus,kombibus motociklete biciklete

kembe tjera

Intervistoi:_____

Data:_____

8.4. Appendix IV – GIS model for measuring distance Indicator



8.5. Appendix V – GIS Model for measuring Richness



