Measuring Mixed Use Land in Large Cities and Its Impact on Reducing Commuting and Congestion Cost

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Abid Rehman

Abstract

Efficient use of urban land is very important for the economic efficiency and economic growth of a country, as cities are considered as the engine of growth. This study seeks to measure the mixed used of urban land for commercial and residential purpose in the large cities of Pakistan by using the indices of measurement for mixed use of land. The primary aim of this study is to analyze the impact of mixed use of urban land for commercial and residential purpose on reduction in commuting and congestion cost. This study also review and compare all the indices use in previous research by using Spearman's correlation. The results suggest that most of the cities in Pakistan are not using urban land efficiently. Our survey results also show that there is significant reduction in commuting and congestion cost due to mixed use of urban land for commercial and residential purpose.

Chapter 1: Introduction

1.1 Introduction:

Pakistan is facing serious problem of urban land scarcity due to large number of rural-urban migrants and inefficient urban land use. At least 40% of the population of Pakistan is living in cities and it is estimated that this ratio will reach up to one half in 2030, urban population in Pakistan is 63.1 million and it is estimated up to 110 million in 2030. Some other studies (Ali Raza, 2003) even state that urban population will be more than 60% up to 2030. An interesting fact is also that land area is same but population of cities increase by urban-rural migrant as well as explosive increase in population. God has not increased supply of land since creation of this universe but demand for land is increasing exponentially over time. Therefore, judicious land use is an important aspect and there is great need for use of efficient urban land and the consequences of inefficient land use in the big cities are traffic congestion, high commuting cost, pollution and other hazards.

Now a days Mixed-use of land[1] is a key component of the urban planning both in developed and developing countries, as cities are growing very rapidly. This is considered as the way forward to new urbanism and compact cities but this concept is not new as we think about past, when there were no automobiles, people often refer to mixed-use of land for their work and residence. There was difference between historic application and modern mixed-use of land as historic mixed-use development evolve gradually with time without any planning due to absence of automobiles but modern mixed-use developed in short period of time with proper planning (Schwanke,2003) .

[1] It is the concept in which we can use same land for both residential and commercial purpose.

There are also two ways in which we can use the land mixed use first is to use the land mixed vertically like Singapore, Hong Kong did in Mei Fu Sun Chuen development[2] and secondly use the urban land mixed horizontally like the U.S.A, Canada and other European countries did (Ganeson, 2005). It is also an important component of the smart growth[3] policies which can lead to more sustainable urban development (Choi, 2008). Furthermore urban planners suggest mixed-use development to gain access to greater densities and its benefits, overcome on health, environmental and issues of commuting cost (Herndon, 2011). This awareness about the efficiency of urban land use is increasing day by day and city planners are also thinking about this concept to optimize the use of urban land and cost solutions (Bertuad, 1998).

There are several indices which are used in the previous research for measuring mixed use of land and market concentration. First time Atkinson index was used to measure the income inequality and market concentration (Atkinson, 1970). Later on many indices were introduced based on the criteria of percent/proportion; Balance index; Herfindhal-Hirschman index; Entropy index; cluster index; Dissimilarity index; Exposure index; and Gini index. These all measures are different in the sense that some of them measure proportions and some measures percentages of the land use for the commercial and residential purposes and also some of the measures are integral measures[4] and some are divisional measures[5] in that sense these all measures different with each other (Song, Merlin and Rodiguez, 2013).

Our study is covering here all the indices used to measure mixed-use of land, which are mentioned above and also going to find that how much these measures are similar to each other

[2] See from Multiple and intensive Mixed-use of land: Case study of Singapore by Ganeson (2005).

[3] See from are we growing smart? By Choi (2008).

[4] See comparing the measures of urban land mix use by yan song, Louis Merlin, Daniel Rodiguez (2015).

[5] See comparing the measures of urban land mix use by yan song, Louis Merlin, Daniel Rodiguez (2015).

by using correlation. We have also used one of the measure above to find the mixed-use of land in the big cities of Pakistan.

1.2. Objectives of study:

The main objectives of the study are following:

- Measuring Spearman's Correlation among the indices used for measuring mixed-use of land.
- Measuring how efficiently urban land is being used in big cities of Pakistan.
- Impact of mixed-use of land on reduction in the commuting cost and congestion cost.

1.3. Significance of study:

When we are building cities without mixed use of land we have to build two parallel cities at a time and we also know that how important is mobility of goods as well as people for economy. We have to follow congestion and commuting problems are the externalities which are the reasons of deviation of equilibrium allocations from the pareto-optimal allocations. The current rate of urbanization is 3 percent and if we are unable to make our cities sustainable in next few decades we will face enormous problems of congestion, pollution and chronic health issues. So we need planning in our cities for sustainable development.

The significance for introducing the concept of mixed-use of land is to reduce traffic congestion, distance between work and job place, automobile dependency[6], carbon emissions caused by heavy traffic (Rabianski, 2009).

[6] Automobile dependency means you can go to your job place from you home without Automobile.

In most developed countries especially in U.S.A, Europeans countries and developing countries it is witnessed that increase in population has caused increase in economic activities which causes increase in city size. As a consequence of this increase outward spread causes problem of low density distance due to inefficient urban land use which causes increase in the distance and people travel (Frokenbrock, Mathur and Schweitzer, 2001).

Land use pattern decide about the transport choice of the people either people go to office by walk, bicycle, public transport or solely rely on private automobile. We have seen especially in the case of Pakistan cities are built for cars and encourage the people to buy more cars and also spread is considerably large between the work and residence place due to which commuting cost[7], time cost and environmental issues are much high in our cities. Land use and transport integrated policies can improve the cost issues, economic and environmental dimensions of sustainability which can play an important role to reduce the need to travel, land consumption and commuting cost (Macario, 2005).

Road traffic congestion is the big problem of the large urban areas and there is also enormous cost of congestion in the form of gasoline and time cost. In the case of Pakistan there were several steps taken by government to reduce congestion such as widening of roads but these initiatives didn't yield desired outcome. Cities are designed such that employment is at center of city and all people move to center of city for job at the same time in the morning and come back to house after doing job to their home from center of city which causes traffic congestion.

Main reason is that people don't use the commercial and residential land mixed so mixed-use of land is much better as compared to exclusive use of urban land (Wheaton, 2003). Literature

[7] Cost bear by any person to reach to its desire destination is called commuting cost.

suggests that Mixed-use of land can also be managing strategy for the excessive traffic congestion for these large urban areas because mixed use of land encourage the automobile independence as mention above due to which traffic on road can be reduced and also congestion cost.

This study will contribute to having debate on efficient land use patterns, viable traffic solutions and other related issues. There is policy gap we are focusing on the policies which are temporary like build new and wide roads which encourage more cars and then after few years congestion and commuting problems remain same. This research is going to fill in this policy gap regarding policies to overcome problem of congestion and commuting in urban areas of Pakistan.

1.4 Organization of study:

Rest of the work is organized as follows. Chapter 2 reviews literature on Measuring mixed use of urban land for big cities of Pakistan and its impact on reduction in congestion and commuting cost. Chapter 3 gives theoretical framework model and describes about the indices which use for measuring the mixed use of land. Chapter 4 explains about the level of urban land mixed-use in the twenty big cities of Pakistan by using the indices of measurement for mixed-use. Chapter 5 explains how much will be the reduction in congestion and commuting cost as the result of mixed use of land. Chapter 6 concludes the study.

Chapter: 2 Literature Review

This section discusses some studies which are postulating that how can we measure mixed use of land by using different measures, benefits of mixed-used development in term of reduction in commuting cost and congestion cost. There is no exact definition of mixed-use or there is not one definition on which all people agree but the latest definition from US [composed of BOMA International (BOMA), the International Council of Shopping Centre's (ICSC), the National Association of Industrial and Office Properties (NAIOP) and the National Multi Housing Council (NMHC)] is following:

"A mixed-use development is a real estate project with planned integration of some combination of retail, office, residential, hotel, recreation or other functions. It is pedestrian-oriented and contains elements of a live-work play environment. It maximizes space usage, has amenities and architectural expression, and tends to mitigate traffic and sprawl." (Niemira 2007, p. 54)"

The term "mixed-use" was introduced in the field of urban planning in 1960s and then there was no importance given to that term but when cities arise with the problems of pollution, congestion and commuting, city planners thought about the sustainable cities so the concept of mixed-use development used again in 1990s to avoid these problems in cities, in that era there was rapid increase in urban population due to high economic growth. Which create more problems to the cities which also contribute in the revival of mixed-use development later on sustainable cities became main components SDG's then the importance of mixed-used further increases.

If we see in the historical perspective in the old times when there were no transport, and walking was the basic means of transportation and it was the need of time that people built such environment in which there was less distance between residence and job place in the towns and cities (morris,1994). Furthermore company towns and model downs were developed in US in 1645 later on in UK there were Garden cities in 1928 which carefully balance the distance between industry and residence of people, (Howard, 1965).

There is vast empirical literature which proves that mixed-use of land can play an important role to overcome the problems of congestion and commuting facing by cities. In Table 2.1 we summarize some of the literature available on the mixed use of land.

Table 2.1: Summary of Literature Review.

Study	Country and Data	Results
A Methodological Analysis of segregation indexes by (Dudley and Duncan, 1955)	No data is used it is core structural study.	• This paper is fundamentally a summary of mathematical analysis of all measures and also it highlights the problem of authentication of segregation indices. • Difficulties in findings a logic for using the index number.
A Generalized Index of Dissimilarity by (Sakoda, 1981)	No data is used it is core structural study.	• Explain about the basic construction and formulation of Dissimilarity index. • Clarification of index in two directions and it is related to more than two groups at a time.
The Dimensions of Residential Segregation by (Massey and Denton, 1988)	USA	• Talk about the dimensions of segregation and this research defines that segregation is multi-dimensional occurrences. • Discuss segregation indexes which I am using in my research
Mixed-land use and commuting: Evidence from the American housing survey by (Cavero, 1996)	USA and data using from American housing survey 1985.	• All previous researchers gives the concept of the mixed use of land and benefits first discover this question by data • Paper explains the presence of neighboring commercial land-uses is also associated with quite low vehicle ownership rates and short commuting distances among residents of a mixed-use neighborhood. • Residential densities exerted a stronger effect on commuting mode selections than levels of land-use mixture, except for walking and bicycle commutes. • the effects of reducing auto-commuting, commute distances, and vehicle ownership rates

		suggest that moderate-to-high density, mixed-use neighborhoods average less vehicle-miles-traveled (VMT) per capita than lower density, completely residential ones
A framework for reforming Urban land policies in Developing countries by (Dowall and Clark, 1996).	Policy paper for the development countries by joint collaboration of UNDP/World Bank/UNCHS Urban Management Program (UMP).	• This Policy paper cover a wide range of topics, including land information management, land registration, land development policies, standards for land regulation, and urban spatial planning. • This report concludes that Developing countries need to reassess and reform their urban land policies. Many cities use master plans, zoning, subdivision regulations, building codes and other public policies to shape development. • A six-step framework for reforming urban land policy has been obtainable: land market assessments; decentralization of land management authority; deregulation of inappropriate and costly land-use controls; transfer of ineffective public land development agencies; implementing titling, registration and information systems to improve land market efficiency; and alternative planning and accounting systems for financing infrastructure
Where did the new urban economics go after 25 years? By (Button, 1998)	USA but its general foundation of urban economics.	• Phases how urban economics evolve, meaning of this word how change after 1960. • new urban economics has satisfied its capacity of letting greater quantification of urban limitations as aids to policy making
	Korea	• This paper identify the three potential factors of urban efficiency e size of the city, the speed at which people and goods are moved in the city, and the sprawl or the relative location of jobs and homes in the city. • In this study efficiency is in general defined as labor productivity that is output per worker. Total productivity would be a better sign of efficiency • Results show that there is a city size for which the difference between benefits and costs, also called the net benefit, is highest, and which is the so-called optimal size of cities. • In bordering terms, there is a downward sloping marginal benefit curve B(S) and an mounting

		sloping marginal cost curve C(S): the point at which they intersect defines the optimal size S* of cities • . When the city size increases by 100 persons, the labor market increases by about 20 jobs and 18 workers within 25 minutes.
Utilization of urban residential land: a case study of Singapore by (Dapaah, 1999)	Singapore and three case studies	• So the prime urban land is not using sub optimally and paper suggest that for the optimal use of land we have a pricing system on the basis of opportunity cost and land use capacity.
Transportation Investment and Urban Land Use Patterns by (Frokenbrock, Mathur and Schweitzer, 2001)	USA	• What land use patterns would be encouraged if a particular transportation investment were to be made within the city? · • What types of transportation investments would be advisable to help achieve a desired land use pattern?
Traditional Neighborhoods and Auto Ownership By (Hess and Ong, 2001).	Data collection through telephonic survey from 20,161 households in Portland.	• This study check effects of land use patterns on auto ownership • Results show that land use mix changes from diverse to homogeneous, the probability of owning an auto decreases by 31 percent.
Canada's experience in planning for sustainable development by (Grant, 2001).	Canada policy base paper just recommendations.	• Paper explain the Canadian experience of developing the communities which has greater mixed use development to resolving the long-term problems that Canadian communities face: automobile dependency, regional disparity, lack of affordable housing, de-industrialization, environmental degradation, fiscal restraint, and over-consumption of non-renewable resources.
Integrating land use and transport - Guidelines for planning and development by NSW Department of Urban Affairs and Planning (2001).	Australia just guidelines	• These embody the critical objectives of reducing the growth in vehicle kilometer's travelled (VKT),improving air quality and reducing greenhouse gas emissions , building more compact cities , promoting economic development and creating jobs. • Whole document theme was that use Integrating land use and transport policies to overcome problem of commuting cost and efficiency. • Report use 10 principles to reduce the problem of commuting cost and efficiency and mixed-use of land is one among them.
The Costs of	USA and data	• Paper finding are the automobile dependency

Automobile Dependency and the Benefits of Balanced Transportation by (Litman, 2002)	taken by Active transport survey.	cost which is 7800 US$ the huge cost annually. • Paper also finds time cost due to delay in congestion which is actually congestion cost • Paper also suggests overcoming on automobile dependency we should change land use pattern and go towards mix use of land and compact cities.
Commuting, Congestion, and employment dispersal in the cities with mixed land use by (Wheaton, 2003)	USA no data use, just use preposition to prove all results.	• This paper explains the two extremes of land use and its effect on employment dispersal and wage rate, commuting distance and congestion. • First effect is high agglomeration forces with low wage rate, greater commuting distance, and high density. • Other effect is low agglomeration forces by use land mixed with high wage rate with low commuting distance and minimum congestion.
Walking, Bicycling, and Urban Landscapes: Evidence from the San Francisco Bay Area by (cervero and Duncan, 2003)	2000 Bay Area Travel Survey (BATS) which contains up to two days of daily activity information for members of 15,066 randomly selected households in the nine-county San Francisco Bay Area.	• Study find link between urban environment and non-motorized travel. • Study shows strong indication on the importance of urban landscapes in shaping foot and bicycle travel is needed if the urban planning and public health professions.
Optimal Urban Land use and zoning by (Hansberg, 2003).	USA, purely mathematical modeling and qualitative analysis use	• Paper results shows that there is difference between Pareto optimal and equilibrium allocation of land due to externalities and because of mono centric structure greater commuting and congestion cost. • Paper also suggest that city government should use zoning policies as well as different types of subsidies and taxes to take advantage of gain • Optimal allocations are somewhere in between the agglomeration and disperse.
Which Reduces Vehicle Travel More: Jobs-Housing Balance or Retail-Housing Mixing? By	2000 Bay Area Travel Survey (BATS) which contains up to two days of daily	• Study shows that mix use of land is best strategy and signature feature of smart growth. • Previous study mention above by author is giving not so much good results as this mix use strategy gives.

(Cervero and Duncan, 2004)	activity information for members of 15,066 randomly selected households in the nine-county San Francisco Bay Area.	
Multiple and intensive use of urban land by Ganesan. (2005).	Hong Kong	• how we can use land intensively through residential and commercial use
The mix use trend: a case study of north Ohio by (hirt, 2007)	Canada	• Through this data author suggest that mix use of land in north Ohio exists and it getting popularity among planners and mixed use has become popular in Europe • the functional, social and ecological benefits of mix use of land and check weather mix use of land is supported in Ohio
Managing urban traffic Congestion Summary document by the transport research center (2007).	Just recommendations for All European's countries.	• Paper explains basic about congestion, its measurement, causes, managing techniques, and institutional arrangements encouraging or discouraging appropriate responses to congestion. • Managing techniques are parking management, pricing policies, improving traffic operations, improving public transport, mixed use building structure.
The Generation of Diversity: Mixed-Use and Urban Sustainability by (Evans and Foord, 2007).	UK no data just general policy report by GIS-Based analysis.	• Mixed-use development is the most sustainable development which create more secure environment less need to travel, more attractive and better quality town centers, more local employment and services.
Impact of current land-use patterns on public transport and human settlements by (Mtantato, 2007).	South Africa. General data of population and traffic for the big cities.	• Paper discuss problem facing by the people of South Africa regarding commuting and poor public transport system in big cities as population of cities increases so rapidly. • Problems are overcoming the legacy of apartheid and its policies; legislative gaps; poorly located low-cost housing and low densities, leading to extensive commuting; high transport costs; and

		unsustainable and inefficient public transport • Recommendations are government should implement transport and land integrated policies by using mix use development.
Spatial and transport planning integrated policies: guidelines for northwest Spain by (Salas-Olmedo, 2008)	Northwest Spain	• LUT policies are fulfill by using the mixed-use of land so reduce car travel • Role of car pricing in the reduction of car use • Compact cities require for sustainable development.
Are we growing smart? : A new vision for urban development in Asia and the pacific by (Choi, 2008).	No data use general theories and it's for whole Asia.	• The paper argues that smart growth policies can lead to more sustainable and equitable urban development by overcoming the current unplanned sprawl • Paper also explain the implications of smart growth principles for Asia-Pacific urbanization • Paper emphasize that Asian cities used mixed use of land and compact building design and walkable communities.
Feasibility of Using Jobs/Housing Balance in Virginia Statewide Planning by (Miller, 2010)	USA and using national household transportation survey data for Virginia.	• The impact of job housing balance on commuting is that vehicle miles traveled reduce by 28% and travel time reduces by 13.3%. • No single criterion for balance in USA means percentage of land use for residential and commercial purpose in not known.
Mixed-Use Development in Theory and Practice: Learning from Atlanta's Mixed Experiences by (Herndon and Drummond, 2011).	Atlanta and using different sources.	• This paper explains Basic theories of mixed-use development and few case studies also. • Mixed land uses were an essential aspect of cities throughout most of human history. • "Mixed use cannot resolve all the problems of the city, but cities that lack mixed use cannot hope to enjoy long-term prosperity or viability" (Grant, 2004).
Comparing measures of urban land mix use" by (song ,Merlin,2013)	Simulated data and for USA	• This is basically an approach to measure the urban land use mix in order to understand which methods are most suitable under which conditions and which methods are almost same in their results by using the Monte carols simulations.
Urbanization in Pakistan: causes and consequences by (Kugelman, 2013)	Pakistan	• Drivers of urbanization in Pakistan are migration as the result of independence and war against terror and rapid increase in population

		also. • Social consequences are strengthening electoral system due to urban-based political parties. • Economic consequences are high growth industries in the cities and advanced telecommunication
Urban transport system and congestion: a case study of Indian cities by (Alam and Ahmed, 2013)	India and not specific data for one city it's for Asia	• This paper first describes some of the factors contributing to congestion in Asian cities in general. • Rapid increase in population and more demand for mobility. • phenomenal increase in private car ownership and the resulting growth in the number of private vehicles are responsible for the high level of congestion in cities • policies imply by Singapore and china to control congestion also given • gaps are fuel subsidies, drivers education and road safety, promotion of automobile industry, • Less effective parking policies.
Land Use Impacts on Transport How Land Use Factors Affect Travel Behavior by (Litman, 2014).	USA no data just general policy report.	• Mixed use of land reduces vehicle travel and increase use of alternative modes, mainly walking. Mixed-use areas normally have 5-15% less vehicle travel • Land mix-use reduces vehicle ownership as cause congestion reduces significantly.

2.1. Conclusion

In this chapter theoretical and empirical aspects of mixed-use of land regarding measurement and its relationship with reduction in commuting and congestion cost reviewed. Theoretically and empirically it is suggested that mixed-use of land has significantly impact on reduction in congestion and commuting cost. A lot of literature suggests that there should be integrated land use transport policies to avoid the problem of congestion in the cities. Literature also suggest that mixed-use of land is the key component of smart growth and necessity of cities in the current situation.

Chapter 3: Theoretical Framework

This chapter will describe the techniques for the mixed-use of land and their comparison with each other by Spearman's correlation for the data generated for hundred cities with the variable city size range between 2000 unit areas to 10000 unit areas through the Monte Carlos simulations.

There are many types of indices which are used to measures the mixed-use of commercial and residential land use. Basically all the indices come from the range of social science research pertaining the concept of mixing, segregation, or concentration and we are going to use these indices which are capturing the concept of distance and quality are applicable to urban land use context (Merlin, 2013).

3.1. Mathematical Notations:

Here we are discussing two types of urban land use that is Residential and commercial, let the amount of land used for residential purpose is $\mathbf{A}$, for commercial is $\mathbf{B}$ and total amount of covered land is $\mathbf{C}$, so the covered area is $\mathbf{C = A+B}$.

Let the percentages of these two these two land use are **L** and **M** define as $\mathbf{L}=\frac{\mathbf{A}}{\mathbf{C}}$ and $\mathbf{M}=\frac{\mathbf{B}}{\mathbf{C}}$ and $\mathbf{L+M=1}$.Furthurmore, we divided these areas in to **n** towns and land area use in each town denoted by lowercase letter with the subscript of town. So $\mathbf{a_1, a_2, a_3 \ldots a_n}$ and $\mathbf{b_1, b_2, b_3 \ldots b_n}$ are the areas of each land use while total area of land in each town is $\mathbf{c_1, c_2, c_3 \ldots\ldots c_n}$. So we can use these areas as:

$$a_1 + a_2 + a_3 \ldots + a_n = A \quad (1)$$

$$b_1 + b_2 + b_3 \ldots + b_n = B \quad (2)$$

$$c_1 + c_2 + c_3 \ldots + c_n = C \quad (3)$$

Similarly we have also found the percentages of land used in each town as compared to overall and with respect to area of those towns:

$$l_i = \frac{a_i}{c_i} \;;\; m_i = \frac{b_i}{c_i} \;;\; r_i = \frac{a_i}{A} \;;\; s_i = \frac{b_i}{B} \;;\; t_i = \frac{c_i}{C} \quad (4)$$

We can see in equation (4) that l_i is the percentage of residential land use in town over to total land of town, m_i is the percentage of commercial land use in town over to total land of town, r_i is the percentage of residential land use as compared to area use for the residential land in whole city, whereas s_i, $t_i$the areal percentages of commercial land use as compared to area use for the residential land in whole city.

$$\sum_i r_i = \sum_i s_i = \sum_i t_i = 1 \quad (5)$$

Now there are two types of measures used for the mixed use of land; integral measures and divisional measures.

3.2. Integral measures:

Integral measures are used micro-scale variation within the area under analysis while Land use patterns of great diversity. One of the drawbacks of the integral measures are that these are clearly sensitive to the size of the areas under analysis a version of the Modifiable Areal Unit

Problem or MAUP (Dark &Bram, 2001). Some of the integral measures are using in this research are:

3.2.1. Percentage and proportions:

This is the simplest index used to measure mixed-use of land in which we take the proportion of land used for residential and commercial purpose with respect to total area which is written above as L and M.

3.2.1.1. Mathematical formulation:

Mathematical formulation of the index is given below

$\mathbf{L} = \frac{\boldsymbol{A}}{\boldsymbol{C}}$ and $\mathbf{M} = \frac{\boldsymbol{B}}{\boldsymbol{C}}$ and $\mathbf{L+M=1.}$

3.2.2. Balance Index (BAL):

Balance index is basically used to measures the degree to which two different types of land uses or activities (i.e. residential & commercial) exist in balance with each other with- in an area. The Balance Index range from 0 to 1 with higher values associated with greater land use mix, i.e. greater levels of balance.

3.2.2.1. Mathematical formulation:

Mathematical formulation of the index is given below

$$\text{BAL} = 1 - \frac{|\boldsymbol{A} - \propto \boldsymbol{B}|}{(\boldsymbol{A} + \propto \boldsymbol{B})}. \qquad (7)$$

In this index A and B are the lands areas used for the commercial and residential purpose and " $\propto$ " is consider as adjustment coefficient and it show that what will be the optimal value of land use in the city i.e. $\propto = \frac{A^*}{B^*}$,whereas A^* and B^* is the optimal land use for residential and commercial purpose respectively. This index values varies between 0 and 1 and values approaches to 1 means greater mixed-use of land.

3.2.3. Entropy index (ENT):

In the entropy index we measure mixed-use of land in the relative percentage of each land use areas. This index is used in various natural sciences also for the mixing of fluid and their integration so higher level of entropy indicates the great integrated mixture same like that we can use this index for the mixed-use of land and this index varies between zero and one (Song, 2004).

3.2.3.1. Mathematical formulation:

Let l^j be the percentage of residential land use in town over to total land of town j and let k be the number of land uses types so mathematical formulation of the index is given below:

$$\text{ENT} = -\frac{\left[\sum_{j=1}^{k} l^j \ln l^j\right]}{\ln(k)} \qquad (8)$$

Entropy index values vary from 0 to 1 and 1 indicates that land for both types use with same percentage like 50, 50%. So gap between these two types of land use increases then value of Entropy index approaches to zero.

3.2.4. Herfindhal-Hirschman Index (HHI):

It is considered as the index of market concentration which is basically used widely in the field of economics, using same concept of distance measurement we can also use this index for the measurement of mixed-use of land.

3.2.4.1. Mathematical formulation:

Let l^j be the percentage of residential land use in town over to total land of town j and let k be the number of land uses types, Mathematical formulation of the index is given below:

$$\text{HHI} = \sum_{j=1}^{k} (100 * l^j)^2 \qquad (9)$$

This index values range between 0 and 10,000 and higher value of HHI index refer to greater mixed-use of land.

3.3. Divisional measures:

Divisional measures are those measures which are used for the large areas, like large city size having so much towns deal with the divisional measures, dealing with these divisional measures we have to divide city or area in to many sub areas called as the towns. There are also some drawbacks of these divisional measures such that we use rectangular shape proxy for measurement of city size but the shape of city size is irregular, another one drawback is that these measures are highly sensitive to geography (Dark & Bram, 2007).

3.3.1. Atkinson Index (ATK):

This index is basically an index used to measure the land use diversity among residential and commercial use by assigning the value of perimeter ∈ which varies between 0 and 1, first time this index is use by Atkinson for measuring extreme land use imbalances (Atkinson, 1970).

3.3.1.1. Mathematical formulation:

Let s_i be the percentage of land use for the commercial purpose among the whole land use for the commercial purpose in the town i , whereas ∈ is the parameter for land use diversity and it varies between 0 and 1 so mathematical formulation of the index is given below:

$$\text{ATK (B)} = 1 - \left[\frac{1}{n} \sum_{j=1}^{n} (s_i)^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}} \qquad (10)$$

Values of Atkinson index varies from 0 to 1 so 0 indicates greater mixed-use of land and values approaches to 1 indicates less mixed-use of land.

3.3.2. Cluster Index (CLST):

This is basically index which is used for checking the residential and commercial clustering. It takes only one type of land area as input and shows that the particular land type is how much clustered in the whole land area.

3.3.2.1. Mathematical formulation:

Let s_i be the percentage of land use for the commercial purpose among the whole land use for the commercial purpose in the town i, b_i, c_i and B are the basically percentages of land use in town i for the commercial area used and total area of town respectively, whereas d_{ii^*} shows the distance between centroid of both towns (Denton, 1988).where, e is the exponent which is using to make this function in exponential form. Mathematical formulation of the index is given below:

$$\text{CLST (Y)} = \frac{\sum_{i=1}^{n} s_i \sum_{i^*=1}^{n} b_{i^*} e^{-d_{ii^*}} - \frac{B}{n^2} \sum_{\substack{1 \le i \le n \\ 1 < i^* < n}} e^{-d_{ii^*}}}{\sum_{i=1}^{n} s_i \sum_{i^*=1}^{n} c_{i^*} e^{-d_{ii^*}} - \frac{B}{n^2} \sum_{\substack{1 \le i \le n \\ 1 < i^* < n}} e^{-d_{ii^*}}} \quad (11)$$

The values of cluster index varies between 0 and 1, for higher values we have greater mixed-use of land and for lower values as approaches to zero we have less mixed-use of land.

3.3.3. Dissimilarity index (DIS):

This index is basically used to tell the distribution of land use for the specific purpose i.e. commercial or residential among the whole land so, the index will be defined if there is evenness in the land use for commercial and residential purpose or not in the town (Duncan, 1955).

3.3.3.1. Mathematical formulation:

Suppose r_i is the percentage of residential land use as compared to area use for the residential land in whole city, whereas s_i is the areal percentages of commercial land use as compared to area use for the residential land in town *i* among the *n* towns Mathematical formulation of the index is given below

$$D = 0.5 \sum_{I=1}^{n} |r_i - s_i| \quad (12)$$

The values of this index varies between 0 and 1, for higher values we have greater mixed-use of land and for lower values as approaches to zero we have less mixed-use of land.

3.3.4. Exposure Index (EXP):

This is the index used for the measurement of mixed-use of land by using the degree of contact and interaction among the areas, if we say that there are greater interaction among the two subjects in the particular area it means there is greater mixed-use of land (Messy & Denton, 1988).

3.3.4.1. Mathematical formulation:

Suppose r_i is the percentage of residential land use as compared to area use for the residential land in whole city and s_i is the areal percentages of commercial land use as compared to area use for the residential land, whereas l_i is the percentage of residential land use in town over to total land of town, m_i is the percentage of commercial land use in town over to total land of town i so mathematical formulation of the index is given below:

$$\text{EXP (a)} = \sum_{i=1}^{n} s_i l_i \tag{13}$$

$$\text{EXP (b)} = \sum_{i=1}^{n} r_i m_i \tag{14}$$

In the above equations we have measure the interaction among the commercial and residential areas and its values range between 0 and 1, higher values indicates greater mixed-use of land whereas less values indicates low mixed-use of land.

3.3.5. Gini index (GINI):

Gini index is basically a measure of inequality and it was used first time by Gini in 1955 to measure the income inequality among the groups and it also shows how evenness is between incomes of different groups, same index can be used to measure the land use inequality or distribution of land among different purposes (Merlin, 2013).

3.3.5.1. Mathematical formulation:

Suppose r_i is the percentage of residential land use as compared to area use for the residential land in whole city and s_i is the percentages of commercial land use as compared to area use for the residential land in town i, whereas σr_i and σs_i are the cumulative percentages of residential and commercial land. Mathematical formulation of the index is given below

$$\text{GINI} = |1 - \sum_{i=1}^{n}(\sigma r_{i+1} + \sigma r_i)(\sigma s_{i+1} + \sigma s_i)| \quad (15)$$

It basically measures land use balance and its values range between 0 and 1, whereas 0 shows that there is less balance in land use for commercial and residential and 1 shows perfect balance among the land use.

3.4. Method for data generation

The data generated for hundred cities with fixed city size of 10000 units through Monte Carlos simulations in the previous research by (Merlin, 2013) and find out the correlation among all indices as shown in Table 3.1. While the method for data generation in the current study is for hundred cities with the variable city size range between 2000 units areas to 10000 units areas by the Monte Carlos simulations in Appendix A. We also checked the correlations among all indices after changing the data generation from fixed city size to variable city size in the Table 3.1.

3.5. Results

Table 3.1 Mean Spearman's correlation coefficients
in absolute value in the case of fixed city size.

	Percent	Exposure (LU = R)	Exposure (LU = NR)	Atkinson (LU = NR, e = .1)	Atkinson (LU = NR, e = .5)	Atkinson (LU = NR, e = .9)	Atkinson (LU = R, e = .1)	Atkinson (LU = R, e = .5)	Atkinson (LU = R, e = .9)	Balance	Entropy	HHI	Dissimilarity	Gini
Percent	1.000	0.992	0.992	0.946	0.936	0.917	0.947	0.937	0.918	0.002	0.002	0.002	0.004	0.004
Exposure (LU = R)	0.992	1.000	0.972	0.963	0.955	0.937	0.914	0.903	0.883	0.000	0.000	0.000	0.068	0.070
Exposure (LU = NR)	0.992	0.972	1.000	0.914	0.903	0.883	0.963	0.955	0.937	0.004	0.004	0.004	0.076	0.076
Atkinson (LU = NR, e = .1)	0.946	0.963	0.914	1.000	0.997	0.985	0.855	0.844	0.823	0.082	0.082	0.082	0.224	0.230
Atkinson (LU = NR, e = .5)	0.936	0.955	0.903	0.997	1.000	0.993	0.843	0.832	0.812	0.095	0.095	0.095	0.241	0.249
Atkinson (LU = NR, e = .9)	0.917	0.937	0.883	0.985	0.993	1.000	0.822	0.811	0.791	0.118	0.118	0.118	0.259	0.271
Atkinson (LU = R, e = .1)	0.947	0.914	0.963	0.855	0.843	0.822	1.000	0.997	0.984	0.078	0.078	0.078	0.232	0.238
Atkinson (LU = R, e = .5)	0.937	0.903	0.955	0.844	0.832	0.811	0.997	1.000	0.993	0.091	0.091	0.091	0.249	0.256
Atkinson (LU = R, e = .9)	0.918	0.883	0.937	0.823	0.811	0.791	0.984	0.993	1.000	0.114	0.114	0.114	0.266	0.277
Balance	0.002	0.000	0.004	0.082	0.095	0.118	0.078	0.091	0.114	1.000	1.000	1.000	0.569	0.611
Entropy	0.002	0.000	0.004	0.082	0.095	0.118	0.078	0.091	0.114	1.000	1.000	1.000	0.569	0.611
HHI	0.002	0.000	0.004	0.082	0.095	0.118	0.078	0.091	0.114	1.000	1.000	1.000	0.569	0.611
Dissimilarity	0.004	0.068	0.076	0.224	0.241	0.259	0.232	0.249	0.266	0.569	0.569	0.569	1.000	0.973
Gini	0.004	0.070	0.076	0.230	0.249	0.271	0.238	0.256	0.277	0.611	0.611	0.611	0.973	1.000

3.5.1. Explanation of Table 3.1

Table 3.1 shows the correlations among the indices in the case of fixed city size. In the data generation (Merlin, 2013) use the size of all hundred cities fixed which is ten thousand. Results shows that there is high Spearman's correlation coefficient among the percent, Exposures and Atkinson index and there is very high Spearman's correlation coefficient among the balance, Entropy, HHI, Dissimilarity and Gini index. Overall, results shows that all integral measures have high correlation among them. While, all divisional measures also have high correlations.

Table 3.2 Mean Spearman's correlation coefficients in absolute value in the case of variable city size

	Percent	Exposure (LU = R)	Exposure (LU = NR)	Atkinson (LU = NR, e = .1)	Atkinson (LU = NR, e = .5)	Atkinson (LU = NR, e = .9)	Atkinson (LU = R, e = .1)	Atkinson (LU = R, e = .5)	Atkinson (LU = R, e = .9)	Balance	Entropy	HHI	Dissimilarity	Gini
Percent	1.000	0.000	0.001	-0.004	0.000	0.001	0.001	0.017	0.001	0.004	0.883	0.884	0.000	0.004
Exposure (LU = R)	0.000	1.000	0.930	0.604	0.001	0.002	0.001	0.001	0.375	0.003	0.053	0.044	0.394	0.003
Exposure (LU = NR)	0.001	0.930	1.000	0.817	0.004	0.005	0.005	0.003	0.324	0.002	0.051	0.038	0.353	0.002
Atkinson (LU = NR, e = .1)	0.004	0.604	0.817	1.000	0.007	0.009	0.009	0.004	0.180	0.002	0.037	0.02	0.212	0.002
Atkinson (LU = NR, e = .5)	0.000	0.001	0.004	0.007	1.000	0.932	0.607	0.002	0.382	0.002	0.046	0.05	0.400	0.002
Atkinson (LU = NR, e = .9)	0.001	0.002	0.005	0.009	0.932	1.000	0.819	0.001	0.330	0.000	0.041	0.04	0.360	0.000
Atkinson (LU = R, e = .1)	0.001	0.001	0.005	0.009	0.607	0.819	1.000	-0.006	0.183	0.003	0.024	0.03	0.216	0.003
Atkinson (LU = R, e = .5)	0.017	0.001	0.003	0.004	0.002	0.001	0.006	1.000	0.000	0.679	0.008	0.025	0.001	0.679
Atkinson (LU = R, e = .9)	0.001	0.375	0.324	0.180	0.382	0.330	0.183	0.000	1.000	0.001	0.108	0.10	0.960	0.001
Balance	0.004	0.003	0.002	0.002	0.002	0.000	0.003	0.679	0.001	1.000	0.010	0.001	0.002	1.000
Entropy	0.883	0.052	0.052	0.043	0.046	0.046	0.024	0.008	0.108	0.010	1.000	0.96	0.113	0.010
HHI	0.880	0.046	0.034	0.026	0.052	0.053	0.032	0.025	0.105	0.001	0.963	1.000	0.110	0.001
Dissimilarity	0.000	0.394	0.353	0.212	0.400	0.360	0.216	0.001	0.960	0.002	0.113	0.11	1.000	0.002
Gini	0.004	0.032	0.002	0.002	0.002	0.000	0.003	0.679	0.001	1.000	0.010	0.00	0.002	1.000

3.5.2. Explanation of Table 3.2

Table 3.2 shows the correlations among the indices in the case of variable city size. In the current study we changed the data generation process in this research from fixed city size to variable city size and range for the hundred cities varies from two thousand to ten thousand units. Rationale for changing this data generation was to make the data generation closer to real world situation.

The results shows that there is no fixed pattern of Spearman’s correlation coefficient among the percent, Exposures and Atkinson, balance, Entropy, HHI, Dissimilarity and Gini index. The reason for this change in the Spearman’s correlation coefficient in the both tables is mainly due to two reasons. First reason is the sensitivity of these measures towards the city size and geography. Second reason which plays important role is that shape of cities in the case of variable city size, which is not regular in most of the cases like a square or circle in the case of variable city size due to which results are not same in the Table 3.2 as compared to Table 3.1.

Chapter 4: Data and Methodology

4.1. Introduction:

Pakistan is facing a serious problem of urban land scarcity due to large number of rural-urban migrants and inefficient urban land use. More than 50% of the population of Pakistan is living in cities if we use old definition of urban area (Ali Raza, 2003). An interesting fact is also that land area is same but population of cities increase by urban-rural migration as well as explosive increase in population so, there is great need for use of efficient urban land to avoid the problems regarding commuting and congestion in our cities. Traffic congestion, high commuting cost, pollution are the negative externalities which are causes of deviation of equilibrium allocations from the pareto-ptimal allocations. So, to avoid the problem of congestion and commuting cost we have to follow one of the policy is Mixed-use of urban land to enhance efficiency. (Masood & A.Naqvi, 2011).

Current rate of urbanization is 3 percent and if we are unable to make our cities sustainable in couple of decades we will face huge problem of congestion, pollution and chronic health issues. Therefore, we need planning in our cities for sustainable development. Current study suggest that to use the urban land efficiently and build the compact cities by doing mixed-use development to avoid the problem of congestion, commuting cost in term of gasoline burning and time cost, pollution and health issues.

In this chapter we measured the mixed-use of land in the big cities of Pakistan, as there is great history of mixed-use of land in rural areas of Pakistan where people use their lower floor of house for shops and for their work.

4.2. Data:

The data source for this chapter is Urban Unit of Pakistan, percentages of land use for the commercial and residential purpose were required as the input for the HHI index which is shown in the table 4.1.

Table 4.1: Percentages of land use

Cities name	Residential Land Percentage	Commercial Land Percentage
Karachi	52.500	1.820
Lahore	61.300	3.449
Faisalabad	38.000	4.000
Peshawar	52.000	4.000
Rawalpindi	55.680	2.780
Gujranwala	23.910	3.470
Islamabad	55.000	5.000
Multan	55.820	1.140
Bahawalpur	53.200	2.000
Quetta	56.410	2.540
Gujarat	50.000	3.000
Sargodha	54.000	2.300
Jhang	43.020	1.490
Shekhupura	35.620	0.890
Abbottabad	14.520	1.130
Kasur	19.720	0.880
Rahim yar khan	11.375	1.200
Sahiwal	31.310	1.760
Dera ghazi khan	21.250	1.290

Data source: Urban Unit of Pakistan (2013)

In the Table 4.1 we have percentages of land use for the residential and commercial purpose in the big cities of Pakistan. If we see the ratio between residential and commercial land use it is much greater as compared to USA and other developed countries. In USA there is ratio of 6 or 7 between residential and commercial land by the data inventory of land use in 2001. If we take a look on the table we can roughly guess that this ratio varies between 10 and 35 in the big cities, so this shows the land use imbalances in the urban areas of Pakistan.

Table 4.2: Total covered area of land.

Cities name	**Total land area**	**Total covered area**
Karachi	3527	1915.866
Lahore	1772	1148.256
Faisalabad	1300	546
Peshawar	1257	703.92
Rawalpindi	5286	3087.024
Gujranwala	3198	873.054
Islamabad	906	543.6
Multan	3721	2119.4816
Bahawalpur	237.2	130.9344
Quetta	2653	1563.9435
Gujarat	3192	1691.76
Sargodha	5854	3295.802
Jhang	8809	3920.8859
Shekhupura	5960	2175.996
Abbottabad	1969	308.1485
Kasur	3995	822.97
Rahim yar khan	11880	1493.91
Sahiwal	3201	1058.5707
Dera ghazi khan	11992	2702.9968

Data source: Urban Unit of Pakistan (2013)

In the Table 4.2 we have given the total area of land for all the cities and total land area use for the commercial and residential purpose. We have taken the total area used for the commercial and residential purpose and this area is taken by 1998 census of Pakistan.

Table 4.3: Land Area use

Cities name	**Residential Area**	**Commercial Area**
Karachi	1851.675	64.191
Lahore	1086.236	62.02
Faisalabad	494	52
Peshawar	653.64	50.28
Rawalpindi	2943.2448	143.7792
Gujranwala	764.6418	108.4122
Islamabad	498.3	45.3
Multan	2077.0622	42.4194
Bahawalpur	126.1904	4.744
Quetta	1496.5573	67.3862
Gujarat	1596	95.76
Sargodha	3161.16	134.642
Jhang	3789.6318	131.2541
Shekhupura	2122.952	53.044
Abbottabad	285.8988	22.2497
Kasur	787.814	35.156
Rahim yar khan	1351.35	142.56
Sahiwal	1002.2331	56.3376
Dera ghazi khan	2548.3	154.6968

Data source: Urban Unit of Pakistan (2013)

In the Table 4.3 we have land areas uses for commercial and residential purpose in each city and these areas calculated by percentages given for commercial and residential purposes from the city documents of Urban Unit.

4.3. Methodology:

For the measurement of Mixed-use of land in the chapter we are going to use Herfindhal-Hirschman Index and reason for using this index is that, it is least effected index by size and geography of the city. Herfindhal-Hirschman Index details are given below:

Herfindhal-Hirschman Index (HHI):

It is considered as the index of market concentration which is used widely in the field of economics, and using same concept of distance measurement we can also use this index for the measurement of mixed-use of land.

Mathematical formulation:

Let l^j be the percentage of residential land use in town over to total land of town j and let k be the number of land uses types, Mathematical formulation of the index is given below:

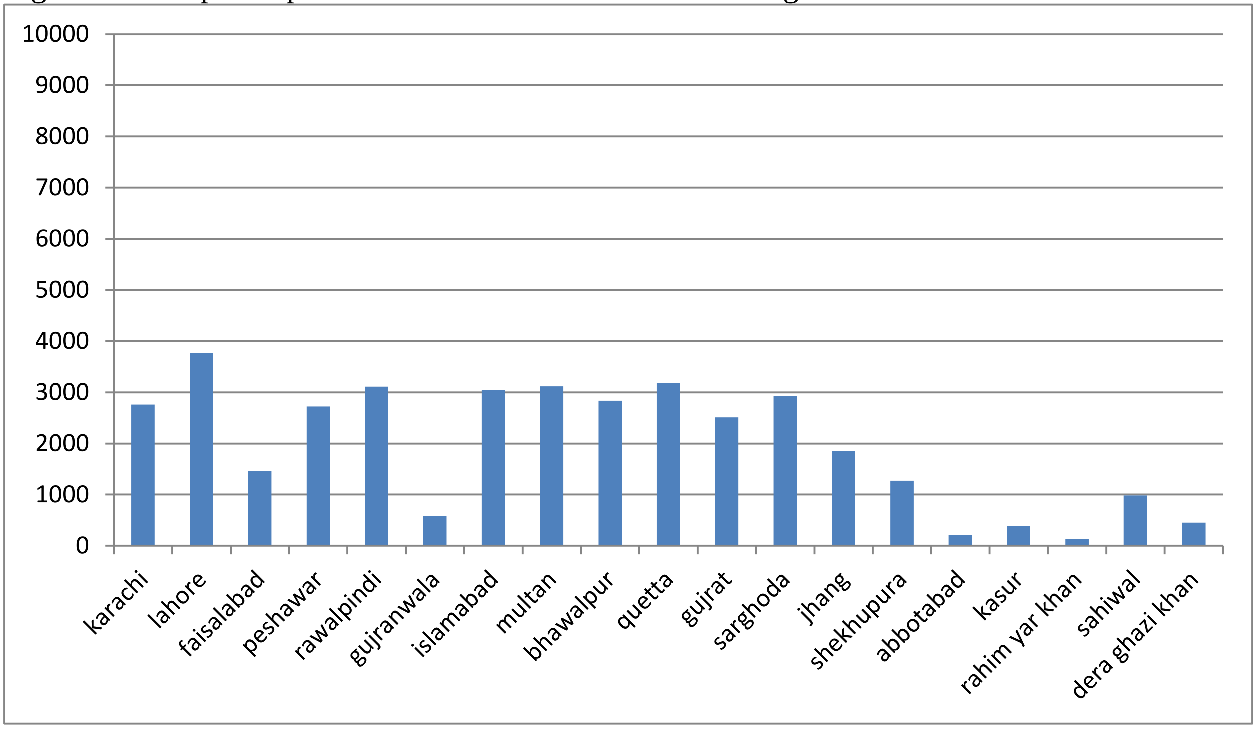
$$\text{HHI} = \sum_{j=1}^{k} (100 * l^j)^2$$

This index values range between 0 and 10,000 and higher value of HHI index refer to greater mixed-use of land

4.4 Results:

In the Figure 4.1 we have results which show up to what extent there is mixed-use of land in big cities of Pakistan by using the Herfindhal-Hirschman Index (HHI), values of this index range between 0 and 10,000.

Figure 4.1: Graphical presentation of mixed-use of land in big cities



4.4.1 Explanations:

From the Figure 4.1 we can observe that values of HHI index varies between 130.830 and 3769.585. Highest value is for Lahore because this city has historical prospective of mixed-use of land and old buildings during the Mughal era is also proving this argument. While, lowest value is for Rahim Yar Khan located in the northern Punjab which is the least developed area in Punjab so houses are much dispersed. It is interesting to see here that the city using most the mixed-use of land and city has least value of HHI index both belonging to Punjab so from here we can guess about the land use diversity in the Pakistan.

Rawalpindi has also some trend of using mixed-use of land and it is not developed by planning rather it is due to traditional architectures which usually prefer building use for mixed-use development, so this mixed-use in Rawalpindi evolve traditionally and takes so much time that's why value of HHI index is much better as compared to other cities of Pakistan.

If we look at the HHI of Islamabad it is slightly higher as compare to other cities because this city is well planned constructed but not doing mixed use of land. If we look at the whole index its value is not much good because of this city sprawl. This city contain sectors which has market in the center of each sector. So, distance between markets is residential houses is optimal in relative sense that is why value of HHI index is relatively high.

Chapter 5: Measuring commuting and congestion cost

5.1. Introduction

In this chapter we find out the impact of mixed use of urban land on commuting and congestion cost by using the comparison of two markets in the same area of Islamabad in which there is people living in the buildings structure which are doing mixed use of land for commercial and residential purposes and people which are not using mixed use of urban land. By the comparison of both markets variables of commuting and congestion cost we find out the impact of doing mixed use of land for commercial and residential purpose on the reduction in commuting and congestion cost.

5.2. Data

Primary data is used in this chapter, and data collection take place by the process of personal interviews in the survey through designed questionnaire from the both type of people (i.e. people living in the buildings structure which are doing mixed use of land for commercial and residential purposes in the markets of Islamabad and people which are not using mixed use of urban land) which is available in Appendix B.

5.3. Description of variables

In Table 5.1 we have variables which is used in the analysis and their description.

Table 5.1: Description of Variables

Variables	**Description and Measurements**
Travel distance	It is distance travel by the people on daily basis, it is measured by the distance travel by from work place to residence. Unit of the variable is kilometre.
Travel time	It is the time which people consume in travelling from work place to residence,

	Unit of the variable is minutes.
Time Delay due Congestion	It is the time delay due to congestion during travel from work place to residence, it is measured by multiplying delay time with the value of time of a person.
Maintenance Cost	The cost bear by the people which have their own vehicle in term of wear and tear cost of vehicle. This cost is measured in rupees.
Commuting cost	It is cost of travel of the people on daily basis, it is measured by the cost of travelling from work place to residence. This cost is measured in rupees.
Congestion cost	Congestion cost is measured by the different costs which are time cost, fuel cost and maintenance cost. Unit of variable is measured in rupees.

5.4. Sampling

The study conducted on a sample of one hundred and fifty shopkeepers from the two markets of Islamabad where people living in the buildings structure who are doing mixed use of land for commercial and residential purposes and the area in who people are not using mixed use of urban land. The sampling type which is used in this study is the stratified sampling. We selected people which contain characteristics regarding their choice of living either they are using mixed use of urban land or not.

5.5. Methodology

Current study used basic tools of exploratory data analysis for the qualitative data analysis. Whereas, non-parametric approach used for further analysis.

5.5.1. Qualitative Analysis

In this study we used the tools exploratory data analysis for the descriptive analysis, which are five stats summary for finding the deviation of data from the median and dispersion in the data.

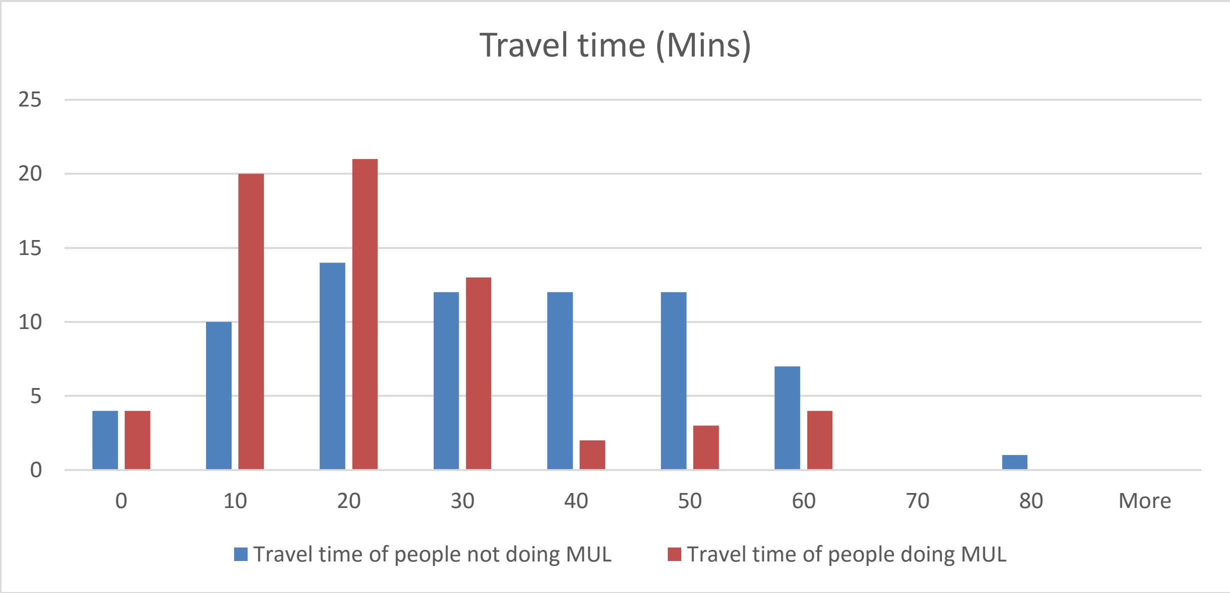
Non parametric approach and contingency table used for Hypothesis test done on the p-value and chi-square values.

While we did comparison between variables values in the case of people doing mixed use of land and people are not doing mixed use of land. Wilcoxon- sign sum rank test also used to explain the reduction in commuting and congestion cost in result of MUL.

5.6. Results

5.6.1. Travel time

Figure 5.1: Graphical presentation of Travel time with and without MUL[8].



In the Figure 5.1 we have comparison of daily time consumed by people on travel who are using mixed use of land for d residential purpose and who are not using mixed use of land. We can see that the blue bars show the travel time of people who are not using mixed use of land and the red bars show the travel time of people which are using mixed use of land. Most of the people doing

[8] Mixed use of Land

MUL have travelling time ten or twenty minutes but the majority of people not doing MUL are travelling thirty to sixty minutes.

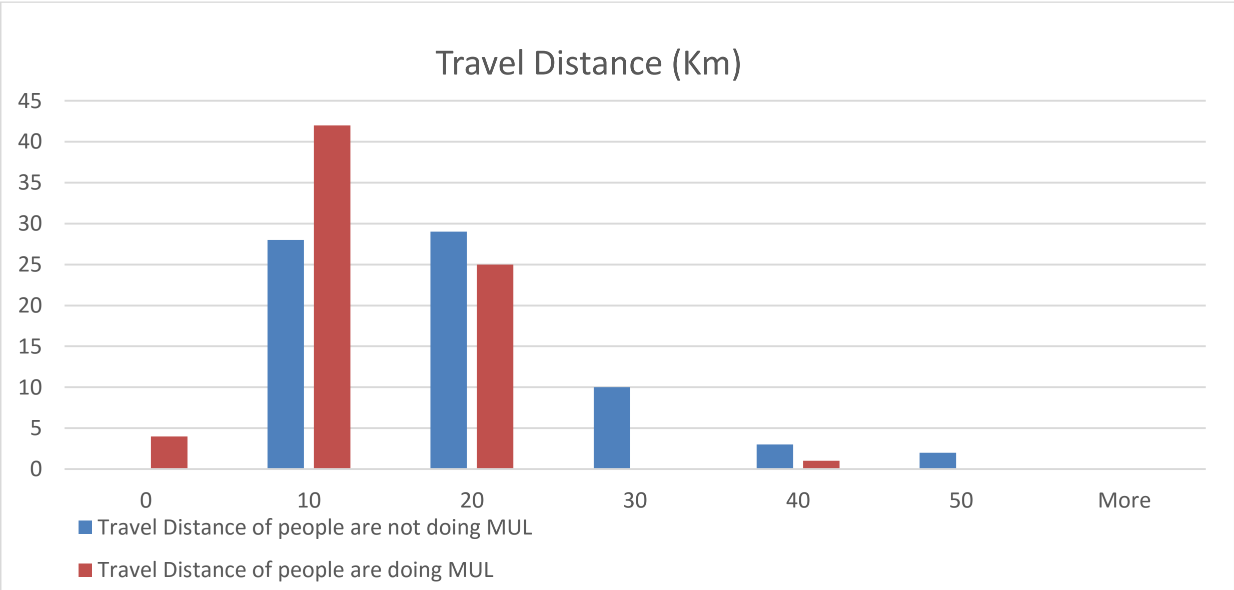
Table 5.2: Data summary of Travel time

	Min	Max	Q1	Median	Q3	Mean	SD
With MUL	0	60	10	15	27.5	19.64179	14.92339
Without MUL	0	75	10	20	30	22.33333	16.97302

In the Table 5.1 we have summary stats of travel time for the both groups of people. We can see from the table average time consumed by people who are doing mixed use of land on travelling is twenty minutes and average time consumed by people who are not doing mixed use of land on travelling is twenty three minutes. Lower twenty five percent are consuming ten minutes for both groups, while, twenty five percent of people above median which are doing mixed use of land and using twenty seven minutes while, other group use thirty minutes. Difference between lower and upper twenty five percent of median is not same so data is not uniformly distributed.

5.6.2. Travel Distance

Figure 5.2: Graphical presentation of Travel distance with and without MUL



we have comparison of daily distance consumed by people on travel which are using mixed use of land for commercial and residential purpose and which are not using mixed use of land in the Figure 5.2. We can see that the blue bars show the travel distance of people who are not using mixed use of land and the red bars show the travel distance of people who are using mixed use of land. It is interested fact that as the distance travel by people is increasing, number of people using MUL is decreasing as compared to people who are not using MUL.

Table 5.3: Data summary of Travel distance

	Min	Max	Q1	Median	Q3	Mean	SD
With MUL	0.5	50	2	14.5	20	7.194444	7.021572
Without MUL	0	35	1	5	12	13.77083	11.54007

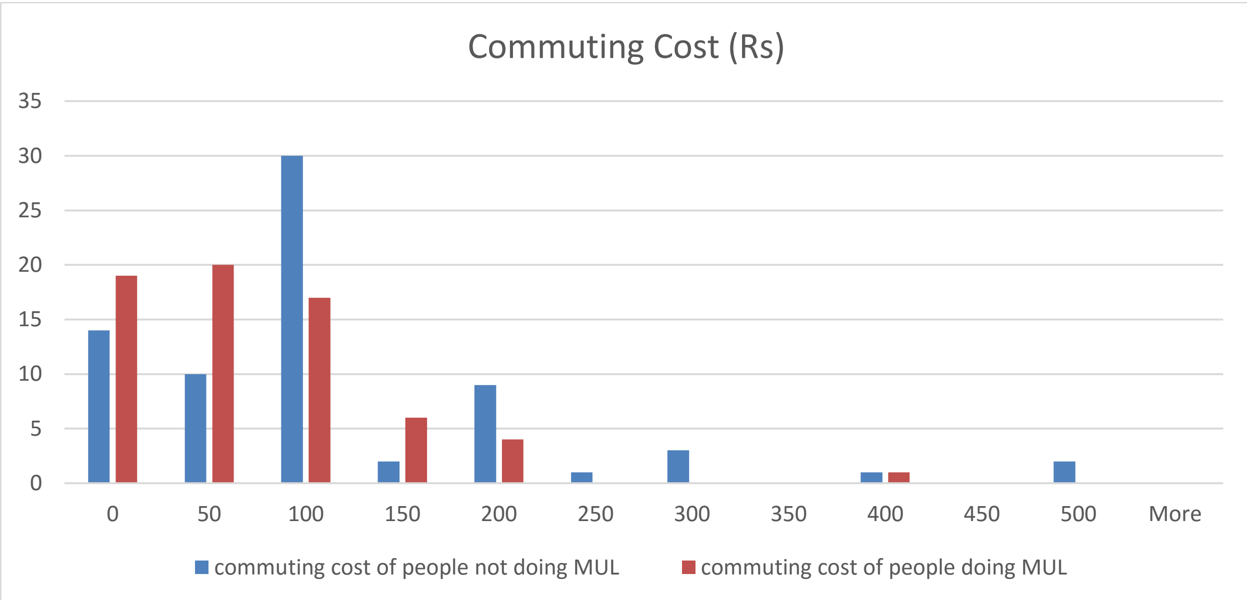
In the Table 5.3 we have summary stats of travel distance for the both groups of people. From the table average distance travelled by people which are doing mixed use of land is seven kilometer per day. While, average time consumed by people who are not doing mixed use of land on travelling is fourteen kilometer. Lower twenty five percent from the median who are doing mixed use of land are travelling two kilometer per day as compared to the other group it is two kilometer per day. Whereas, twenty five percent of people above median who are doing mixed use of land are travelling twelve kilometer per day while, other group is travelling twenty kilometer per day.

5.6.3. Commuting Cost

5.6.3.1. Measurement

It is the cost which is bear by a person daily during travel in term of rupees.

Figure 5.3: Graphical presentation of Commuting cost with and without MUL



In the Figure 5.3 we have comparison of commuting cost bear by people on travel who are using mixed use of land for commercial and residential purpose and who are not using mixed use of land. In the figure blue bars show the commuting cost of the people who are not using mixed use of land and the red bars shows the commuting cost of the people who are using mixed use of land. By the comparison of both blue and red bars we can see that majority of people doing MUL lies in the category of low commuting cost, whereas the people who are not using MUL lies in the categories having high commuting cost.

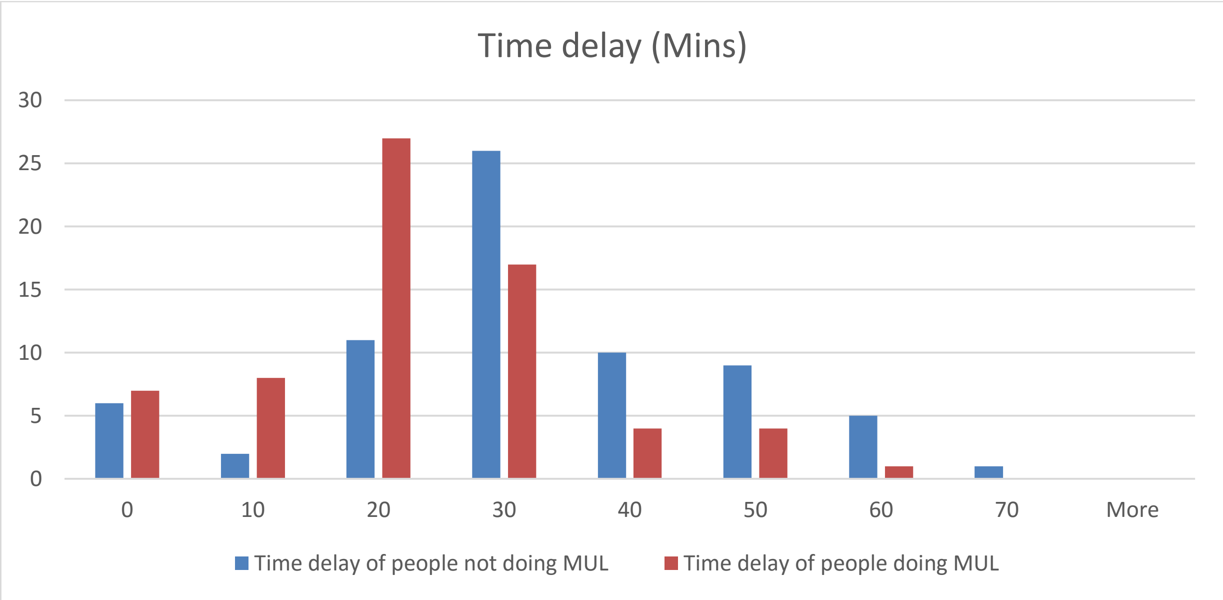
Table 5.4: Data summary of Commuting cost

	Min	Max	Q1	Median	Q3	Mean	SD
With MUL	0	400	0	50	100	67.16418	70.29906
Without MUL	0	500	50	100	109.388	110.4085	105.8506

Table 5.4 shows the summary stats of commuting cost for the both groups of people. We can see from the table on average commuting cost of the people who are doing mixed use of land is sixty seven rupees per day. While, average commuting cost by people who are not doing mixed use of land on travelling is one hundred and ten rupees. We can also see that twenty five percent of people above median who are doing mixed use of land have hundred rupees per day while, other group is commuting cost is one hundred and ten rupees per day. Difference between lower and upper quartile from the median shows that the data is not uniformly distributed from the right and left.

5.6.4. Time Delay due to Congestion

Figure 5.4: Graphical presentation of time delay due to congestion with and without MUL



In the Figure 5.4 bars show the comparison the time delayed due to congestion on daily basis by people which are using mixed use of land for commercial and residential purpose and which are not using mixed use of land in the above graph. Blue bars show the delay time due to congestion on daily basis of people who are not using mixed use of land and the red bars shows the time delay due to congestion by the people who are using mixed use of land. Figure shows significant difference between delay times of the both groups of people, huge red bars in the beginning show that the time delay due to congestion is less for the majority of people who are doing MUL is less than the other group of people.

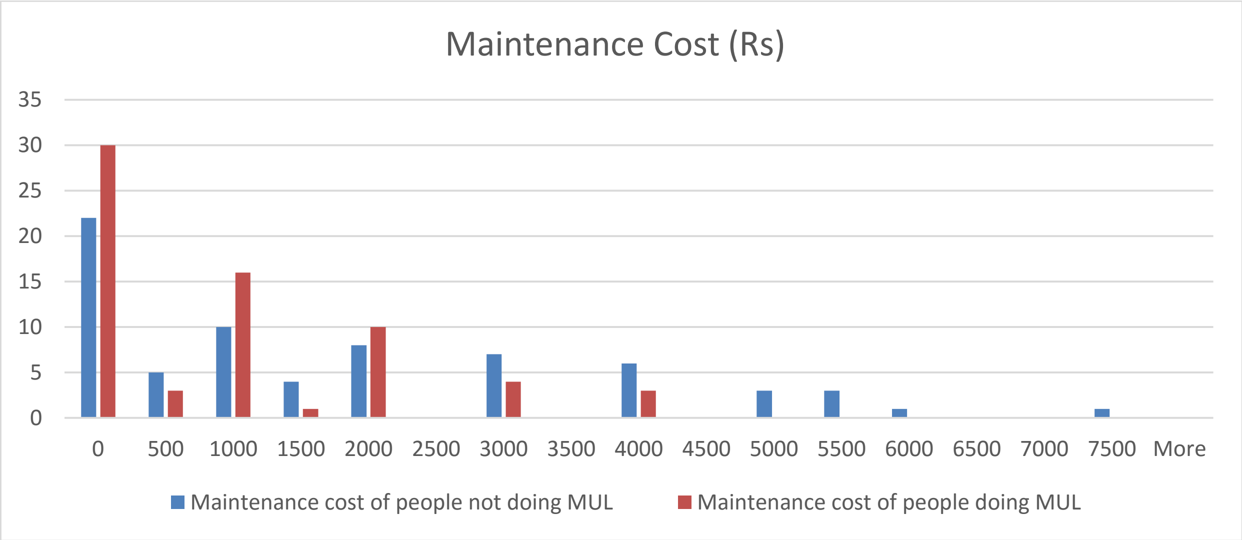
Table 5.5: Data summary of delay due to congestion

	Min	Max	Q1	Median	Q3	Mean	SD
With MUL	0	45	15	17.5	30	20.36765	12.5533
Without MUL	0	70	15	27.5	40	25.88571	18.66742

Data summary of the time delayed by the both groups of people shown in Table 5.5. According to Table 5.5 on average time delay of the people who are doing mixed use of land is twenty per day. While, average time delay by people who are not doing mixed use of land is twenty five minutes per day. We can also see that twenty five percent of people above median who are doing mixed use of land have time delay due to congestion is thirty minutes per day while, other group forty minutes time delay per day.

5.6.5. Maintenance Cost

Figure 5.5: Graphical presentation of Maintenance cost with and without MUL



In the Figure 5.5 we have comparison of Maintenance cost bear by people on travel who are using mixed use of land for commercial and residential purpose and are not mixed use of land with the help of histogram. Blue bars in the figure shows the maintenance cost of the people who are using mixed use of land and the red bars show the maintenance cost of the people who are using mixed use of land. We can see that majority people who are not using MUL have high maintenance cost as compared to other group.

Table 5.6: Data summary of Maintenance cost

	Min	Max	Q1	Median	Q3	Mean	SD
With MUL	0	4000	0	500	1000	940.2985	1118.109
Without MUL	0	7500	0	1000	2750	1428.571	1795.402

Table 5.6 shows the summary stats of maintenance cost for the both groups of people. We can see from the table on average maintenance cost of the people who are doing mixed use of land is nine hundred and forty rupees per month. While, average maintenance cost by people who are not doing mixed use of land is one thousand four hundred and twenty eight rupees. Table 5.6 also that twenty five percent of people above median which are doing mixed use of land have one thousand rupees per month while, other group is maintenance cost is twenty seven hundred and fifty rupees per month.

5.6.6. Congestion Cost

5.6.6.1. Measurement of congestion cost.

We calculate congestion cost from the three variable

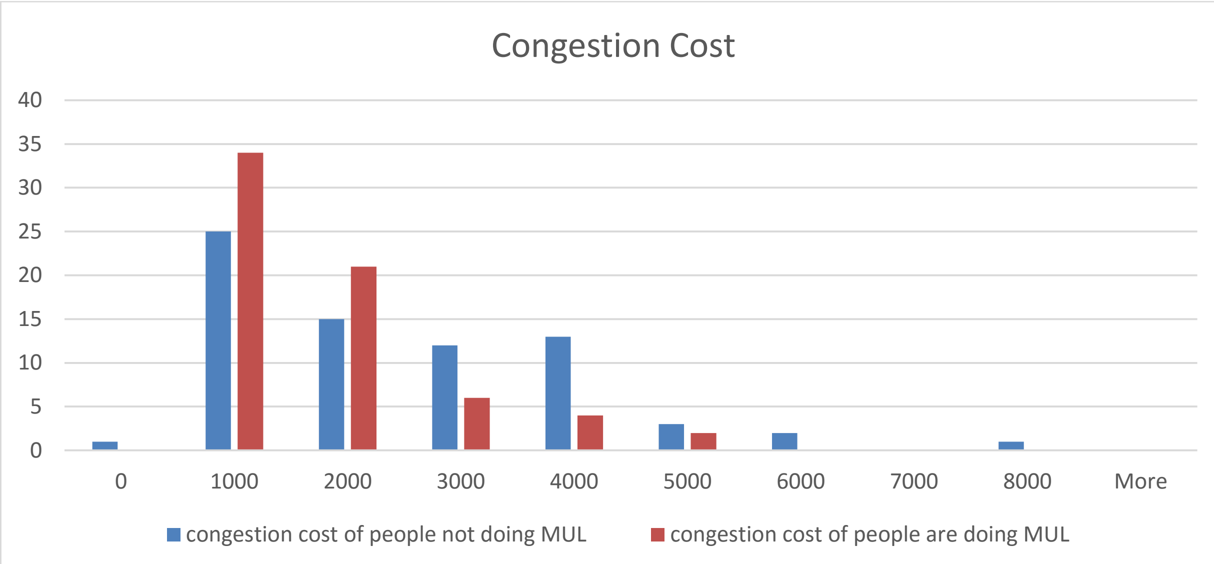
$$\text{Time cost} = \text{Time delay due to congestion on daily basis} \times \text{value person for time} \quad (16)$$

$$\text{Fuel cost} = \text{Extra fuel consume due to congestion.} \quad (17)$$

$$\text{Maintenance cost} = \text{wear and tear cost of people who has their own vehicles.} \quad (18)$$

$$\text{Congestion cost} = \text{time cost} + \text{Extra fuel cost} + \text{Maintenance cost} \quad (19)$$

Figure 5.6: Graphical presentation of Congestion cost with and without MUL



In the Figure 5.6 we compared the congestion cost bear by people during travel who are using mixed use of land for commercial and residential purpose and who are not using mixed use of land in the above graph. Blue bars show the congestion cost of people who are not using mixed use of land and the red bars show the congestion cost of people which are using mixed use of land. Figure also shows that people who are doing mixed use of land and the people who are not doing mixed use of land have significant difference in their congestion costs.

Table 5.7: Data summary of Congestion cost

	Min	Max	Q1	Median	Q3	Mean	SD
With MUL	1.933333	4136.914	97.95875	723.8392	1618.008	1007.878	1049.988
Without MUL	0	7836.464	154.9771	1374.175	3053.527	1659.224	1576.023

Table 5.7 shows the summary stats of congestion cost for the both groups of people. We can see from the table on average congestion cost of the people who are doing mixed use of land is one thousand and seven rupees. While, average congestion cost by people who are not doing mixed

use of land on travelling is sixteen hundred and fifty nine rupees. We can also see that twenty five percent of people above median who are doing mixed use of land have sixteen hundred and eighteen rupees while, other group is congestion cost is three thousand rupees.

5.7. Non Parametric Tests

We used two non-parametric tests in our analysis for the significance of our variables. One is called Chi-Square test and other one is Wilcoxon test and these two tests measures the significance our hypotheses by t-statistics, p-value and Chi-Square values. For both tests we have same hypothesis.

Ho = Medians of commuting and congestion cost are identical for both groups

H_1 = Median of commuting and congestion cost for the both groups differ by non-zero

Table 5.8: coefficients of significance in Chi-Square Test and Wilcoxson sum Test

Variables	**Chi-Square Test**		**Wilcoxon sum rank Test**	
	Calculated value	Tabulated Value	T-statistics	p value
Commuting cost	7.053429924	3.84	2.785613816	0.00309466
Congestion cost	7.86219573	3.84	2.733233117	0.003640665

Table 5.8 explains the significance of our variables by chi-square test and Wilcoxon sum rank test. In the above table we can see that chi-square calculated value is greater than tabulated value. So, we reject our null hypotheses, which means that median of commuting and congestion of people which are doing mixed use of urban land for commercial and residential purpose and people which are not using it is not same.

Table 5.8 also show that the p-value is highly significant in the Wilcoxon sum rank test we are going to reject our null hypotheses, which means that median of commuting and congestion of people which are doing mixed use of urban land for commercial and residential purpose and people which are not using it is not same.

We have seen from the both Non-parametric test it is concluded that people which are using mixed use of land for commercial and residential purpose bears more commuting and congestion cost as compare to the people which are not doing mixed use of land for commercial and residential purpose.

Chapter 6: Conclusion and Policy Recommendations

The relationship between economic growth and cities has attracted significant attention among the economists all around the world in recent years. Economic growth and economic efficiency can be achieved by efficient use of resources. Urban land is the key component for the production and we have to use urban land efficiently by adopting mixed land use pattern, which will reduce commuting and congestion cost. Mixed use of land for the commercial and residential purpose is measured by using different indices in the literature. In our study we reviewed all those indices and find Spearman's correlation among the indices. We generate data of hundred cities with twenty five towns in each city with variable by using the Monte Carlos simulations for measuring mixed use of land.

Previously it was done by (Merlin, 2013) and rationale for doing that was to generate data series for our cities which is more near to real world situation. When we found results by using Spearman's correlation, it shows that correlation among these indices change due to change in the data generation process, as these are sensitive to the city size and geography. Among all those indices we use Herfindhal-Hirschman Index (HHI) for measuring the mixed use of urban land for the commercial and residential purpose because this index was less sensitive towards the geography and city size.

We used data collected from Urban Unit of Pakistan and some previous research done for the big cities of Pakistan. We required percentages of land use for commercial and residential purpose in the cities of Pakistan as an input for our indices which we got from document of cities crafted by

Urban Unit, Government of Punjab. Results indicates that in most of the cities of Pakistan are not using their land efficiently despite that there is land scarcity in our cities.

After measuring mixed use of urban land we find the impact of mixed use of land on commuting and congestion cost, as literature also suggest that there is great link between mixed use of land for commercial and residential purpose and reduction in commuting and congestion cost due to walkable communities. To test our hypothesis that due to MUL there is significant reduction in commuting and congestion cost. We designed a survey from the two markets in the same area, one is market in which people are doing mixed use of land and other one in which people are not doing mixed use of land and did analysis by using non parametric approach. Our findings confirm that there is significant reduction in commuting and congestion cost due to mixed us of land for residential and commercial purpose.

On the basis of our findings we suggest that there is need to explore the issue of mixed use land for commercial and residential purpose in the cities of Pakistan to enhance the contribution of cities in the economic growth of country through economic efficiency. Our results also suggest that we need to adopt mixed use pattern for commercial and residential purpose to avoid the problem of high commuting and congestion cost in our cities.

Our findings need further investigation, we have evidence based policies for making our cities as hubs of sharing ideas, innovations, having economies of scale and benefits of specialization. Otherwise, we fear our cities can be hubs of crime, pollution, unemployment, congestion and disease. Since, this is a very preliminary maiden study on the issue, so there is great scope for future research in this fielding in other dimensions of mixed use land. These dimensions includes the impact of mixed use of land for the environmental protection and resource use.

Appendix A: Codes for Data Generation Through Monte Carlos Simulations

```
# Global constants
sims <- 1000 # Number of times to repeat simulation
# sims <- 5 # Number of times to repeat simulation
cities <- 100 # Number of cities in our simulation universe
# cities <- 10
citysize <- (2000:10000)# Size of each city
districts <- 25 # Number of districts each city is divided into
#districts <- 6
divisions <- 40  # Number of equal size divisions for each district
land_uses <- 2
districtsize <- citysize/districts
parcelsize <- citysize/(districts*divisions)
citysize
districtsize
parcelsize
# Different mixed use metrics to compare
# 1 - Percent
# 2-6 Atkinson Indices
# 7 - Balance index
# 8 - Dissimilarity index
# 9 - Entropy Index
# 10 - Exposure Index 1
# 11 - Exposure Index 2
```

```
# 12 - Gini Index

# 13 - Herfindahl Hirschman Index (HHI)

scores <- 13

scores <- 11

# Generate empty matrix for filling later

sim_data <- array(0,dim=c(sims, cities, districts, land_uses))

wgt_data <- array(0,dim=c(sims, cities, districts, land_uses))

####################################################

# Generate city land use patterns

# NB: Generating districts before cities did not work, as cities, as the sum of randomly generated districts,

#     looked too similar due to the Law of Large Numbers


#####

# Generate the amount of land use in each city first; then divide total city land use among the districts

# Generate amount of each type of land use for each city

# city_lu <- array(c(runif(sims*cities, min=200, max=1000), runif(sims*cities, min=0, max=200)), dim=c(sims,cities,land_uses))

# Data Generating Process 1:  The amount of residential and nonresidential land are generated independently

####################################################

# Generate percentages

# 1 - Percentage of each land use in each district (adds to 100% for each district)

# 2 - Percentage of total city wide land use in each district (adds to 100% for each city)

# apply(sim_data,c(1,2),sum) Creates sums over all simulations and over all cities

# apply(sim_data,c(1,2,3),sum) Creates sums over all simulations, cities, and districts
```

```
# Create empty matrices for filling with percent data
sim_dst_pct <- array(0,dim=c(sims, cities, districts, land_uses))
sim_cty_pct <- array(0,dim=c(sims, cities, districts, land_uses))

# Loop to compute percentage of each land use in each district relative to the district total
# apply creates the marginal sums over all land use types
for (lu in 1:land_uses) {
  sim_dst_pct[,,,lu] <- sim_data[,,,lu]/apply(sim_data,c(1,2,3),sum) }

# Loop to compute percentage of each land use in each district relative to the city total
# apply creates the marginal sums over all districts (keeps sims, cities, and lus separate)
for (d in 1:districts) {
  sim_cty_pct[,,d,] <- sim_data[,,d,]/apply(sim_data,c(1,2,4),sum)}
  ######################################################
  # Examine the simulated data for cities and districts
  # Look at the first city in the first simulatoin
  sim_data[1,1,,]
  mean(sim_data[1,1,,1]) # Average of land use 1 over the 25 districts in City 1
  # Sum of total land area for every city in simulation 1
  apply(sim_data[1,,,],1,sum)# Every value should equal citysize
  apply(sim_data[1,,,],c(1,2),sum)# Every value should equal districtsize
  # Both should display city land use distributions for simulation 1
  apply(sim_data[1,,,],c(1,3),sum)
  city_lu[1,,]
```

```
########################################################
# Calculate Mixed Use Measures
# Mixed use metrics to cover: Entropy, Dissimilarity, HHI, Exposure. One summary index for each city.
# Different mixed use metrics to compare
# 1 - Percent
# 2-7 Atkinson Indices
# 8 - Balance index
# 9 - Dissimilarity index
# 10 - Entropy Index
# 11 - Exposure Index 1
# 12 - Exposure Index 2
# 13 - Gini Index
# 14 - Herfindahl Hirschman Index (HHI)
scores <- 14


city_indices <- array(0,dim=c(sims,cities,scores))
for (sim in 1:sims){
  for (city in 1:cities){
    # Pre-Processing - used for multiple formulas
    #    city_lu_pct <- city_lu[sim,city,]/sum(city_lu[sim,city,])
    # 1 - Percent - percent of less common land use, land use 2
    city_indices[sim,city,1]<-city_lu_pct[sim,city,2]
    # 2-4 - Compute Atkinson Indexes
    eps1 <- c(0.5, 2)
```

```
eps2 <- 1-eps1

eps3 <- 1/(1-eps1)

#    city_indices[sim,city,2] <- 1 - sum(
((sim_cty_pct[sim,city,,1]^eps2[1])*(sim_cty_pct[sim,city,,2]^eps1[1])) )^eps3[1]

city_indices[sim,city,2] <- 1 - (districts^-eps1[1] * sum(sim_cty_pct[sim,city,,2]^eps2[1])
)^eps3[1]

city_indices[sim,city,3] <- 1 - ( exp(mean(log(sim_data[sim,city,,2]))) /
mean(sim_data[sim,city,,2]) )

city_indices[sim,city,4] <- 1 - (districts^-eps1[2] * sum(sim_cty_pct[sim,city,,2]^eps2[2])
)^eps3[2]

city_indices[sim,city,5] <- 1 - (districts^-eps1[1] * sum(sim_cty_pct[sim,city,,1]^eps2[1])
)^eps3[1]

city_indices[sim,city,6] <- 1 - ( exp(mean(log(sim_data[sim,city,,1]))) /
mean(sim_data[sim,city,,1]) )

city_indices[sim,city,7] <- 1 - (districts^-eps1[2] * sum(sim_cty_pct[sim,city,,1]^eps2[2])
)^eps3[2]

# 5 - Compute Balance Index

city_indices[sim,city,8] <- 1 - abs(city_lu[sim,city,1]-
city_lu[sim,city,2])/sum(city_lu[sim,city,])

# 6 - Compute Dissimilarity Index

city_indices[sim,city,9] <- 0.5 * sum( abs(sim_cty_pct[sim,city,,1]-sim_cty_pct[sim,city,,2])
)

# 7 - Compute Entropy Index

city_indices[sim,city,10] <- -
sum(city_lu_pct[sim,city,]*log(city_lu_pct[sim,city,]))/log(land_uses)

# 8 - Compute Exposure Index 1 - One exposure index for each land use

city_indices[sim,city,11] <- sum(sim_cty_pct[sim,city,,1]*sim_dst_pct[sim,city,,2])

city_indices[sim,city,12] <- sum(sim_cty_pct[sim,city,,2]*sim_dst_pct[sim,city,,1])

# 10 - Compute the Gini Index
```

```
# Pick land use to order by
# order_lu <- 2
# Create ordering for cumulative sums
dis_ord <- order(sim_cty_pct[sim,city,,2]/sim_cty_pct[sim,city,,1]) # 2 corresponds to second land use
# Create array of cumulative percents
gini_x <- cumsum(sim_cty_pct[sim,city,dis_ord,1])/sum(sim_cty_pct[sim,city,dis_ord,1]) # 1 corresponds to first land use
gini_y <- cumsum(sim_cty_pct[sim,city,dis_ord,2])/sum(sim_cty_pct[sim,city,dis_ord,2])
gini_x_i <- c(0,gini_x)
gini_x_i_1 <- c(gini_x,1)
gini_y_i <- c(0,gini_y)
gini_y_i_1 <- c(gini_y,-1)
gini_x_i_1-gini_x_i
gini_y_i_1+gini_y_i
city_indices[sim,city,13] <- 1 - sum( (gini_y_i_1 + gini_y_i)*(gini_x_i_1 - gini_x_i) )
# 11 - Compute HHI Index
city_indices[sim,city,14] <- sum( (100*city_lu_pct[sim,city,])^2 )
 }
}
```

Appendix B: Questionnaire

Questionnaire:

Measuring commuting and congestion cost:

<u>Section I:</u>

(i) Name --

(ii) Profession ---

(iii) Qualification ---

(iv) Age ---

(v) Area of city --

(vi) Income ---

(vii) Distance from shop to Resident (Km) ---

(viii) Time consumed on travel (office/education/shop)--

(ix) Daily cost on travel (office/education/shop) ---------------------------------

(x) Living in the sane building or near in which work / Doing MLU

yes	No

<u>Section II:</u>

Q 1: On average how many kilometers you travel daily?

1-10 km	10-15 km	15-20 km	20-25 km	More than 25 km

Q 2: What is your Mode of travelling?

car	Public transport	Motor cycle	Bi cycle	Walking

Q 4: What is average fuel consumption of your vehicle?

Q 5: How much time it takes to reach to your destination in rush hours?

Q 6: How much time you spend to reach to your destination in normal hours?

Q 7: Normally how many people go along with you in your travel?

1 Person	2 Persons	3 Persons	4 Persons	5 Persons

Q 8: What is the monthly maintenance expenditure on vehicle?

Rs.1000	Rs.2000	Rs.3000	Rs.4000	Other

Q 9: What is life of tyres of your vehicle?

1 year	1.5 years	2.0 years	2.5 years	Other

Q 10: How much time you are wasting daily due to high traffic rush while travelling to work place and shopping?

Upto 15 Mins	15-30 Mins	30-45 Mins	45-60 Mins	60-90 Mins

Q 11. While your travel you stuck in the road due to traffic congestion?

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

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