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Identifying mixed use indicators for including informal settlements as a distinct land use: Case study of Delhi

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Abstract

This paper explores the possibility of including 'informal settlements' as a distinct category of land use in context of travel behaviour studies. Characteristics of these settlements are first outlined to differentiate them from formal residential settlements. Further, the process adopted for compiling informal settlements data from different sources is described. This underscores how readily available satellite imagery, census dataset and other secondary dataset can be used to quantify 'Informal' land use. This dataset is compiled using satellite imagery and other relevant sources of information for the year 2014. Seven primary land use categories are included in the study including Residential, Commercial, Educational, Industrial, Public/semi-public, Recreational and Informal. We then examines the utility of existing land use mix indicators in capturing the presence of informal land use in context of Delhi. Land use entropy, Herfindahl-Hirschman Index and Land use dissimilarity are calculated for both cases of including and excluding informal land use. Paired t-test indicates that though these indicators are able to capture the presence of 'Informal' land use, the effect size remains small. All of these indicators use proportions of geographical footprint of different categories of land use for mix estimation. Although in case of 'Informal' land use the geographical footprint usually remains small and scattered irrespective of the fact that these are high density mixed use settlements. The paper brings out specific limitations of these indicators. Limitations of the indices include aggregation at zonal level, insensitivity to nomenclature assigned, and their symmetric nature.

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Keywords: Land use mix, informal settlements, mix indicators, travel behaviour

1. Introduction

Informal settlements are the physical manifestations of socio-economic inequality in an urban area. These also represent an unsolved challenge for the land use policy. Residents of these settlements are mostly the immigrants who come to the city in search of employment. Shortage or absence of affordable housing options, force the city migrants to build shelters by occupying public land. Mostly, these would be close to the employment opportunities. Hart (1973) introduced the term informal sector which was further expanded by many researchers including Gerxhani (2004) with the original notion of self-employed outside formal wage economy. This unofficial system caters to squatter landlords,

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tenants, merchants, consumers, builders, laborers, and also the squatter investors and brokers (Tiwari, 2007). Informality in urban context refers to the existence of any activity outside the official planned vision for the city. Various other adjectives attributed to these self-planned settlements in the literature include ‘illegal’, ‘squatting’ and also ‘unregulated or uncontrolled’ growth (Fekade, 2000). These activities can range from mainly residential e.g. squatters and slums to the commercial e.g. street vendors occupying road spaces. Defining informal settlements as unofficial, illegal or unplanned denies their inhabitants the opportunities to get jobs or housing in formal establishments. Glenn and Wolfe (1996) suggest that informality and illegality of informal settlements is being increasingly understood as an externally imposed residual category. Kombe and Kreibich (2000) argue that potentials and limitations of informal settlements are becoming subjects of urgent research and policy deliberations.

Shatkin (2004) argues that growth of the informal settlements is a shelter crisis inherent to globalizing cities. Which is further attributed to contradiction between rising property values accompanied to ‘global city’ and shelter needs of low income people. Two major reasons have been associated with their growth and existence in developing countries (Sassen, 1999; Scott et. al., 2001) Firstly, the rapid expansion of cities require low-cost labour which has led to accelerated rural-urban migration. Secondly, business investments concentrated in the cities has led to inflated land prices forcing low-wage earning poor people to look for unauthorised residential places near opportunities for employment. Thus, informal settlements are sometimes seen as providers of affordable housing (Bernnan, 1993). According to UNHABITAT (2003), the informal settlements are marked by substandard and dense housing mainly source of accommodation for the poor people. Referred to as ‘slums’ these are mainly characterized by overcrowding, poor structure quality, insecure residential and ownership status and lacking access to safe water, sanitation and infrastructure. It further sees growth of informal settlements as failure of national housing policy and delivery system. Most of the developing countries are unable to meet the housing demand and hence growth of informal settlements comes as a natural response to the rapid urban growth.

Government’s response to these settlements earlier ranged from excluding these settlements from any infrastructure extension plan (Zaghloul, 1995) to outright demolition or displacement (Fekade, 2000). Eventually, the governments have been forced to acknowledge that these settlement exist because or in response to public policies (Dowall, 1991). The distinct characteristics of informal settlements and its inhabitants warrants its recognition as separate category of urban growth. The first step in this direction would be to identify and acknowledge the existence of these settlements formally, in land use and infrastructure plans of the city. These informal settlements are not generally acknowledged, as a distinct land use category, and even if touched upon, quantifying informal land use is seldom a part of the study. This paper questions the adequacy of the conventional nomenclature and categories of land use that are used to describe the developed land in the context of Delhi. It is argued that the complete socio-economic diversity and challenges are not captured through conventional land use classifications. The paper elaborates on as to how readily available satellite imagery and other related secondary datasets can be used to provide a reasonably good informal land use database. The study emphasizes the use of GIS based approach to analyze the geographical composition and distribution of different land uses. We further look into the aspects of identification of ‘slums’ as a distinct category of ‘informal’ land use and its implications on estimating the land use mix in the context of travel behaviour related studies.

Beginning with the background of the issue the following section outlines the compelling evidence and reasons that support identification of informal land use. Next we look into the aspect of growth in urban and slum population in Delhi. Next we describe the existing land use distribution in Delhi. Later section looks into the existing set of indices that are used to quantify or measure the land use mix. Further we look into the calculations of all the identified indices for calculating the mix with and without including the ‘informal’ land use category. Finally, we discuss the strength and weakness of each identified index and the need for further assessment.

2. Identifying informal settlements or slums as a distinct land use category

Conventional categories of land use include residential and non-residential categories. Non-residential categories mainly include commercial, public offices, educational, industrial and recreational etc. informal settlements are generally included within residential category of land use. Owing to the distinct character of ‘slums’ it is advisable to consider them as a separate land use. Similar to the accepted notion of ‘slums’ worldwide, Census (2011) defines ‘slum’ as a residential area where dwellings are unfit for human inhabitation by reason of dilapidation, overcrowding, faulty arrangements and design of such buildings, narrowness or faulty arrangement of street, lack of ventilation, light, or sanitation facilities or combination of these factors which are detrimental to safety and health. Thus conventional 'residential' land use can incorporate anything but a settlement as described by the above definition. By their very character, both physical and social, the slums need to be identified as a separate category of land use. Otherwise, there presence may not be acknowledged if classified under conventional 'residential' land use.

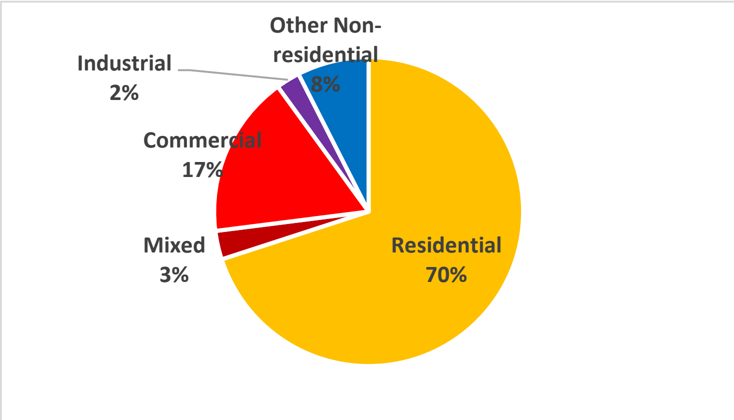

Fig. 1. Proportion slum houses as per their usage. (Census, 2011)

Census (2011) also provides distribution of slum houses in Delhi as per their use as shown in Fig 1. A total of 520,000 slum houses are covered under Census (2011). Contrary to general belief that slums are residential areas, Census (2011) shows that nearly one third of the slum houses are being used for non-residential purposes. Thus slums are not only providing shelter to the urban poor but also offer an alternate source of informal employment. Apart from shops and other commercial usage, it is interesting to note that slum houses are also being used as schools and small manufacturing units. Though informal employment and non-residential usage of houses within slums adds another dimension, this is beyond the scope of this study. Relying only on census data to ascertain the gravity of mobility issues of informal settlement dwellers is not advisable. As shown in earlier sections, targeted data collection maintained at regional level paints a rather clearer and grim picture of the same.

Identifying 'Informal' land use gives us an opportunity to study the interaction and differences between travel patterns of its inhabitants and that of 'formal' developments. Sadhu and Tiwari (2016) argue that inhabitants of informal settlements have work tour to residential area as most significant category of work tour with 11.7 % of total tours. They further emphasize irrelevance of motorized modes as a mode of personal transport for these dwellers. Further, when they are relocated to the periphery of the city in the name of resettlement, their access to education and employment opportunities is severely hindered. This study also provides important insight into their relevance in the city and dependence of 'formal' residential development on them. This provides important insight into their relevance in the city and dependence of 'formal' residential development on them. Further, Badami et. al. (2004) indicates that the urban poor try to locate themselves near place of work to avoid expenditure on transport. This explains growth of informal settlements near not only the commercial establishments but also adjacent to the large residential complexes. On the other hand, many researchers argue that poverty and limited access to affordable public transport directly translates into their daily travel decisions and they have travel pattern dominated by walking and non-motorized transport (Bryceson et. al, 2003; Hook and Howe, 2005; Sadhu & Tiwari, 2016). Also, the urban poor travel shorter distances as compared to the high income group which rely mainly on private motorized transport (Bryceson et. al, 2003). Many of the transportation studies divide the developed area into residential and non-residential area so as to relate to trip productions and attractions respectively. Even if multiple categories of land uses are included such as commercial, industrial etc. residential use is associated with origin end of the trip and other categories are related to destination end of the trip. Using this narrow definition excludes certain trips that start in informal settlements and end at the residential areas. Thus by identification of 'informal' land use we segregate two groups of people with distinct needs for travel which has significant policy implications.

This study explores the aggregate impact of informal settlements when identified as distinct land use on the land use mix. Here, we can primarily assign three major reasons for identifying slums as a distinct land use category

- Distinct physical and socio-economic character of the informal settlements and its inhabitants
- These are organically developed and generally high density mixed use communities.
- The travel patterns of inhabitants of informal settlements are characterized mainly by walk and NMT trips due to unaffordability of motorized transport including Public transport.
- This adds a new dimension to the study of city level travel patterns, whereby interrelationship of informal settlements and residential settlements may be explored.

3. Urbanisation and growth of slum population in Delhi

Urbanisation is a contemporary urban growth phenomenon as experienced in developed as well as developing nations. India's urban population is the second largest in the world after China (Rahman et al., 2011). In India percentage of population living in urban area has increased from 27.81% in 2001 to 31.16% in 2011 (Census of India, 2001; 2011). This study area is confined to the National Capital of Territory (NCT) of Delhi. Geographical area of Delhi is about 1483 sq. km. The decadal growth of population for Delhi has declined from 47.02% in 1991-2001 to 20.96 in 2001-2011. With a population of 13.8 Million in 2001, the average annual exponential growth rate of population during 2001-2011 has been recorded as 1.92%. The gross population density of Delhi has increased from about 9340 persons per sq. km. in 2001 to 11,300 persons per sq. km. in 2011. Urban population accounts for 97.3% of the total population of 16.7 Million.

About 1.8 Million people live in slums in Delhi (Census, 2011). The total slum population has experienced a decline over the past two decades. During 1991 to 2001, slum population declined by 26.4% and during last decade it declined only marginally by 3.26 % (Census, 2001; 2011). There are about 10 census wards in Delhi having the share of slum population more than 90%. In these wards, most of the census enumeration blocks (EBs) have been identified as slum EBs. Census (2011) covered all the notified, recognized as well as identified slum clusters.

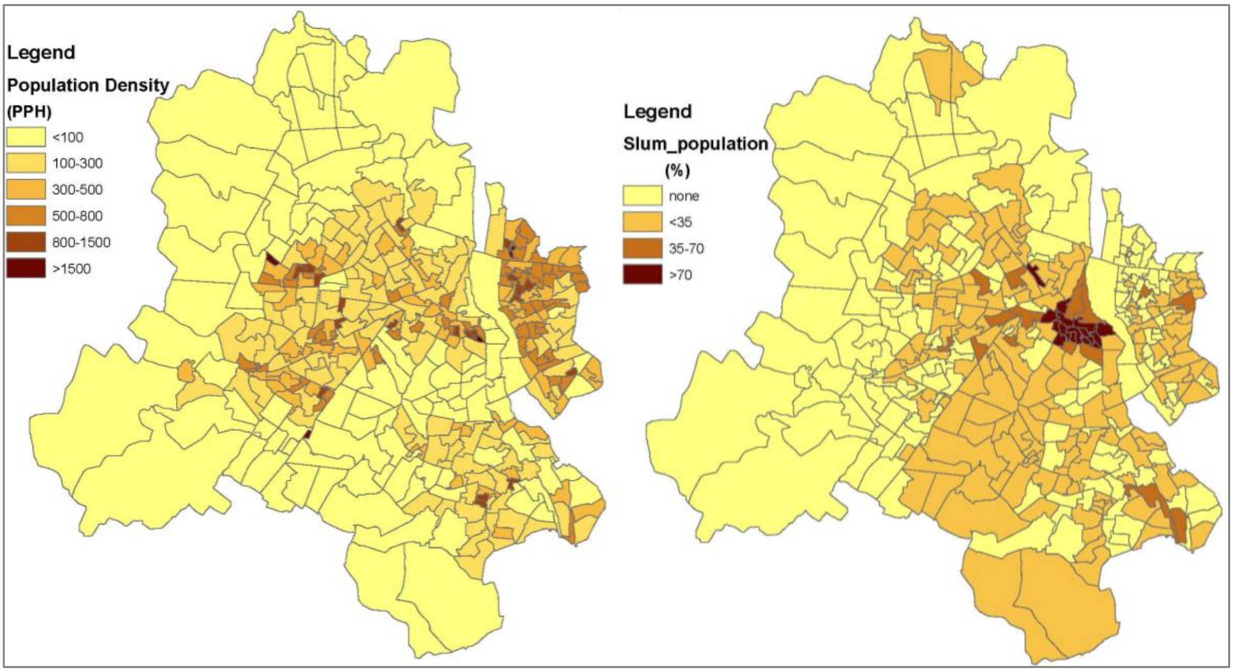

Fig. 2. (a) Urban and (b) Slum population distribution in Delhi (Census 2011)

Identified clusters include slums having at least 300 population or 60-70 households. This results in omission of many smaller squatters and non-notified slums, locally known as Jhuggi-Jhopri cluster (JJC) having smaller number of households. So, another important dataset obtained from Delhi Urban Shelter Improvement Board listing 675 JJCs (DUSIB, 2014) has been included in the analysis. Analysis of these JJCs suggests that these clusters can be as small as having only 6 households to very big JJCs having more than 12000 households. Average population density of these JJCs is calculated to be 1970 PPH. Fig 2 (a) & 2(b) shows the population density and proportion of slum population in census wards of Delhi.

4. Existing land use and spatial distribution in Delhi

Census 2011 data and Land use data for Delhi for the year 2014 were compiled and analyzed for the study. Land use dataset for Delhi was prepared on Geographical Information System (GIS) platform as a part of this study. The resulting dataset includes geographical distribution of built up area as well as its land use category and is shown in fig 3(a). Further, land use mix as represented in terms of land use entropy is depicted in fig 3(b).The preparation of the data was initiated by using administrative boundary shape file for Delhi city along with built up data of 1999 available in GIS format. Since 1999, there have been substantial physical development and changes in the built form and extent of development in the city and hence it called for comprehensive review and update of the same. There are three basic sources of information on land use incorporated as attribute information in GIS, firstly, the data extracted from Google Maps (2014) & Open Street maps (OSM, 2014), secondly, Zonal land use maps available on the Delhi Development Authority (DDA) web portal and thirdly ground verification. Thus land use information was compiled at zone level for all the zones included in the analysis. The compiled GIS dataset is used to calculate land use mix indicators. Careful examination of the existing land use pattern suggests that growth of the city over the years has been on a ring and radial pattern. The development envisaged by previous Master Plans was poly-nodal with a hierarchy of commercial centers located on either ring or radial roads (Delhi Master Plan 2021). And, as a result multiple district commercial centers have come up and additional few are proposed in the peripheral zones.

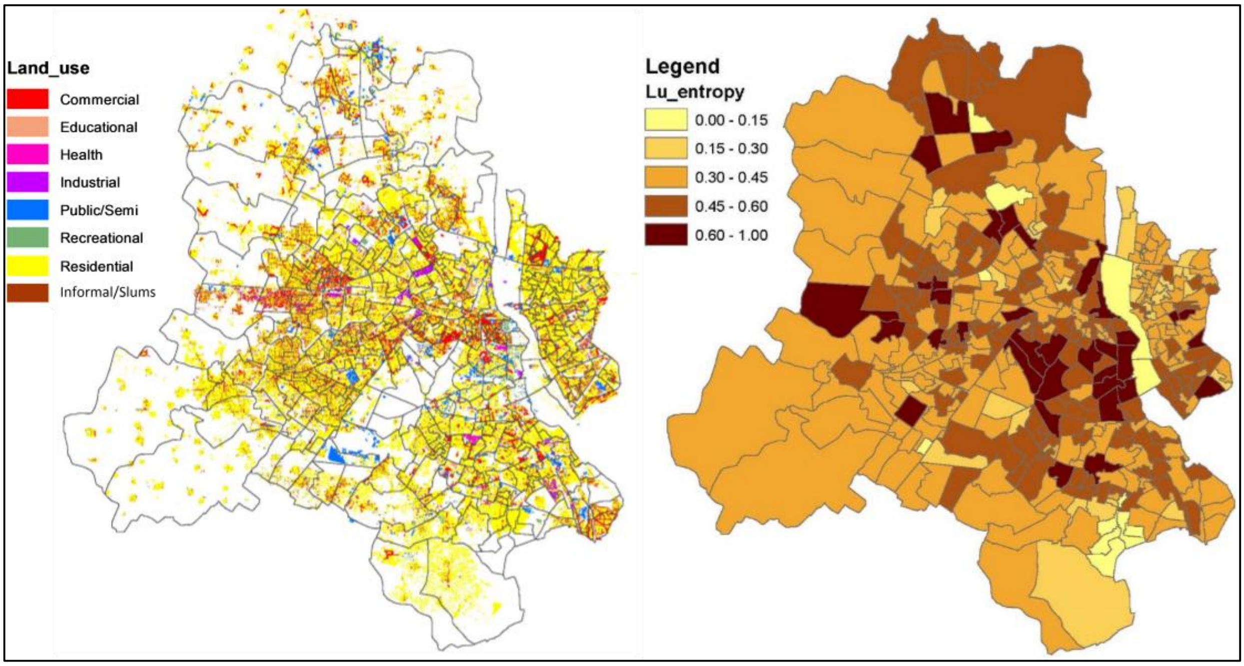

Fig. 3. (a) Existing land use pattern (b) land use mix (entropy) in Delhi (2014)

The existing land use dataset is classified into seven major land use categories namely, residential, commercial, public, educational, health, industrial, recreational and informal. Total built up area is calculated to be about 243 sq.

km. Category wise proportions of the existing land use proportions are provided in the Fig 4. Residential use accounts for about 64.5% of the total built up area. Non-residential has commercial with about 20.7% followed by public, educational, industrial and recreational land uses 5.3%, 2.6%, 1.8% and 1.7% respectively. For land use mix analysis, 'health' category was aggregated with 'public' land use. Recreational land use also includes religious use. Informal land use is calculated to be 3.4 % of the total built up area. Area under roads and parks is not included in the analysis of built up area. Delhi cantonment area was excluded from the analysis due to non-availability of datasets and access restrictions. Proportion of informal land use varies from 1% in select zones to more than 70% in few zones.

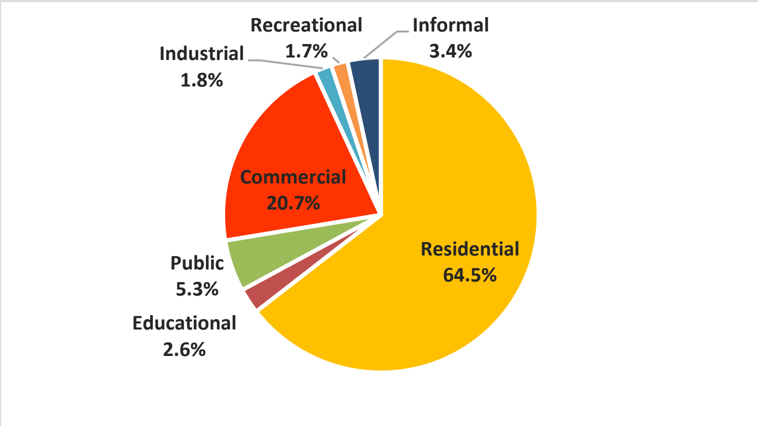

Fig. 4: Existing land use distribution in Delhi for the year 2014

5. Measuring the land use mix and its relevance

The concept of using land use mixing is advocated as a tool to encourage use of active transportation, which includes walking, bicycling and public transport. Land use strategy has a considerable impact on the travel demand. Researchers have adopted diverse approaches to study land use and transport relationship. The underlying principle that by providing a reasonable mix of land uses within walking and NMT range of residential location we can promote walking and bicycling, is rarely contradicted. It is further believed that mixing of complementary land uses can reduce personal vehicular travel and induce demand for public transit. Amongst principles of land use planning, the Development Density (population and employment etc.), Diversity (land use mix and composition) and Design (in terms of accessibility) are the major driving forces (Cervero and Kockelman, 1997) to encourage use of public transport and walking. Multiple indices have been developed to measure land use diversity such as entropy (Frank and Pivo, 1994;Song and Knapp, 2004), Herfindahl index (Herfindahl, 1950), dissimilarity (Duncan, 1955) and Atkinson (Atkinson, 1970) and Gini index (Gini, 1955) and cluster index (Massey and Denton, 1988), to name a few. Calculation of all these indices necessarily includes identifying different categories of land use in context of study.

Song et. al (2013) present an interesting compilation of various land use mix indicators widely used in the fields of transportation, public health and economics as shown in Table 1. These indicators are primarily divided into two categories of 'Integral' and 'Divisional' measures. Integral measures are aggregate measures sensitive to overall distribution of land uses within zones of analysis. Whereas, divisional measures are sensitive to geographical arrangement of land uses within area or zones. Symmetry of the indicators refer to the property of producing same value when values or proportions of different land use categories are switched (Song et al., 2013). Out of these measures, Entropy, Herfindahl and Dissimilarity measures are recommended when more than two categories of land uses are involved. Entropy and dissimilarity indices produce similar results within same value range of 0 to 1 with higher values representing higher mix. However, Herfindahl index provides result in the range of 0 to 10000, with increasing value of Herfindahl index representing lower mix. For our purpose we explore the application of these three indices.

Table 1. Measures of land use mix (adapted from Song et. al 2013)

Sr.	Measure	Type	No. of Land use types (k)	Symmetric	Value Range	Higher value indicates (LU-Mix)	Reference
1	Proportion	Integral	k =1	No	0 to 1	High	
2	Herfindahl Index (HHI)	Integral	k ≥ 2	Yes	0 to 10,000	Low	Herfindahl, 1950
3	Balance	Integral	k = 2	Yes	0 to 1	High	Cervero & Duncan, 2003
4	Entropy	Integral	k ≥ 2	Yes	0 to 1	High	Song & Knaap, 2004
5	Gini	Divisional	k = 2	Yes	0 to 1	Low	Gini 1955
6	Dissimilarity	Divisional	k ≥ 2	Yes	0 to 1	High	Duncan and Duncan, 1955
7	Atkinson	Divisional	k =1	No	0 to 1	Low	Atkinson, 1970
8	Cluster	Divisional	k =1	No	0 to 1	Low	Massey & Denton, 1988
9	Exposure	Divisional	k = 2	No	0 to 1	High	Massey & Denton, 1988

5.1. Land use entropy index

The land use entropy is used as a measure of diversity in land use mix. Frank and Pivo (1994) contributed to the development of the following concept of ‘Entropy’. They argue that entropy can be used to understand the balance of land uses and their proportions. Land use entropy is calculated as shown in Eqn (1).

$$Entropy = -\frac{1}{\ln(k)}\sum_{j=1}^{k} P_j \ln(P_j) \tag{1}$$

Where, j is the number of the distinct land use types and P_j is the proportion of developed land in the jth use type in the census tract or zone. In the entropy equation, the total land is considered, and this equation is further improved by using only proportions of developed land so that category wise built-up areas are well represented. Values of Land use entropy varies from 0 to 1. Zones having similar proportion of land use in each category have value near to 1 and areas having rather uneven distribution among different categories and a single dominant land use are closer to 0 representing lesser mix. Fig 5 shows the land use entropy distribution in Delhi. Entropy values for each zone were calculated for six conventional categories of uses excluding informal land use. Maximum and minimum values of zonal entropy were observed to be 0.90 and 0.041 respectively. Mean value of zonal land use entropy comes out to be 0.44 with a standard deviation of 0.12.

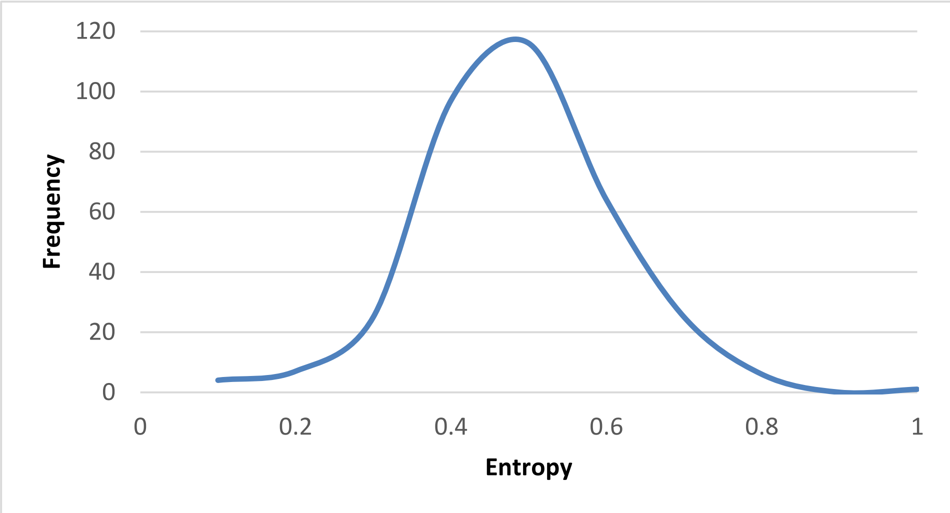

Fig 5. Frequency distribution of zonal entropy values

5.2. Herfindahl - Hischman index

Herfindahl-Hirschman index (HHI) is a commonly adopted measure of market concentration. This can be a useful measure to quantify land use mix (Song et. al., 2013). Values of HHI range from 0 to 10000. HHI is calculated using formulation given in Eqn. (2). Where, P_j refers to the proportion of land use type j.

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

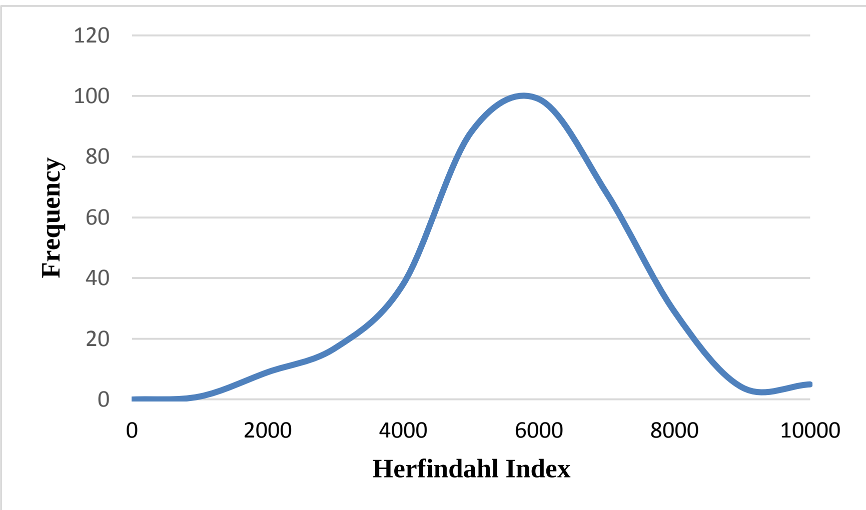

Fig 6. Frequency distribution of zonal Herfindahl Index values

In contrast to the land use entropy, higher values of HHI represent lower mix. Fig 6 shows zonal HHI distribution for Delhi. HHI values for each zone were calculated for six conventional categories of uses excluding informal land use. Maximum and minimum values of HHI were observed to be 9548.2 and 408.3 respectively. Mean value and standard deviation for HHI comes out to be 5220.8 and 1487.2 respectively.

5.3. Land use dissimilarity index

Originally proposed by Duncan (1955), Cervero and Kockelman (1997) further introduced the concept of 'land use dissimilarity index' in transportation studies. This is generally calculated by dividing the zones into hectare grid of size i.e. 100m X 100m. Land use dissimilarity is calculated as per the formulation in Eqn (3).

$$Dissimilarity = \frac{1}{K}\sum_{j}^{k}\sum_{i}^{8}\left(\frac{x_i}{8}\right) \quad (3)$$

Where, j is the number of distinct land use types, i represents land uses dissimilar to that of reference parcel. Here, K is the number of developed hectare grids, x_i= 1 for land use different than central grid cell land use and x_i= 0 for land use similar to the central grid cell/hectare land use. Thus if all the land uses in immediate contact of the hectare grid cell under consideration are the same as the reference hectare land use then the diversity value will be 0, and if all are different, the value will be 1. Fig 7 shows the zonal dissimilarity distribution in Delhi. Dissimilarity values for each zone were calculated for six conventional categories of uses excluding informal land use. Maximum and minimum values of zonal dissimilarity were observed to be 0.73 and 0.01 respectively. Mean value of zonal land use dissimilarity comes out to be 0.31 with a standard deviation of 0.16.

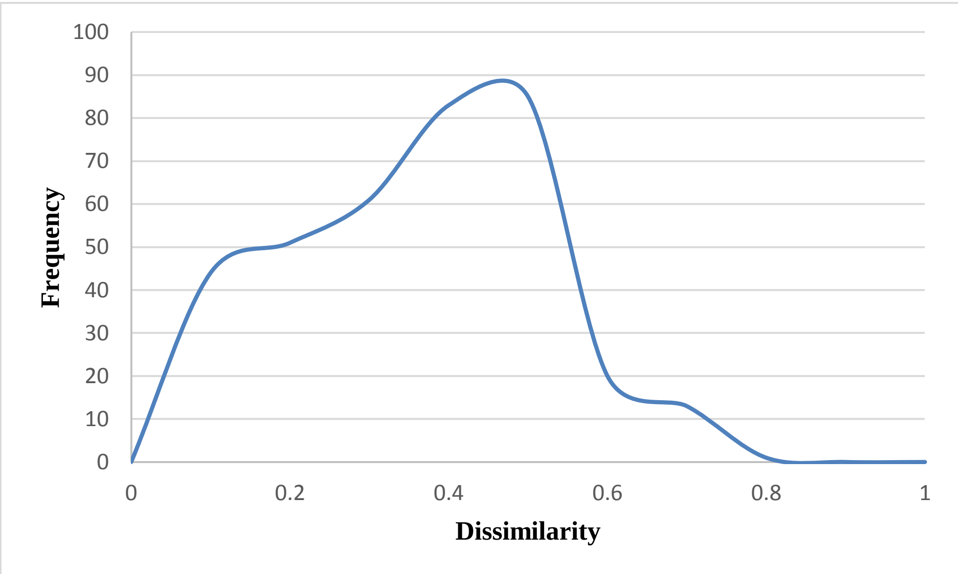

Fig 7. Frequency distribution of zonal Dissimilarity Index values

6. Data and methods

Paired t-test is used to check whether values of entropy, Herfindahl and dissimilarity indices change significantly by including informal land use category with other six categories of residential, commercial, public offices, industrial and recreational generally used in official master plans. The study area has been divided into 360 Zones as used by RITES (2011). Out of 360 zones, two zones representing the Yamuna River and its catchment area are excluded from the analysis. These zones have been carved out of census ward map of Delhi (Census, 2011) to maintain transferability of the census datasets. The slum population totals at ward level were first associated with the geographical ward map of Delhi. The population totals were further calculated at zone level based on proportion of built up and its distribution in the zones carved out of the ward under consideration. The necessary datasets including land use and slum population were compiled for each zone. Delhi has 272 municipal wards excluding New Delhi (the central administrative district) and Cantonment areas. New Delhi administrative district is further divided into 10 wards

Data used in the analysis can be divided into following subsets. Census (2011) provides information on population totals at ward level that are translated into zones based on the proportion of built up area in that zone. Slum population total are obtained from census (2011) at ward level and used to extract slum population at zone level. DUSIB (2014) provides information on geographical extent footprint in terms of area and population for 675 slums locally known as JJCs. This dataset enables us to calculate 'informal' land use for each zone where slum population is known but area is not known. Additionally it identifies smaller informal clusters that otherwise would not qualify as 'Slum' in case of Census. Land use dataset prepared on GIS format is used to calculate proportions of different categories at zone level using 'spatial join' analysis using ArcGIS. These proportions are used to calculate the land use entropy and Herfindahl indices for a group of six and seven categories of land use as explained earlier. Lu_entropy_6 and Herfindahl_6 refers to the entropy and HHI values calculated for six land use types excluding 'informal' land use. Whereas, Lu_entropy_7 and Herfindahl_7 refers to the entropy and HHI values calculated for seven land use types including 'informal' land use. A summary of these indicators are provided in Table 2.

Table 2. Descriptive statistics for Entropy, Herfindahl and Dissimilarity indices

	Lu_entropy_6	Lu_entropy_7	Herfindahl_6	Herfindahl_7	Dissimilarity_6	Dissimilarity_7
n	358	358	358	358	358	358
Max	0.90	0.88	9546.8	9548.2	0.72	0.79
Min	0.04	0.06	408.3	2017.7	0.001	0.001
Mean	0.44	0.45	5220.8	5336.6	0.31	0.32
SD	0.12	0.13	1487.2	1331.5	0.158	0.164

7. Results and discussion

A paired sample t-test was conducted to compare the values of entropy and Herfindahl index with and without including the 'informal' land use. Table 3 provides the t-test statistics. We found significant difference between Lu_entropy_6 (M= 0.44, SD=0.122) and Lu_entropy_7 (M= 0.45, SD=0.133). Similar were the results for Herfindahl_6 (M= 5220.8, SD=1487.4) and Herfindahl_7 (M=5336.61, SD= 1331). Dissimilarity also captures the presence of informal land use with Dissimilarity_ 6 (M=0.31, SD= 0.158) and Dissimilarity_7 (M= 0.32, SD=0.64). The values obtained underline the value ranges for both the indicators. The difference gets further highlighted in Herfindahl index due to higher value range of 0 to 10000. Though increasing values in case of Herfindahl index present lower mix in contrast to the higher values representing higher mix in case of entropy and dissimilarity indices. The results suggest that including informal land use as a distinct category has a significant effect on both the indicators with t= -4.2 (p= 0.001), t= -5.0 (p= 0.001) and t= -8.0 (p=0.001) for Entropy index, Herfindahl index and Dissimilarity index respectively. Tables 2 and 3 provide the relevant test statistics. Further, Confidence interval for all the three pairs of indicators lie on one side zero. For e.g. confidence interval for difference of paired observations for HHI lies between -160.00 to -70.00 and hence does not contain zero, which in turn means there is less than 1% probability in our case that true mean of difference would be zero. Though the correlation statistics suggest high correlation still indicators are assigned different values when informal land use is taken into account. Thus it is advisable to include 'informal' as a distinct category of land use while studying the intensity of mixed use in this context.

Table 3. Paired samples t-test

		t	df	Sig. (2-tailed)
Pair 1	Lu_entropy_6 & Lu_entropy_7	-4.264	357	0.000
Pair 2	Herfindahl_6 & Herfindahl_7	-5.051	357	0.000
Pair_3	Dissimilarity_6 & Dissimilarity_7	-8.040	357	0.000

7.1. Strengths of the mix indicators in capturing 'informal' land use

The study establishes that when it comes to including 'informal settlements' as a separate category of land use the commonly accepted indicators of entropy, dissimilarity and Herfindahl indices are able to capture their presence though the effect size remains small. As expected, it results in the overall increase in the value of mix indicators. Hence these can be employed in the travel behaviour related studies to represent actual value of land use mix present in the study area. Though their application and effectiveness while studying travel behaviour of informal settlements needs to be further explored

7.2. Shortcomings of the mix indicators in capturing 'informal' land use

Detailed calculation and comparison of these indicators enables us to point out certain inherent shortcomings of the indicators explored in the study.

- Integral vs Divisional measures

Integral measures being aggregate measures are calculated at zonal level. Entropy and Herfindahl indices used in this study are calculated using proportions of land use under different categories at zone level. These indicators remain insensitive to the changing composition i.e. changing arrangement of land use parcels, at sub-zonal level. Although dissimilarity captures mix at hectare grid level, yet it appears that averaging it again at zonal level based on number of hectare grids defeats the purpose. Thus an integral measure which incorporates divisional aspect needs to be developed.

- Symmetric nature of indicators

All of the above indicators are symmetric, which means the value of mix remains the same even if the proportion of land uses are switched. Though symmetry may be desirable when collective impact of aggregate mix is being looked into. But, asymmetric measures may be more suitable while studying the impact of a special category of land use. Hence, an asymmetric indicator which can be generalized for more than two categories of land use is more desirable.

- Insensitivity to the nomenclature assigned

Another aspect of calculating these indicators is desired to be looked into. This refers to the indifference of the indicators to the nomenclature assigned. It is well documented that within non-residential usage, namely, commercial, industrial and public spaces etc. have different kind of travel patterns associated with them. But all of the above indicators assume these categories to have similar impact on the mix. This assumption leads to indicators which are less sensitive to travel patterns. Thus a possibility of production or attraction weighted indicator arises where impact of each land use is weighted according to its travel related impact.

8. Conclusions

In contrast to the rich literature discussing the impact of land use mix on travel behavior this paper questions whether the conventional classification of land uses adequately captures the physical and socio-economic diversity, which exist in an urban area. It is established that using modern analysis techniques we can include a neglected section of society i.e. urban poor living in informal settlements in planning process as a step towards truly inclusive land use planning. Using GIS techniques, it is possible to calculate geographical extent of these settlements. Selected indicators are calculated with and without including 'informal' land use. Results indicate that it is possible as well as advisable to incorporate 'informal settlements' while calculating these indicators. Though the effectiveness with which the established indicators of mix capture the difference in context of travel behaviour related studies, remains to be seen. Finally, it is argued that 'informal' land use needs to be incorporated in conventional list of land uses for three primary reasons. Firstly, due to their distinct character as compared to conventional residential area. Secondly, informal settlements being mixed use communities offer shelter as well as employment opportunities to the urban poor. Thirdly, it enables us to explore their relationship with other land uses including 'residential' in terms of travel behavior of its inhabitants.

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