博士論文（要約）

論文題目　Evaluation of relation of spatial urban forms with urban quality of life in rapidly urbanising high-density cities of developing nations: a case of Kolkata, India.

(開発途上国の急速に都市化する高密度都市における都市構造と生活の質の関係性評価：インドのコルカタを例に)

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The 'Compact-City' paradigm is currently accepted as the ultimate remedy for urban sustainability and is argued to endorse 'well-being' or higher urban quality of life (UQoL). Following the success of its implementation in low density cities of developed nations, many rapidly urbanising developing country cities are adopting 'compact-city' policy as a silver bullet for a sustainable future. While compact-city form, characterized by 'high-density' may produce better urban quality of life in low density cities of the developed world but its connotation in the high-density cities of developing nations remains debatable. The question now lie is that, can compact urban form foster higher UQoL for cities those are already compact or will it only tend to overload on resources? Non-existence of any conclusive answer leaves a probability, that under the contextual settings, compact urban form may associate with better UQoL. Seldom, these generalized assessments take into account the varied socio-economic and cultural context inherent in these cities.

Hence, this dissertation tries to answer that how compact urban form relates to urban quality of life in context of rapidly urbanising cities of developing nations. It is hypothesized that urban form is a causal factor of UQoL and that compact urban form can promote higher UQoL.

To answer this fourfold research objectives are formulated: (1) to identify the underlying dimensions urban form and objective UQoL in terms of spatial & non-spatial domains of urban environment at intra-city level.(2)to assess the relationships between UQoL and Urban forms (3) to evaluate the causal relation of urban forms on objective UQoL(4) To develop basic recommendations as a basis for effective planning, improved UQoL as implicated through a sustainable urban form. To assess the said relationship a case study of the megacity Kolkata, India was chosen. The city's semblance to typical high-density cities of developing nations along with sporting highest average density was primal motivation for the choice.

Neighbourhoods were chosen as the spatial unit of analysis. The primary aim was to find the latent dimensions of urban form and UQoL and thereby seek inter-relation among them. To address the socio-economic cultural diversity inherent in these cities an adjustment variable of Socio-Economic-Cultural Index (SECI) was formulated. UQoL annotations were derived using the domains of life which were suitable to the context of developing world especially reflected in context of Kolkata, while performing for the universal comprehension and comparability. Thus essentially the domains that dominate the base level of physiological needs in developing countries were considered in this research.

Data availability, both spatial (GIS) and non-spatial, was one of the major challenges of this research. Kolkata being very close to international boundary is a restricted zone for which data dissemination policy of Govt. of India is restricted. Whatever was available was in the form of paper maps from various government sources and neighbourhood level census abstracts. The paper maps were processed and digitized in ArcInfo 10.1 (Desktop) for extracting the neighbourhood boundaries which was used for further analysis. Comparing the various sources to produce one usable map for analysis purpose was a challenging task. Data quality checks like location accuracy of the digitized features were performed by collating them to available known spatial data resources like GoogleEarthR images. Various public amenities and environment related data like bus availability within the neighbourhood, hospital availability within 2 kms of the neighbourhood, primary school availability, environmental pollution, network

connectivity etc were not present at the spatial neighbourhood scale. Multiple spatial methods were adopted to derive the neighbourhood level indexes, like two-step floating catchment area method for hospital and primary school availability, space- syntax for connectivity index, kriging interpolation for estimating neighbourhood level pollution index, etc. To estimate the bus availability from the available bus route information, an estimation methodology was devised which was a modification of the existing procedure of estimating spatial variability of vehicle pollution within a city. Finally an overall data quality check of the prepared data resulted in a data accuracy of 98.62%.

In the absence of direct income data a surrogate indicator which cumulatively reflected socio-economic and socio-cultural diversity was devised to derive a neighbourhood level Socio-Economic-Cultural Index (SECI). Multiple indicators like literacy, economic earner, availing banking facility; assets' ownership was used to substitute income and variable like female literacy, female work participation and proportion of special category population depicted cultural factors. Multivariate statistical procedure of principal component analysis was used construct a standardize SECI for each neighbourhood. Finally the neighbourhoods were hierarchically classified into quintiles of SECI representing below poverty line population to very high income group cohort.

The derivation of the dimensions of UQoL was achieved by applying another multivariate statistical procedure of latent factor model. The factor model extracted four latent dimensions which correlated to four major domains of urban life. These were namely public amenities or facilities or 'City Lines'; habitable surrounding or 'Built-Environment'; ease of access or 'Accessibility' and external environmental quality like air pollutant concentrations or 'Environment' factor. The index to measure urban form were derived from literature and modified under contextual setting. Since the central focus was to find out that whether compact-urban form fosters higher UQoL, so urban form dimensions which enabled in distinguishing neighbourhoods in terms of compactness as opposed to disperse condition was required. Generally, compactness is measured by urban density, but no available standard of density exists which correlates to compactness (i.e how dense should be a compact city). Thus, rather than using absolute density, a proportional scale was devised which could find the relative position of the neighbourhoods and distinguish them in terms of compact vs disperse. This also removed bias of ad hoc imputation of high and low density thresholds. The urban forms were defined using three devised indices namely 'Compactness', 'Footprint' and 'Mixed-use Entropy'. The compactness index surrogated for housing density, footprint was a representation of land area consumption by population and mixed-use was calculated using Shannon's Entropy which separated neighbourhoods having concentration of similar from dissimilar land uses. The compactness and footprint indexes had values ranging from 0 to +1 with 1 being the balanced condition. For compactness 0 and +1 reflected dispersion and compaction respectively. For footprint index values closer to 0 reflected low consumption (compact) vs +1 meaning high consumption (disperse) condition. Similarly, the mixed-use index ranged from 0-1 with 0 meaning similarity or low mix of land uses or dispersion, 1 being dissimilar or high-mix of land uses or compaction and 0.5 being the balanced condition. The notion of high-mix of land uses being compact condition is based on the premise that when there is high mix of land use then availing urban facilities within a short reachable distance becomes possible, thus promoting compact-city.

Following the derivation of dimensions of UQoL, urban form and SECI, the neighbourhoods were

classified into ascending cohorts using hierarchical cluster analysis based on internal inertia gain. The neighbourhoods were clustered into five ordered groups representing very high, high, moderate, low and very low UQoL for each dimensions of UQoL. For the urban form dimensions the neighbourhoods were classified into three groups representing compact, moderate and disperse. A classification procedure based on the successive use of two multivariate statistical methods of Multiple Correspondence Analysis followed by cluster analysis based on hierarchical ascendant on the UQoL dimension was used to identify the cumulative UQoL patterns. Overrepresentation analysis (ORA) based on cluster enrichment technique was performed to describe the characteristics of the patterns. The methodology of ORA is borrowed from biological sciences where it is used for gene classification. The probability of relation between the UQoL patterns and urban form dimensions were derived by logistic regression with UQoL4 and dispersed urban form being the reference category for the dependent and independent variables respectively. Based on on exploratory analyses, adjustment was performed for socio-economic-cultural factors. Finally, structured latent variable models were applied to understand the causal paths in the relation. Urban policy variable of population and dwellings intensification (i.e growth or decrease of population or dwellings with growth and decrease implying positive and negative intensification respectively) was introduced in the latent variable model in order to help in simulating the UQoL shifts by remodelling the urban form variables.

The classification resulted in four cumulative UQoL patterns from UQoL1 to UQoL4. For ease of explanation, based on the characteristics,UQoL1 to UQoL4 were termed as highType1, HighType2, Low and VeryLow UQoL patterns. Mapping these patterns helped to highlight the spatial trends pattern across neighbourhoods in the city. The UQoL1 pattern overrepresented categories of very high built-environment, accessibility and SECI but had low cohorts of citylines and environment. Pattern UQoL2 was characterized by very high citylines and environment, high to moderate built environment, accessibility and SECI. Next two patterns were a gradual decrease of scale from UQoL2 pattern, with UQoL3 and UQoL4 representing moderate and very low categories of all UQoL dimensions respectively. Spatially UQoL1 was more concentrated on the newer neighbourhoods where as UQoL2 was more concentrated on the older parts of the city. This directly implied that pace of spatial growth of the city happened faster than the citylines growth & whatever is added is only growth through road infrastructure. As one of the direct implications of road development is growth of real estate speculations so high quality housing (reflected here by built environment) emerged as soon as the city grew along newly added transport corridors. This also reflects the recent trends of suburbanisation policy witnessed in most developing country cities. Thus in urge to accommodate rapid urbanisation, the urban policy makers only provide for growth opportunities by expanding spatially without much regard to the provision of essential citylines like hospital or primary school required for sustaining higher quality of urban life.

The logistic regression showed that UQoL1 (HighType1) had no association with urban form and it was mainly an outcome of very high SECI condition. This outcome supports the previous explanation of high end real estate development in the newer neighbourhoods of the city. The odds of association of compact-mix-use neighbourhoods with UQoL2 (HighType2) were higher than UQoL4 (Low). Similar trend was also displayed by UQoL3 (Moderate) implying that compact urban forms with high mix-use had a higher probability of association with higher UQoL in the city of Kolkata. The latent variable model showed

UQoL was directly proportional to Compactness and mixed-use while were inversely related to the intensification variable. The relationship strength of UQoL with the urban form variables had 87% agreement depicting that currently in Kolkata compact conditions were more associated with higher UQoL. When this relationship was used to simulate certain urban form changing conditions especially in the dispersed –low UQoL neighbourhoods, it was found that by increasing compactness and mix use the UQoL of these neighbourhoods increased. But even by keeping the mix-use condition constant and only altering the population intensification by re-distributing and increasing intensification of dwellings, the UQoL of these neighbourhoods could be converted to higher UQoL cohorts. Without sufficiently altering the urban form, implementing simple policies of promoting higher dwelling density in the neighbourhoods also enabled in bringing higher UQoL.

These results showed that compact urban form does foster higher UQoL and that the city of Kolkata is still in a phase of transition but are changing rapidly. The current policy of Kolkata planners is to create counter magnets in the form of New Towns to accommodate urbanisation. These new suburbia only have very high UQoL of built environment but if citylines are to be considered they still depend heavily on Kolkata. If this trend continues then the central city might lose population but extreme dependency will lead to further overloading of city infrastructure. This type of development is very alarming for any city's sustainable future. This will lead to a greater disparity and implicate on the livability. Policies directed towards balancing the growth curves of urbanisation and UQoL are essential. Currently most cities in rapidly urbanising developing economies have compact polycentric development in their horizon but if that development is only lopsided then creating high-density-high quality city will only remain unachievable.