DYNAMICS OF SPATIO-TEMPORAL URBAN EXPANSION IN SOUTH WEST DELHI REGION: A GEO-SPATIAL APPROACH FOR URBAN DISASTER MANAGEMENT

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ABSTRACT:

Constantly increasing population and up-scaling economic growth has certainly contributed to fast-paced urban expansion, but simultaneously, as a result, has developed immense pressure on our natural resources. Among other unfavorable consequences, this has led to significant changes in the land use and land cover patterns in megacities all across the globe. As the impact of uncontrolled and unplanned development continues to alter life patterns, it has become imperative to study severe problems resulting from rapid development and leading to environmental pollution, disruptions in ecological structures, ever increasing pressure on natural resources and recurring urban disasters This paper presents an approach to address these challenges using geospatial data to study the land use and land cover change and the patterns and processes of urban growth. Spatio-temporal changes in land-use/land-cover were assessed over the years using multi-date high resolution satellite data. The land use classification was conducted using visual image interpretation technique wherein, study area was categorized into five different classes based on NRSC classification system namely agricultural, built-up, urban green (forest), and fallow land and water bodies. Post-classification change detection technique was used for the assessment of land-cover change and transition matrices of urban expansion were developed to quantify the changes. The results show that the city has been expanding majorly in its borders, where land masses have been converted from agriculture based rural areas to urban structures. An increase in the built-up category was observed with the transformation of agricultural and marginal land with an approximate change of 8.62% in the peri-urban areas. Urban areas are becoming more densely populated and open barren lands are converted into urban areas due to over population and migration from the rural areas of Delhi and thus increasing threat towards urban disaster. Conservation and sustainable management of various natural resources is recommended in order to minimize the impact of potential urban disasters.

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1. INTRODUCTION

Growth in the urban sector is a complex process in a dynamic framework (Sahana, 2018). Globally, this is an ongoing process that tends to increase the priority towards urban planning. Urban growth can be defined as “the spread of new developments in an urban area to the surrounding land” (Dadhich, 2011). More than half of the world’s population resides in cities, and is projected to reach 67.2% by 2050 (United Nations, 2012), increasing urban sprawl and raising new issues to be dealt with. A UN report highlights that in Asia urbanization is increasing at a highest rate of 1.5 per cent per annum (United Nations, 2014). In 21st century, urbanization has become a demographic issue in India as well (Ramchandra, 2015). Herein, the urban areas are expected to grow by 404 million people between 2014 and 2050 witnessing historical rural-urban transformation (United Nations, 2012). The World Bank, in one of its reports, also states that the urban population has increased from 28.3% in 1950 to 50% in 2010 in the megacities of India (World Bank, 2011). There were around 53 urban agglomerations with over 1 million people in 2011 as compared to 35 in 2001, which are further expected to increase substantially in the coming years (Census of India, 2011). This tremendous growth has forced researchers to map and monitor the urban and peri-urban landscape globally.

Urban land that covers less than 3% of the total global terrestrial surface, but its impact on ecology and the environment is massive (Li, 2014). Urbanization has been widely studied in different dimensions focused on perspectives varying from socio-economic and environmental in urban agglomerations (Cohen, 2006), to economic in peri-urban setup (Ravallion, 2007), to the loss of vegetation (Ramachandra, 2012) and also with respect to urban emissions (Banerjee, 2011; Ramachandra, 2009). Urbanization promotes socio-economic development of a region with significant improvement in the quality of life, but it also involves degradation of natural and semi-natural surfaces into impervious surface (Li, 2013; Taubenb€ock, 2009). Urban development contributes to unfavorable ecological and environmental consequences such as loss of agricultural land, deforestation, loss of water bodies, alteration of natural drainage, air pollution, water contamination, health hazards, microclimatic changes (Kalnay, 2003), reduced green spaces and increased land fragmentation (Grimm, 2008; Li, 2013; Li, 2000; Pickett, 2011; Miller, 2012). This results in a major transformation of land use, surrounding environment and even community cultures, thereby altering an entire city's ecology (Kumar, 2018).

Remote Sensing and GIS techniques are widely being used to analyze urban growth across the globe (Kar, 2018) as they explicitly reveal spatial patterns of land use/ land cover and changes over a large geographic area in a recurrent yet consistent way (De Fries, 1998; Homer, 2007; Peng, 2012). Different change detection algorithms have their own merits and no single approach is optimal and applicable to all cases. In practice, different techniques are often compared to find the most useful change detection result for a specific application (Berberogula 2009). In post classification comparison, multi-temporal land use maps are generated independently to identify and quantify the change (Deng, 2009; Ellis, 2008; Yuan, 2005). Whereas, in the pre-classification method the change is identified directly by comparing images (Berberoglu, 2009; Lu, 2004; Singh, 1989). Visual image interpretation and object-based approaches are used for land use change monitoring for very high spatial resolution images (Li, 2014).

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Delhi is among one of the fastest growing urban expansions in the world. Huge areas of croplands and grasslands have been converted into building, roadways, streets and parking lots over the last couple of years. The urban population of Delhi, which was 2.4 lakhs in 1911, increased to 14.37 lakhs in 1951 and to 164 lakhs in 2011 (Census of India, 2011). This indicates an apparent 68 fold increase in the urban population of Delhi over the century. Economic survey of Delhi 2010-11 states that during 2000s, the urban village population of the state was 0.88 million, which infers that 6.4% of Delhi's population resides in urban villages. The urban area in Delhi has increased rapidly over the past few decades (Chadchan, 2012; Jain, 2016; Mohan, 2011), therefore it seems necessary to analyze the trend of urban growth and deduce its future effects on other land cover features. Land use pattern change in the fringe areas, specifically in the North, East and South-West districts of Delhi. The medium and low dense residential areas have been given up at the cost of high dense residential areas (Netzband, 2009). Delhi is highly prone to multiple hazards like earthquake, flood, fire accidents as well as building collapses and epidemics. It lies in the seismic IV zone and is surrounded by river Yamuna (Kumar, 2018). Currently, Delhi is going through a massive infrastructure development stage with a large number of bridges, flyovers and the metro projects under construction. Urban areas are developing at a rapid pace. The population growth and physical assets in hazard-prone area, lack of basic infrastructure, access to affordable land, substandard construction of buildings and infrastructure increase the vulnerability and exposure of the urban population to hazards. In this paper, an attempt has been made to quantify the land use change for the duration 2008 and 2015 and study the consequence of urban expansion on the occurring disaster.

2. STUDY AREA

Delhi is located between latitudes 28º24' to 28º53' N and longitudes 76º50' to 77º20' E with a total area of 1,483 sq. km. Present study has been carried out on the South West District of Delhi located at 28.5929° N, 77.0346° E and surrounded by the West District on the north, South Districts on the east, Gurgaon of Haryana state on the south and Jhajjar of Haryana on the west as depicted in fig.1. It is the second largest district covering an area of 420 sq km. It constitutes three subdivisions namely Delhi Cantonment, Najafgarh and Vasant Vihar. The district has a population of 22,92,363 as per the census, 2011 and average population density is 5458 persons per Sq. Km.

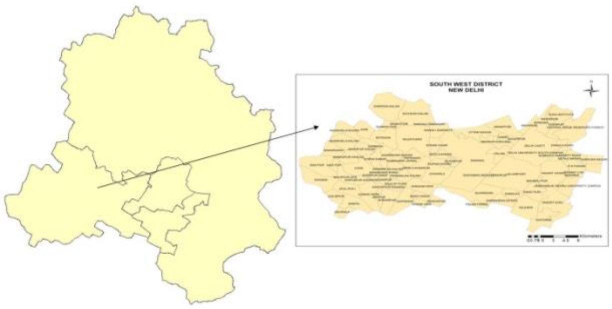

Figure 1: Study Area

3. METHODOLOGY

For the present study, Quickbird images with spatial resolution 2.5m was used for the years 2008 and 2015. Topographical sheet of the study area was obtained from Survey of India for reference. For the data processing and mapping ERDAS IMAGINE and ArcGIS software was used. Image enhancement was performed in order to reduce the noise to have spatially compatible of the two images. As the imagery was of very high resolution, hence Visual Image Interpretation technique was used for the classification. Herein, the objects were identified and interpreted based on the basic characteristics i.e. tone, texture, pattern, shadow, shape, size and association. The NRSC level I classification scheme was followed to derive the land use classes for the years 2008 and 2015(Joseph, 2015). Majorly five land use classes were derived namely: Built-up, agriculture, fallow land, urban green and water body. Urban green class constitutes all the parks, urban forests, green land, plantation sites (Artmann, 2019). Both the vector and raster comparison method was used for the change detection analysis. Change detection model was run in ERDAS imagine and the positive and negative changes has been identified. Also, category wise land conversion has been identified from vector data set using ArcGIS. After the change detection, the area with the haphazard growth were identified and studied in detail. For both the years 2008 and 2015, the buildings were digitized and the aerial distance between the buildings was calculated in order to understand the accessibility of the responding vehicles and personnel to the disaster event location.

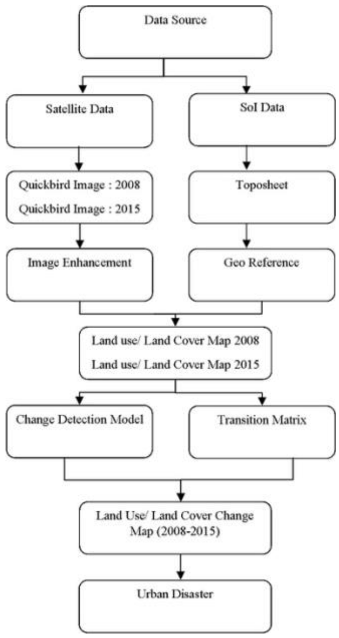

Figure 2: Flow Chart of Methodology

4. RESULTS AND DISCUSSION

4.1 Land Use/Land Cover Analysis for 2008 and 2015

The land use land cover map of 2008 showed that the total urban area in the south west Delhi accounts for 33.42% and the agriculture for 44.06% (Table 1). Agriculture is found to be dominant covering an area of 17792.85 ha. Built-up land is spreaded in clusters over an area of 13495.19 ha. Built-up includes industrial, institutional, residential, streets and all kind of impervious area. A few shallow water bodies are also present in the villages along with a major storm water drain constituting an area of 451ha covering 1.11% (Fig 3). Both the drain and the water bodies are subjected to seasonal variation. The urban green land including parks, urban forests, residential gardens covers area of 7871.92 ha i.e. 19.49% of the total area.

Land Use Classes	Area (ha)	% area
Urban green	7871.92	19.49
Fallow land	764.01	1.89
Agriculture land	17792.85	44.06
Built-up land	13495.19	33.42
Water body	451.48	1.11

Table 1: Land Use/ Land Cover 2008

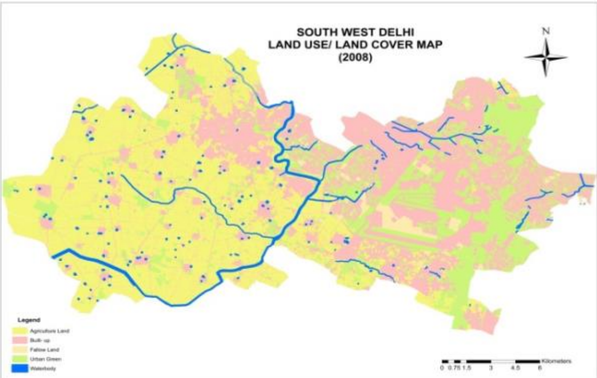

Figure 3: Land Use/ Land Cover Map 2008

In 2015, the same land use classes were studied. Agricultural land covers an area of 17321.83 (42.90%) (Table 2). Built up land has the area of 15236.61ha comprising of Asia's biggest sub-city Dwarka (37.73%). Only 1.03% of the total area is covered with water body with an area of 419 ha (Fig 4). Urban green area covers 17.68% of the total area of 7141.74ha. Certain land is categorized in Fallow Land which covers only an area of 256.12 ha i.e. 0.63% of the total.

Land Use Classes	Area (ha)	% area
Urban green	7141.74	17.68
Fallow land	256.12	0.63
Agriculture land	17321.83	42.90
Built-up land	15236.61	37.73
Water body	419.13	1.03

Table 2: Land Use/ Land Cover 2015

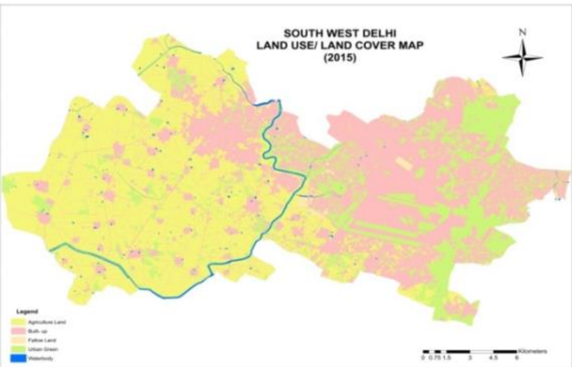

Figure 4: Land Use/ Land Cover Map 2015

4.2 Land Use/Land Cover change 2008-2015

Land use/land cover change is a continuous process as a result of natural and human factors. Both negative and positive change is observed in land use categories. The transformation of agricultural land into urban built-up land increases the impermeable surface. There is continuous fall in the agricultural land reduction in the area of 471.02 ha and increase in the built-up area by 1741.42 ha (Table 3). Positive change is observed only in the built-up class with an increase of almost 4.31% of the total change. This increase is observed in both rural and urban settlements. The reduction of 471ha area is observed in agricultural land. The fallow land is reduced by 507ha and urban green land by 730ha. Small change is observed in the land cover area of water bodies as the major water body is storm water drain that has a delineated path whereas, encroachments are observed on the peripheral area. The results from the change detection model depicted that there is no fixed pattern or place of change (Fig 5).

Land Use classes	Area 2007(ha)	Area 2015(ha)	Change Area (ha)	% change
Urban green	7871.92	7141.74	-730.17	-1.80
Fallow land	764.01	256.12	-507.88	-1.25
Agriculture land	17792.85	17321.83	-471.02	-1.16
Built-up land	13495.19	15236.61	1741.42	4.31
Water body	451.48	419.13	-32.34	-0.08

Table 3: Land Use Change (2008-2015)

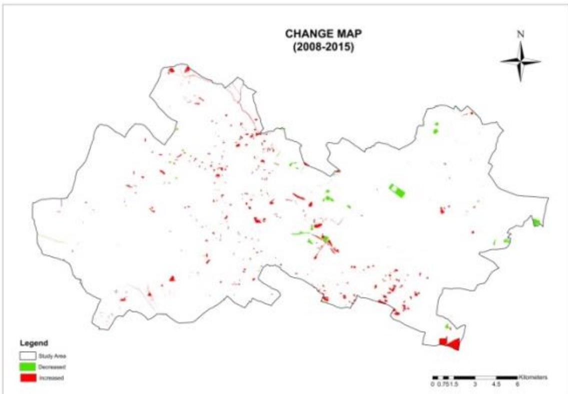

Figure 5: Change Map (2008-2015)

4.3 Change Dynamics of LULC

To understand land encroachment for different land categories for the study period, a change detection matrix was prepared which reveals that (Table 4):

- About 17.45 ha of urban green land is converted into fallow; 13.87 ha into agriculture; 980.38 ha into built-up.
- About 135.86 ha of agricultural land is converted into urban green; 93.4 ha into fallow; 271.46 into built-up.
- About 25.55 ha of fallow land is converted into urban green land; 13.52 ha into agricultural; 586.76 ha into built-up and only 5.92 into water body.
- About 89.49 ha of built-up land is converted into urban green land; 12.99 ha into fallow; 2.03 ha into agriculture.

- About 33.02 ha of the area covering water body is converted into urban green lands.

Land Use	Urban green	Fallow land	Agricultu re land	Built-up land	Water body	Total
Urban green	6857.82	17.45	13.87	980.38	2.4	**7871.92**
Fallow land	25.55	132.26	13.52	586.76	5.92	**764.01**
Agricultu re land	135.86	93.4	17291.99	271.46	0.14	**17792.8**
Built-up land	89.49	12.99	2.03	13390.2	0.46	**13495.1**
Water body	33.02	0.02	0.42	7.8	410.21	**451.48**
Total	**7141.7**	**256.1**	**17321.83**	**15236.6**	**419.13**	**40375.4**

Table 4: Land Use/Land Cover change area during 2008-2015 in hectare

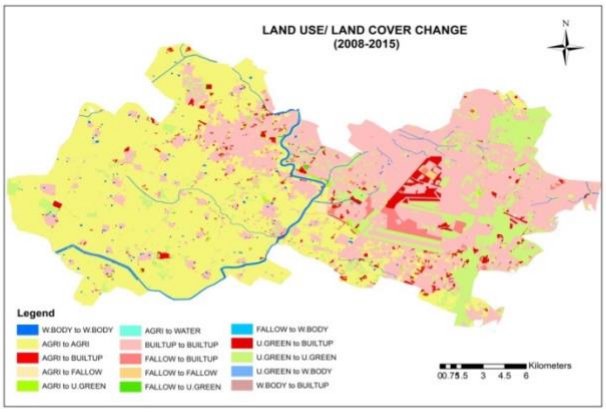

Figure 6: Land Use/Land Cover change map during 2008-2015 for individual classes

Figure 6 depicts the change in the individual classes. The fallow land has been converted into the impervious built-up area in the Delhi cantonment subdivision. The major change in the agricultural to built-up is observed in the periphery of the already existed villages and the already existing residential areas (Fig 8). Few surface water bodies that were present in 2008 were found to be missing and similarly the drain which were present before are submerged in 2015. Both planned and unplanned development is observed in the Vasant Vihar subdivision. In this area, the urban green land area is converted into built-up with the development of residential colonies (Fig 7). Transformation in the airport area is observed where the fallow land is converted into well planned international airport.

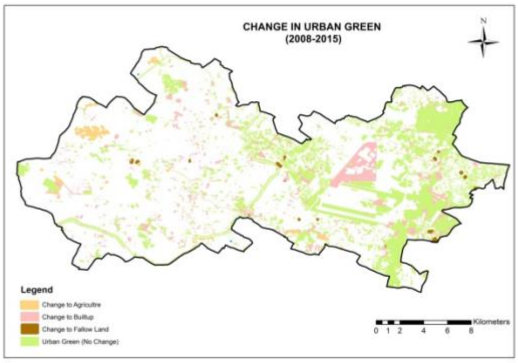

Figure 7: Change in Urban Green (2008-15)

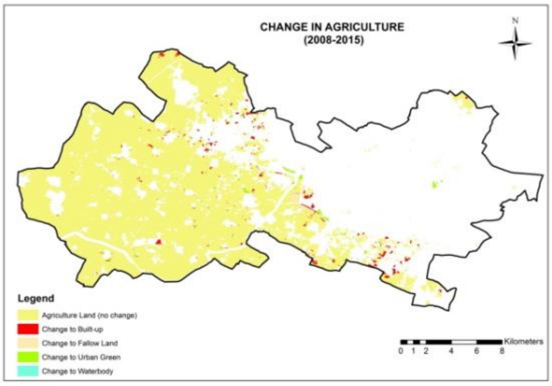

Figure 8: Change in Agricultural Land (2008-15)

4.4 Urban Expansion and Emerging Disaster

In urban unplanned area of South West region of Delhi, constituting parts of Mahavir Enclave and Uttam Nagar (site 2) the buildings were situated in close proximity with each other. Certain open spaces that were identified in 2008 are now encroached with more new building (Fig 9). In-situ urbanization has taken place with wall to wall construction of buildings with only one side opening, making it more vulnerable towards the occurring disaster. The aerial distance calculated between two buildings was found to be in the range of 1.5m to 3m. At site 1, small industries/ commercial activities/ godowns have come up at the cost of productive lands in the Najafgarh subdivision. Apart from this, urban expansion observed near Najafgarh and Munguspur drain (Site 3) which was once a flood prone area due to the adjoining rivers in the periphery. Many unplanned and non-engineered building have been developed in 0.5km buffer area of Najafgarh drain. Site 4 is the area near industrial area of Mayapuri and Naraina, where a huge residential colony is being built-up at the cost of urban green area.

The land use matrix above explains the urban expansion in different parts of South West Delhi. The expansion has taken up in both urban as well as rural areas. Unplanned expansion observed to accommodate rapid population growth, inappropriate land use planning and the failure of building standards. Lack of access roads can prevent relief efforts from reaching to the affected households. The key issues of urban growth leading to disastrous risk are encroachments in urban villages, exploitation of agricultural land for unauthorized development and inappropriate commercial and industrial use, resulting in non-conforming lands. South west region of Delhi falls under high vulnerability class for earthquake, fire, building collapse, urban flood and moderate for industrial hazard (DDMP, 2014). According to Delhi disaster management plan 2014, the multi-storeyed building in cities with inadequate safety measure, narrow lanes, congested, overcrowded buildings, and old buildings with poor electrical wiring are considered under vulnerable locations for multi-hazard. Another criterion could be the number of buildings in an urban area as the higher the density of buildings in the area, the smaller the distance between them. The failure of each building may have a negative impact on other buildings. By-passing of building infrastructure bye-laws, rapid vertical as well as horizontal growth, increase in built up area, mixed use and decrease in the distance of balconies from the street electric poles and the ever increasing occupancy of people in small areas has led to increase in the disaster risk by multi-fold. As per the Master

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Plan of Delhi 2021 building regulations, approval of building plans are to be made compulsory; fire and earthquake norms are to be applied wherever necessary; buildings cannot ignore the lift requirement norms; polluting industries are not to be permitted, household industries to be permitted and commercial uses only to be permitted in areas with proper accessibility by roads not less than 6.0m which is the minimum requirement for fire safety regulations; No projection beyond the building line is allowed. However, the existing scenario depicts that none of the buildings are constructed with proper approval and hence there is a clear violation of the norms.

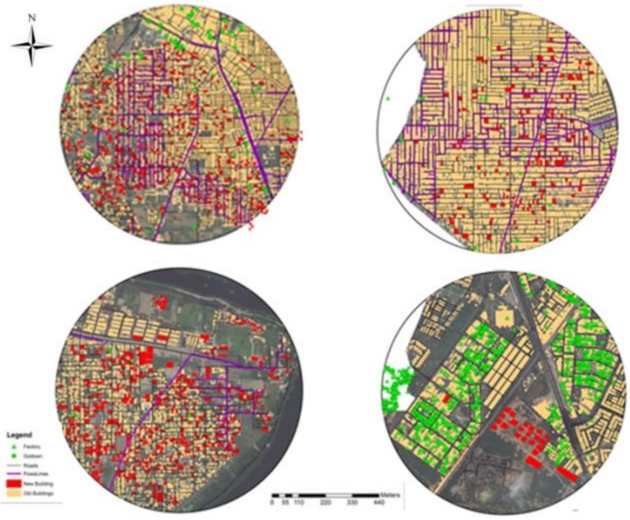

Figure 9: Urban Expansion Sites

5. CONCLUSION AND RECOMMENDATIONS

The present study assessed Land Use/Land Cover changes and the effect of urban expansion on the increasing vulnerability towards urban disaster in the south west region of Delhi using quickbird satellite images. The results showed that the Land Use/Land Cover classes have experienced rapid changes particularly in the built-up category. The Built-up area has increased by 4.31% of the total change area i.e. from 13495.19 ha to 15236.61 ha during the study period 2008 to 2015 which mainly came from agriculture and fallow land. All other classes showed a negative change i.e. decrease in agriculture, fallow land, urban green area and water bodies. The urban green area is reduced by 1.8% which was 7871.92 ha in 2008 to 7141.74 ha in the year 2015. There is an immediate need to take action for reviving the green areas in Delhi in order to keep the environment healthy. The green cover on the either side of the drain area should be maintained as it helps in arresting the soil erosion, remediation, minimization of salinity and improvement in the water quality. There is conversion of pervious surface into impervious which affects the ground water table tremendously. Authorities have identified the location for ground water recharge and those areas needs to be conserved and preserved for the sustainable management of natural resources. The current demand of water as per the recent estimates of Delhi Development Authority, is about 1511 billion liters with the shortfall of about 450 billion liters. The diminishing shallow water bodies also need to be conserved and revived that will also help in ground water aquifer recharge. Holistic approach should be adopted for urban development to appropriately preserve the areas under all land use classes considering the ecological and environmental services.

The effect of rapid urban expansion has been observed on increasing the vulnerability and risk towards the occurring disasters. The non-implementation of developmental plans and violations of regulations can be deemed as the root causes that have led to haphazard development at various locations. The in-situ development of adjacent buildings contributes to frequent building collapse incidences. Hence, the research concludes that in the context of urban expansion, it is imperative to follow and continuously monitor the proper implementation of the prescribed rules and regulations as laid by the government. Urban expansions should be sidelined with proper norms and guidelines for physical infrastructure as a part of master plan with effective enforcement.

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