Journal of Indian Geomorphology
Volume 6, 2018 ● ISSN 2320-0731
Indian Institute of Geomorphologists (IGI)

Urban Geo-forms: Concept and Significance in Anthropogeomorphology

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Abstract: *The recent rates of urbanisation have exceeded all the past records in many countries of the world. The numbers, problems and perceptions of urban landscape are essentially man-centric. In this paper, the concept of urban geo-forms is highlighted and classified as per the observed features in Kolkata Megacity situating in the humid tropics. In the Anthropocene Epoch, artificial forms created by urban materials and processes vary with the surface extent, scale and dynamicity. As these anthropogenic features are often caused by surface deformations, they may result in urban hazards like water-logging and subsidence, and also accidents due to uneven surfaces. Since its initiation, Kolkata Megacity has undergone geomorphic changes and water surface degeneration. The study of urban geo-forms and land use change is therefore, of current importance in hazard management, planning and urban development issues.*

Introduction

Humans' are now the most active geomorphic agent to shape and re-shape the face of the earth by altering the physical landscape. This changeover is more prominent as rural land use/ land cover (LULC) is being converted to give space for urban infrastructure. Expansive urbanisation is taking place throughout the world and more rapidly in the developing countries of the humid tropics. This has provided immense scope for urban geomorphology to become a potential branch of modern geomorphology. 'As such, humans are geological and geomorphological agents and the dominant factor in landscape evolution in the Anthropocene' (Zalasiewicz *et al.*, 2010), which is mostly through establishment of settlements and widespread industrial-urban activities. The post industrial revolution urbanisation is perhaps, the most significant aspect of the Anthropocene Epoch (Harden *et al.*, 2013), in which anthropogeomorphology has been given a distinct identity (Brown *et al.*, 2012) in the form of urban geomorphology.

The traditional application of geomorphic knowledge for planning and management of urban centres has incorporated concepts of environmental and engineering geology. However, the study of contemporary urban geomorphology must seek to understand the urban surface topography and processes of change whereby man can modify a more natural terrain to an anthropogenic landscape. It further needs to focus on the urban patterns and functions and their influences on the development of geo-forms and hydro-geomorphic features. Urban zone management calls for evaluation and risk assessment due to location-specific urban

geomorphic problems and hazards.

The term 'urban geo-forms' is being used here to refer to any urban surface that was not intentionally built in a planned manner but is an outcome of human alterations on the land surface within the assigned habitable limits. Changes in slope character, land use, soil character, river channel geometry, land subsidence and other features developed due to human modifications, can all be included within this term. The main driving force in the development of urban geo-forms is anthropogenic activity.

Objectives and methodology

This paper aims to classify urban geomorphic forms and identify the process responsible for their development.

Since the present work is more conceptual than empirical the methodology is mainly concerned with review of relevant literatures. However, field surveys have been carried out in some representative spatial units within the Kolkata Metropolitan Area (KMA) to understand the functional aspects of the geo-forms.

The methods, therefore, consists of observation though site visits. The work is mostly based on personal experiences of the authors having more than two decades of living in the city and a keen interest on the subject for more than five years during which information and data on various aspects of urban geomorphology of Kolkata have been collected.

Development of urban geo-forms in the humid tropics

The humid tropics is a collective name for the region between the Tropic of Cancer and Tropic of Capricorn, that experiences high solar radiation, continuous heat, high rainfall and widespread vegetal growth, often resulting in high population densities (Gutiérrez, 2005). More than about 33 percent of the world's population is said to reside in the humid tropical region (Bonell *et al.*, 1993). But the living conditions in terms of access to resources and amenities of a reasonably good standard are concentrated only in some selective pockets of large town and cities, leading to uneven development. Water sources, primarily the rivers and large water bodies, play crucial role in the urban growth, which are often characterised by rapid and unplanned expansion, high density of population, ill-maintenance of urban structures and unscientific modifications of the natural geology and geomorphology of the areas (Gupta and Ahmed, 1999). The dominant process that operates in the urban humid tropics is human activity.

Process analysis in geomorphology is included in the framework of process-response systems, in which the process is the working geomorphic agent and the response is the resultant landform. Process analysis may include different approaches, according to the variety of existing geomorphic environments (Goudie, 1981 and 2006). The study of processes promoted a drastic reduction in the spatial and temporal scale records and analysis. It has been argued that "many of us mistake landscapes altered by humans in the past for wilderness that never experienced substantial human influences, and that this misperception hampers our ability to understand the intensity and extent of human manipulation of Earth surfaces" (Wohl, 2013).

The surface of the land is an important resource which human activity is constantly modifying. Rapid population expansion has placed great demands for living space leading to increasing urbanisation and exploitation of marginal lands. The type or scale of modification depends on the level of urbanisation, technological and socio-economic development in the society and government policies. The annual

construction, re-modelling and shift of sediment have contributed to the generation of 'artificial ground' (Price *et al.*, 2011). Various anthropogenic processes that operate in changing the urban topography can be classified as — direct impacts and indirect or unintentional impacts. Direct modifications may include digging for planting of underground lines or pipes, cut and fill surfacing, transfer of materials for construction and layering of roads and pavements. On the other hand, indirect modifications include dumping of wastes, disintegrating of building materials, collapsing or subsidence of surface layer, degenerating channels/ canals due to sedimentation etc.

Classification of urban geo-form elements

Classification based on spatial extent

Based on the experiences of Kolkata Megacity, a seven-tier classification of the spatial extent of the urban surface limits have been deduced for the study (Table 1). The mega-level includes the city along with its fringe areas, satellite towns and green belts. It may also be referred to as a territory, county or municipal area. The macro-level refers to the city, township or a municipal corporation area boundary. Meso-levels extend over a smaller area of 10–200 km^2 and are known as borough boundaries, cantons, communes or census divisions. At mini-level individual wards, census subdivisions of about 1–10 km^2 has been taken into consideration, while at a micro-level the neighbourhood area of less than 0.5 km^2 area is delineated. The lower-most tier is assigned to the household level of about 100 m^2 and may be referred to as the *nano-level*.

Classification based on dynamicity or period of existence

According to the dynamicity or period of existence, urban forms can be classified as *sporadic geo-forms* that last for a day to a month; *short-period geo-forms* lasting for about a year, *medium-period geo-forms* remaining for about five years or so, while

Table 1. Classification of the spatial extent of the urban surfaces with reference to Kolkata city.

Level	Nomenclature of the urban spaces with examples	Area (km^2)	Number of urban population involved
I	Mega (Kolkata Metropolitan Area)	2000	15 million
II	Macro (Kolkata Municipal Corporation)	200	5 million
III	Meso (Borough XIV of KMC)	10	500 thousand
IV	Mini (Ward 121 of KMC)	1	60 thousand
V	Micro (Neighbourhood)	0.05	4 thousand
VI	Nano (Household)	0.0001	10

Table 2. Classification of Urban Geo-Forms According to Period of Existence

Periodicity	Duration	Features
Sporadic	1- 4 weeks	Pole hollows, seasonally water-logged depressions, accumulated hazardous obstructions, rubbish hump and material stacks
Short-term	1-12 months	broken surfaces, pipeline trenches, potholes
Medium-term	1-5 years	Open pits, ditches, undulations
Long-term	> 10 years	Open drains, clogged canals, bridges over open channels leading to sedimentation.

long-period geo-forms have ten years or more lasting time. Arguably no geo-form can be permanent in an urban set up, but the relative permanency or non-permanency depends on the processes of urban renewal and re-development.

Classification based on function

Urban surfaces can be classified into four major types — a) transport line surfaces, b) constructed plots, c) open plots and d) natural water channels. Transport line surfaces are those that have been raised and overlain by asphalt, cobbles, boulders or bricks to make them permanent structures over which different modes of transport can commute. These surface networks are almost instantly identified in an urban area and form the main life-line of the urban limits. Levees, embankments and higher dry paths are best preferred for such structured surfaces. The next prominently identifiable feature is the constructed plots. Buildings for residential and commercial purposes, archaeological forms and monuments all are classified within this group. The layout and architecture of these constructed plots reflects the socio-economic character of the urban surface. The open plots and water bodies include parks, squares and fields still bears some of the natural character of the land, while the water bodies marks the characteristics of groundwater table, natural slope and elevation of the area.

According to the spatial scale of exposure, Urban Geo-forms can be categorised as follows (Table 3):

SCALE 1 categorises those features that may vary with respect to the importance and connectivity of the city such as siltation of the river channel, water-logged regions, alteration of surface slopes etc. that extends over a large portion of the cityscape.

SCALE 2 is designated to such features that have a moderate area of exposure of about a borough area and include land subsidence, erosion of road surface, water-logged depressions and other relatively larger urban geo-forms.

SCALE 3 can be assigned to those geo-forms that affect a lesser number of

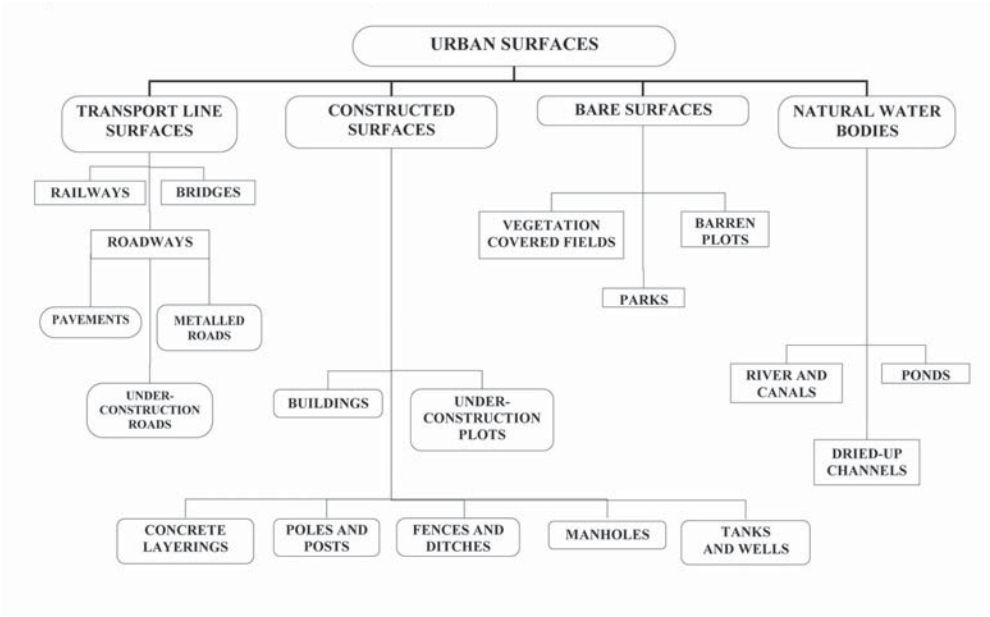

Figure 1. Classification of Urban Surfaces (as in Kolkata)

populations, around a neighbourhood area. This category includes features such as clogging in open drains, ditches along roadsides due to surface failures, degraded pond borders, cracks and broken surfaces.

SCALE 4 refers to geo-forms around a building complex like open man-holes, degraded speed breakers, road cobbles and undulations, debris humps, etc.

SCALE 5 miniature geo-forms that affect only few people, mainly the household members residing near the geo-forms such as broken thresholds, raised road levels compared to that of the houses etc.

All urban geo-forms are included in any one of the above sub-categories according to location whether *in situ* or *ex-situ*.

Identification of urban geo-forms in the Kolkata metropolitan city region

In broad sense, Urban Geo-forms are the surface relief features developing in an urban landscape. In recent studies, anthropogenic surfaces producing the geo-forms are identified as 'artificial grounds' with the major classification of 'made grounds', 'worked grounds' and 'in-filled grounds' to represent erected structures, engraved formations and dumped materials respectively (Price *et al.*, 2011). These features are of relatively permanent nature, having gone through significant geological and geomorphic changes on the natural landscape of a particular geographical area, usually depicted in large scale maps. Kolkata city too has under gone distinctive modifications since its initiation. The urban development of Kolkata and its adjoining areas (now under the KMA) started some 300 years ago with the arrival of the East India Company in 1686. The land was then part of the active delta plains of the river Ganga, with the presence of numerous creeks, salt marshes and flood plains. Initially the levees and other relative highlands were chosen for settlements that started to expand by clearing forests and filling up of low-lying areas. The spatial dimensions of the city of Kolkata (previously Calcutta) markedly increased from a 7 km^2 in 1706 with only 120,000 persons to 95.62 km^2 in 1955 and currently 187.33 km^2 in 2011 with 4,496,694 persons. In 1991–2001 census period the population growth rate was 3.98% which reduced to –1.67% in 2001–2011 in the core areas of the Kolkata Municipal Corporation (KMC). This shows that the KMC limit has reached its capacity to accommodate the population and people are now moving out to occupy the fringes in the relatively low-lying wetland areas of the city.

Table 3. Classification of urban geo-forms according to extent of exposure

Scale	Area of Exposure	Population affected	Examples of urban geoforms
1	1 km^2	>100,000	Urban flooding and water-logged regions, Alteration of surface slopes, Land use conversions and Urban sprawl over agricultural fields or open fields
2	1–0.5 km^2	50,000	Land subsidence, weathering and erosion of road surface and building materials, water logged depressions
3	500–200 m^2	10,000–1000	Clogging in open drains, Collapse of embankments and degraded water bodies, Cracks and broken road surfaces
4	50–200 m^2	100–500	Open man-holes, degraded speed breakers, road cobbles and undulations, debris humps
5	<50 m^2	10	Broken thresholds, raised road levels compared to the houses on both sides, pits and hollows

Source: Prepared by the authors

Urban geo-forms observed in many of the metropolitan cities in India can be categorised into *surface formations* and *surface failures*. Surface formations are those that are formed by dumps and over-topping of urban material whereby bringing positive change in the natural surface elevation or creating raised platforms. Surface failures involve processes such as mechanical wear and tear, tensional breakage, structural design failures and crumbling down of binding materials. Any type of surface deterioration has three general causes' — (a) Environmental causes including weathering, rainfall impact, ground tremors, erosion and aging, (b) Structural causes brought about by repeated traffic loadings and (c) Anthropogenic causes such as cutting, digging and piling without restoration.

The rate at which a pavement deteriorates depends on its environment, traffic loading conditions, original construction quality and interim maintenance. An average Life of Resurfacing Effectiveness (LRE) is about 8 years. The dust and water form the emulsion that temporarily acts as a lubricant leading to crevasses as well as polishing on the road surfaces, leading to skidding of traffic, accidents and related hazards. Total road length in Kolkata is around 2500 km. out of which only 200 km. roads have been given a mastic asphalt top coat since the last eight years. Insufficient routine, periodic or preventive road maintenance; ineffective, delayed or lack of repair of existing potholes and overloading by heavy vehicular traffic have recently caused collapse and subsidence of the road surface in some parts of Kolkata. This is more common in the areas underlain by brick-lined principal drainage lines.

The southerly extension of the city was a result of re-urbanisation and revitalisation when the fringe zones were brought under the jurisdiction of the Kolkata Municipal Corporation, in the year 1984. This part of the city is highly congested due to unplanned urban sprawl and immigrant pressure from the then East Pakistan during 1970s and now from the adjacent South 24 Parganas district. With the rise in land valuation, concept of nuclear families, change in housing preferences from sprawling bungalows to utility flats have changed the built-up character of the area where re-development is an essential drive. All these needs revitalisation of housing plots, transport system, roads, flyovers, footpaths, drainage networks etc. All of this

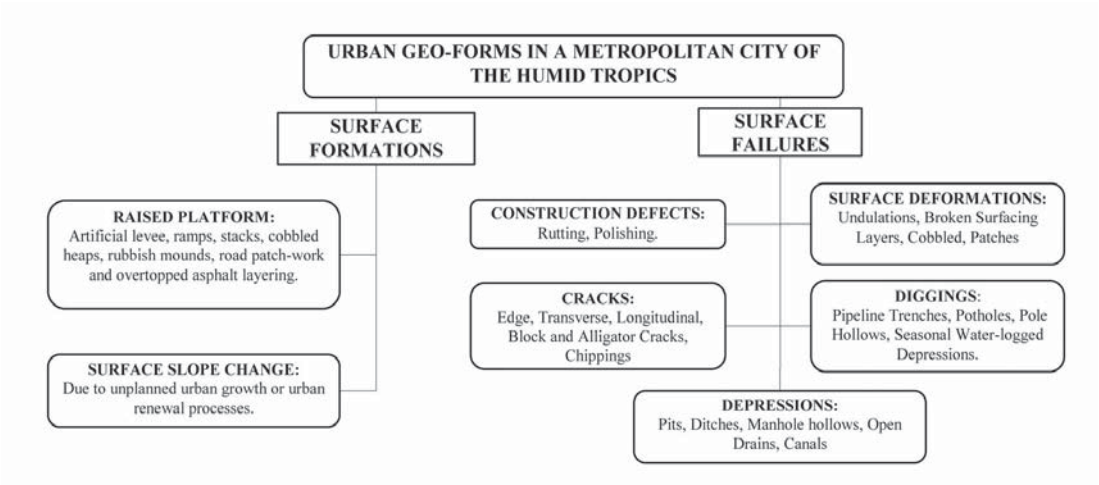

Figure 2. Categorisation of urban geo-forms as observed in Kolkata megacity

Table 4. Evolution of Kolkata and Its Impacts on Local Geomorphology (Source: Bose (1964), Dasgupta (1990)

	Important Developments in the Kolkata Megacity	Geomorphic correlates
Stage I: Prior to 1750	Shift of English trading site from Kassimbazar and establishment of Kolkata as a port city on the eastern bank of the river Hooghly at Fort William and the present CBD area.	Locating the township on a dry point of left bank levee of the river due to the decay of Saraswati river. Sloping towards SE marshes and distributary channels (Adi Ganga, Piyali and Bidyadhari).
Stage II: 1750 to 1799	Expansion of town to the east of river Hooghly 10 km N-S and 3-4 km E-W surrounding the inner core; isolated satellite towns develop along the river course: Chandannagore, Baruipur (NATMO, 2010). The Tolly's nala was excavated in 1780 for water transport and revenue generation. Circular road, the first metalled road in Kolkata, constructed in 1799.	The relatively narrow levee facilitated elongated growth of the town. Eastward sewer lines set up along natural slope and differential tidal fluxes.
Stage III: 1800 to 1859	Discontinuous rapid growth of 3-4 km outward from the Hooghly river, Kalyani to Garden Reach on the E and Bansberia to Shibpur on the W.	For wastewater flow from central and western part, canals were cut with its outflow in the river Hooghly towards the west.
Stage IV: 1860 to 1947	Continuous growth along the entire stretch with further extension of 1-3 km on both sides of the river; Rapid growth of Kolkata proper in north, south and east. Rail line developed.	Setting up of major road and railway line over the levees and further N-S expansion of the urban area. The channel degradation cut off out-flows through the easterly distributaries.
Stage V: 1948 to 1990	Road transport connected the new townships at Kalyani and Bidhannagore; Maximum growth in the entire area, especially towards Barasat and Baruipur (Bhatta, 2009); Average width increased by 5–15 km. Southern marshes reclaimed and Suburban areas evolved (as in Thakurpukur-Behala).	Filling up of the East Kolkata Salt Marsh began in 1950s and completed by 1980s resulted in a bowl-shaped topography across the east-west axis. One of the feeders of the river Bidyadhari dried up. The East Kolkata Wetlands (EKW) is used for organic sewerage-fed aquaculture (Bose, 1944; Ghosh and Sen, 1987)
Stage VI: 1990 to present	Planned townships at Patuli and Rajarhat- Kolkata New Town; Development of E. M. Bypass as N –S Corridor at the eastern boundary of Kolkata. Proposal for the Southern and Eastern Express ways. Much of the EKW, a Ramsar Site since November 2002, is now threatened by the promoters of realty sector as prices of land has gone very high in the area due to the presence of E M Bypass and Basanti Highway.	Illegal filling of the 'bheries' (fish ponds) are reported. Wetlands are being squeezed from three sides. Mass Urban Renewal Process leading to re-structuring of surface cover. Evolution of vertical expansion of the city. Most open drains converted to underground sewerage. Pavements, concrete–asphalt surfacing, speed breaks develop. Infiltration drastically reduced. Eutrophication, sedimentation and degeneration of all existing canals within Kolkata.

is now under the jurisdiction of Kolkata Environment Improvement Project (KEIP). The process will eventually lead to many changes in the existing geomorphology and hydrology of the area. With the filling up of the water bodies and decay of the drainage channels, the problem of urban flood and water logging will be further accentuated (Satpati, 2011).

Conclusions

The knowledge about urban landscape, hazards and management is important to achieve a stable urban environment. The intensity of man-land interaction is quite high in the urban areas. The interaction has prominent concerns for geomorphic and hydrological issues in the Anthropocene and there is a huge scope for urban geomorphic studies in the humid tropics, especially in India, where the urban growth is expected to play significant roles in the coming years. As Kolkata, like most other metropolitan cities in India is plagued with unplanned urbanisation,

studies on Anthropogeomorphology is expected to highlight the problems of human intervention in modifying the urban land use/ land cover. Urban renewal is found to be mostly a continuous cyclic process to adjust to the changes in local geomorphic and hydrological conditions. It is observed that topographical changes take place in steady-state equilibrium at local scales but there is a tendency towards meta-stable equilibrium at larger scales requiring urban redevelopment or relocation in the future. Thus, planners should be aware of both environmental as well as anthropogenic processes apart from socio-economic developmental approaches for assessing the probable hazards and conservations before altering the existing urban landscapes.

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Date received : 28 September 2016
Date accepted after revision: 1 September 2018