Proceedings of the Ninth International Space Syntax Symposium
Edited by Y O Kim, H T Park and K W Seo, Seoul: Sejong University, 2013

INTEGRATING LAND WITH WATER ROUTES:
Proposal for a sustainable spatial network for Keraniganj in Dhaka

031

Farida Nilufar
Bangladesh University of Engineering & Technology
e-mail : faridanilufar06@gmail.com

Labib Hossain
Bangladesh University of Engineering & Technology
e-mail : labib.hossain@hotmail.com

Mahbuba Afroz Jinia
Stamford University Bangladesh
e-mail : arch_majinia@yahoo.com

Abstract

Cities in the delta have unique spatial character being criss-crossed by rivers and canals. Keraniganj Upazila of Dhaka District is a settlement surrounded by two big rivers which are again connected by a canal network. The spatial network of Keraniganj, therefore, has got some significance due to its connectivity with the water-ways. However, as a result of many insentient manmade efforts, the water-ways of this settlement did not developed to any integrated system with the surface routes. Canals are being used as drainage channels or being filled up. Moreover, seasonal floods have detrimental effects on the land-use and infrastructure. As a result the potential development of Keraniganj is being hampered. A new land-use proposal under Detailed Area Plan (DAP) is in process of implementation. Besides, the inhabitants are trying to develop their own solution through a number of local roads. None of them, the professionals or the locals, ever takes the challenge to live negotiating with nature. It appears that the spatial characteristics of the existing and proposed network need to be explored in order to evolve a sustainable spatial network for Keraniganj.

This paper analyses the existing spatial network of Keraniganj and tries to determine the focal points for land-use development. Taking the existing and proposed land-use in consideration, a comprehensive spatial network integrating the land with water routes are examined here. Besides, the impact of local roads of different hierarchy, those are developed away from the planning intervention, are also considered in association with the canal network. The total scenario has an incredible drawback due to regular and continuing flood in every year. It appears that the spatial network suffers from a conflicting situation as the integrated core, being located in relatively lower elevations, gets inundated by recurring floods. Some localized solutions are essential to overcome this situation. The canals, perhaps some selected branches, and part of the network of local roads needs to be identified to ensure a useful spatial network of a sustainable settlement. Finally, a sustainable spatial network is proposed for a water-woven geography of Keraniganj, which is integrated with the proposed land-use.

Keywords: *sustainable spatial network, integrated spatial system; waterways; morphology of city; space syntax*

Theme: *Spatial Morphology and Sustainable Developments (Others)*

1. Spatial sustainability of Keraniganj: A research problem

Generally in urban studies, sustainability of cities considered to depend on the spatial distribution of economic and related activity or, more commonly, through the concept of the ecological footprint, which essentially talk about population and living standards rather than about the spatial form of cities. However, Hillier argues that concepts of structure now need to be brought much more explicitly to bear on the key problem of the twenty-first century city, that of sustainability. Thus, a new concept of spatial sustainability focused on the geometric and configurational ordering of space in cities is predictable. In this theory, as Hillier argues, economic sustainability relates to foreground network and social & cultural sustainability to background network of the spatial structure; besides the environmental sustainability relates to both. (Hillier 2009) Here conceptually a dual generic form of the city is brought to light by space syntax, as a foreground network of linked centers at all scales set into a background network of largely residential spaces. Following this, Hillier argues that some generic ways of arranging the primary spatial structure of the city, that is its street network, might be more sustainable than others. This present research attempts to assess the spatial sustainability of Keraniganj, an Upazila in Dhaka, through the understanding of its deep structure, comprising the land and water routes.

Water network of rivers and canals has significant impact on the cities in delta for environmental, as well as functional reasons. Like many other cities of this type, Keraniganj Upazila of Dhaka District represents an unique character. This settlement is surrounded by major rivers and intertwined by a canal network. The spatial network of Keraniganj, therefore, has attained certain impact due to its connectivity with the water-ways. In spite of such an important natural position, unplanned settlement development and the recent process of filling-up of the flood retention ponds and canals, offer a great threat to the environment of Keraniganj. Besides, the canals and the river routes have not taken in consideration in transport planning. The present scenario of Keraniganj has an incredible drawback due to regular and continuing flood in every year. For the safety of total environment of Keraniganj, a proper development plan should be implemented.

The present research tries to find out the possibility to regain the natural ecological system in the life of the people with a goal towards sustainability. Taking the existing and proposed land-use in consideration, a comprehensive spatial network integrating the land with water routes are examined here with the help of Space Syntax. Different scenarios are assessed here through spatial analysis; and finally, an integrated spatial network is identified for the water-woven geography of Keraniganj which might be more sustainable than others.

2. Study Area: Keraniganj

Keraniganj is a sub-district (Upazila), which lies at the third tier of regional administration in Bangladesh. It includes 11 Unions/Wards, 123 Mauzas/Mahallas, and 399 villages. Keranigonj Upazila lies on the western bank of Buriganga and Dhaka City, the capital of Bangladesh, is on the opposite bank. Thus, Keraniganj is one of the closest suburban areas of capital city connected by three bridges over Buriganga River. In spite of its proximity to national capital, Keranigonj is far backward in respect of development. Even so, Keraniganj Upazila has a relatively higher population density (4760 person/sq km in 2011) compared to national average (1142.29 person/sq km in 2010) and population growth rate is 2.75%/year (2001 → 2011) in comparison to national growth rate (1.566%) for the same period. To accommodate the population pressure Keraniganj is facing a development boom, although unplanned and haphazard. Demand of low-income and middle-income housing near the city core accelerates its

development taking up its low-lying lands, simply filling them up, running street grids, making plots .Government plans to include Keraniganj within its development scheme and proposed some development projects as part of the Detailed Area Plan (DAP)[1] under the Dhaka Metropolitan Development Plan (DMDP) with a view to expand Dhaka City on the other side of Buriganga. Besides, a major national highway passes through Keraniganj, Dhaka-Mawa Road, indicating a strong connectivity from Dhaka to the southern regions of Bangladesh. However, given the development proposals the ecological setting of Keraniganj is significant, which needs to be considered in development planning.

2.1. Ecological setting and existing situation

Keraniganj is surrounded by a ring of rivers; Buriganga and Turag at east and north and Dhaleshwari at west and south. Natural levee, land at higher elevation exists mostly along the banks of rivers but most of its central parts are lowlands. A number of canals are running through Keraniganj and settlements are developed in between like connected islands. Besides, a number of ponds also exist in the eastern part of the area. Indeed, Keraniganj stands in wetlands and its settlements may be termed as wetland habitat. Ecologically, Keraniganj has also another important value. It is one of the flood flow zones in Bangladesh and provides a huge protection from adverse hydraulic effects on human lives in Dhaka city. Besides, Keraniganj is landscaped with large agricultural fields. The total 166.87 sq km area has an intensive agricultural value ensuring food security to adjacent urban areas. Even so, due to unplanned development the total ecological situation of Keraniganj is dreadful.

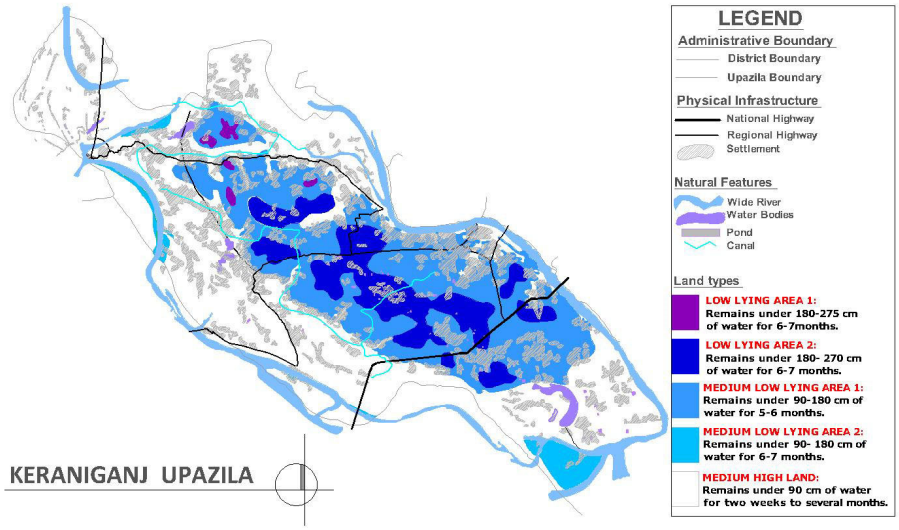

Figure.1 Map of Keraniganj Upazila with natural features - lowlands, canals, rivers.
Source: Survey Map, Detailed Area Plan, Keraniganj (2006)

2.1.1 Flooding

Due to unplanned development, Keraniganj greatly suffers in want of proper channelized canal system and flood retention pond. In spite of its being the sub-flood flow zone of Dhaka city, Keraniganj cannot provide adequate support. Even the medium high lands and roads are also being annually flooded. Two flood retention ponds, as proposed in DMDP at Zinzira area (see Fig

[1] The Detailed Area Plan (**DAP**) is third and last tier of Development Plan for Dhaka City i.e. Dhaka Metropolitan Development Plan (**DMDP**). It provides more detailed planning proposals for specific sub-areas compliant with the Structure Plan and the Urban Area Plan. The general objectives of DAP are to implement the provisions of the DMDP Structure Plan (SP) and Urban Area Plan (UAP) policies and recommendations.

07), have been encroached. That's why the water is over flown. Although there are some low lands where up to 270cm water logging can be occurred, but they are of no use as flood retention pond because of inadequate canal system and filled up areas. As a result, roads connecting important land uses, like Upazila Headquarter, remains under water for a considerable time in monsoon. Following table shows the intensity of flooding in different Unions of Keraniganj.

Table 1: Union wise households by flooding status during severe floods in 1998 & 2004
Source: Household Socio-Economic Survey, DAP for DMDP, Part of Group-D, 2006.

Year	Flooding Status	Hazratpur (%)	Kalatia (%)	Taranagar (%)	Total (%)
1998	Flooded	**92.06**	**74.86**	**100.00**	**88.85**
	Non Flooded	7.94	25.14	0.00	11.15
2004	Flooded	**84.92**	37.85	23.66	**44.58**
	Non Flooded	15.08	62.15	76.34	55.42

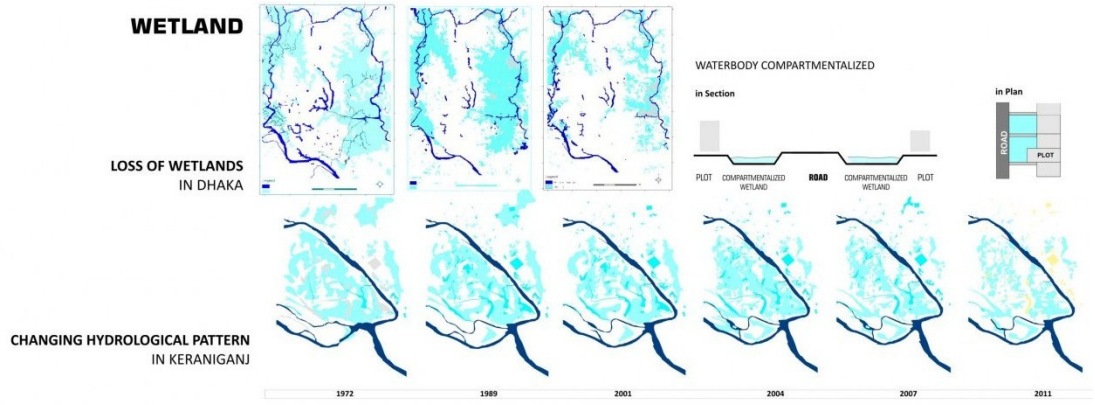

Figure 2 GIS and RS Map Analysis showing Dhaka's loss of wetlands and water bodies and that of Keraniganj with a timeframe from 1962-2012. Source: Islam et, al (2010) and Hossain (2012)

2.1.2. Land Development Process

Though at riverside, haphazard filling and development in Keraniganj has got a momentum in recent decades. As part of a process of aggressive urbanization, the booming housing projects are filling sand extracting from riverbeds. This type of land filling often hamper smooth flow of water causing water logging which results in flood or increase the duration of flood. In absence of proper guideline in land development, developersare following typical plot-based development which have compartmentalized the waterbodies and are hampering natural drainage of Keraniganj. At first, the given plot is being elevated to make the entire plot flood-free with boundary wall and then an earth-mounted road is constructed connecting adjacent 'pucca' road. In this process, great number of road segments in Keraniganj encroach wetlands which has altered the features of wetlands/swamplands and may cause destruction of wetland habitat.

2.1.3. Lack of Drainage and Water logging

In Keranigonj, forcefully elevated roads interfere with cross drainage and causes flooding or drainage congestion in adjacent areas during periods of high precipitation. This causes crop damage, water pollution and sometimes permanent loss of agricultural lands.

2.1.4. Erosion and Siltration

The constriction of waterways by road and road structures in Keranigonj increases velocity of flow to cause erosion during floods and subsequent siltation in the downstream. Improper drainage also causes erosion of road surface and side-slope during rainy season exerting adverse

impact on adjacent lands.

Figure 3. Ecological scenario in Keraniganj
From upper left: 1. Agricultural land being transformed by sand-filing (2011) 2. Developers' signboards on transformed land (2011) 3. Lifeless desert filled with sand (2011) 4. Canals being encroached (2011) 5. Internal Road being inundated during flood (2004) 6. Major high-way got inundated during flood (2004)

2.2. Transportation and Communication: Land and Water routes

Keraniganj has a special ecological character in which canals are intertwined with road system. But like many other settlements of Bangladesh, here the manmade roads are elevated from the ground level to get rid of seasonal flooding. Besides, the canals with natural water flows remain disintegrated from the spatial network. Although known as a riverine country, the inland water ways are always getting less emphasis in the context of Bangladesh. (Jansen, 1989) The traditional role of canals and rivers for water-based transportation is extinguishing in Keraniganj. Here, it is important to note that a great number of culverts are being constructed in Keraniganj to have an unobstructed movement devoid of the canal network. Thus the man-made system tries to run ignoring the ecologically friendly system. However, in many cases, inhabitants directly elevate the land and construct roads, even through the canals or in low lands.

2.2.1. Roads

The area is low lying and flood prone and development requires substantial landfill. Roads are generally narrow, insufficient and unsuitable for vehicular movement. Based on state of construction, roads are Pucca (paved) or Kutcha (unpaved) in Bangladesh. Besides, based on nature of use there are three types of roads at present in Keraniganj. They are Primary roads; Secondary roads (paved and unpaved at Upazila and Union level) and Tertiary roads (paved and unpaved roads at village level). Keraniganj's primary network consists of national and regional highways; and basically connects the major land uses (like administrative centers, growth centers etc) inside the Upazila and outside. In the second tier there are paved roads at the Upazila and Union level; i.e authorized roads. Local authority also has some planning and in this process some unpaved roads are being demarcated for future development.

Beyond this network of authorized roads, some roads are developed by the local people in an unplanned way along with their land development. These roads are mostly unpaved and scatted. They serve the individual rural settlements, sometimes sub-urban or urban plots, which are like isolated islands being surrounded by canals or low laying lands. These spontaneous roads help to connect the settlements with the authorized road system in an unplanned way. The initial construction of these unpaved roads is very peculiar; by elevating the land and obstructing the

natural flow of canals. Usually in public pressure, the local authority takes those unplanned roads under development scheme in due course of time. Thus these roads threaten the ecological setting permanently. Although close to capital city, the development control by proper development authority has been almost absent here. Due to coexistence of urban and rural settlement and administrations side by side, duplication and multiplication of transportation networks has created a very precarious scenario here in Keraniganj.

From axial maps, it is revealed that at present unauthorized Village roads (segments) are 1.6 times of authorized urban roads. Following table shows an emphasized part of Kutcha roads in Keraniganj and their comparison with other types of roads.

Table 2. Length of different types of Roads in Keraniganj
Source: Local Government and Engineering Department (LGED, 2007)

	Type of Road	**Length (km)**	%
a.	Pucca Road	180	26.50
b.	Semi Pucca Road	65	9.57
c.	Kutcha Road	414	60.97
d.	Bridge/Culvert	20	2.94
	Total Length of Roads:	679	100

2.2.2 Canals

Beyond the roads, a connected canal system is also prominent in Keraniganj. At present only a few branches are exiting, and are only used for drainage purpose. However, the flood plain of Keraniganj was intertwined with an extended canal networks which are extinguishing in course of time.

2.2.3. Rivers

Three rivers, Buriganga, Turag and Dhaleshhari, play a major role to connect to the regional river network of Bangladesh. There are traditional ports on the river banks, serving the local traffic by motorized and non-motorized boats. Five bridges over these rivers connect the road network beyond the boundary of Keraniganj.

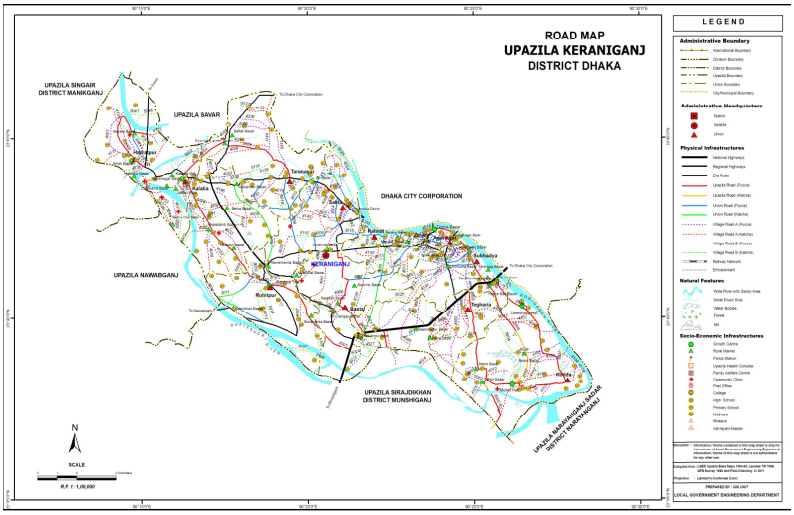

Figure 4. Rivers, Canals Road Network and Existing Land use : Upazila Keraniganj. Source LGED (2007)

2.3. Development Proposals: Ecological considerations and spatial network

Ecological considerations attained the highest priority in Planning of Keraniganj. DMDP Plan (1996-2005) has discouraged the development in the flood flow zone, given the direct flood hazards and the indirect impact on the river currents. In this situation the Government has undertaken the following policy decisions (Policy RS/3):

Flood – Flow Zones: Land development, within the designated flood plain areas of the DMDP Structure Plan, will be controlled in order to avoid obstructions to flood flow, which might otherwise result in adverse hydraulic effects, such as, for example, the rise of flood water levels and changes in flow direction.

Sub Flood – Flow Zone: Development compatible with the rural nature of these mainly rice growing areas, will be permitted on condition that the structures are built on stilts, or on land raised above design flood water level; alignment of structures and raised land to be designed so as not to disturb flood flow.

Flood Retention Ponds: Flood retention ponds are a key and critically important component of the proposed FAP 8A and FAP 8B flood protection schemes. The proposed retention ponds will be designed to reduce the intensity of local flooding within the protected areas and also reduce pumping requirements at times of maximum surface water run-off.

According to the guidelines the following proposals are given in DMAP;

- The extinguishing canal network of Kereniganj should be revived; and
- An integrated canal system should be introduced to carry the water properly so that they cannot be over flown.
- The existing low lands and large water bodies should be used as flood retention ponds with the help of the integrated canal system.

It is important to note that in spite of emphasis on ecological status of Keraniganj in DMDP, no direction is found regarding a spatial sustainability of its network. Under these circumstances, it is important to check the impact of the canals when revived and their compatibility with the road network. It is also important to see how far the integrated system, including roads and canals, can attain the goal of economic, functional as well as social sustainability. Besides, how the internal low-lying areas can be retained in its present status without hampering the functional networks and what can be the alternate communication system of the segregated spatial segments to ensure proper flow of flood. Most importantly, it is imperative to evaluate the ecological sustainability of this area over and above the levels of economic, functional or social satiability. This present research recommends the following propositions and tries revealing the impact of different options with the help of Space Syntax in the next part of the paper.

3. Methodology

Here morphological technique, "Space Syntax" [2], is used to examine the spatial network of Keraniganj and to stress the process of settlement development and its structures over the given state, therefore it attempts to looking at the entire built landscape and its internal logic. Space Syntax is used here as an analytical tool to understand the configurational properties of

2 **Space syntax** defines the degree of spatial order, which exist in organic and planned layout by analyzing the spatial configuration. This theory also proposes a fundamental relation between configuration of space in a city and that way that it functions. **Integration** is the relative depth or shallow ness of the system seen from any particular point within it. The integration value is then rank order in to seven integration band varies from red to blue to represent the degree of integration. The set of most integrated street are collectively known as **global integration core**. The nature of the integration core, its shape size, coverage and so on depends basically on the connectedness and geometry of the urban system and on its mode of growth.

the spatial structure that shapes the morphology of the settlement under consideration. This research also gathered land use data from published sources for evaluation. However, the research mainly focuses on the spatial analysis of Keraniganj by space syntax that will help to evaluate different spatial propositions. In space syntax analysis axial maps[3] were developed based on the settlement map collected from the Local Government Engineering Department (LGED)[4] and from Rajuk[5]. According to the administrative boundary, all the axial maps of Keraniganj has been processed in "Depth Map"[6] to reveal the attributes of the spatial structure and to find out the spatial measure of axial lines as an independent system and also as an integrated system with the canals and rivers. Later on, this will be compared to the existing and proposed land use pattern, ecological and geographical setting to evaluate the sustainability of different propositions. The study will attempt to identify the compatibility of different spatial networks to the land-use and geomorphic character of Keraniganj to determine a sustainable solution for the settlement developing there.

It is suggested that the conventional concept of Integration (for Global R=n, and for Local R=3) is suitable for measuring the to-movement potential. It shows accessibility or how easy it is to get to from all other segments. Besides, Choice (with diff radius) is suitable for measuring the through-movement potential since the measure describes how likely you are to pass through the segment on trips, and so it's potential as a route, from all segments to all others. (Hillier 2009) As geographically Keraniganj works as an island surrounded by rivers, therefore, choice (with diff radius) may represent its through-movement potential within the regional context. The national highway may have some contribution towards that end. However, this paper aims to assess the sustainability of total spatial network of Keraniganj by comparing their accessibility to different functional areas. Towards that end, the integration analysis will be helpful representing the foreground and background networks. Therefore, this paper tries to explore the integration pattern (R=n) of Keraniganj for different scenario in order to measure the to-movement potential of its spatial structure, thereby assessing the accessibility of different segments from all other segments to the functional areas. Within the conceptual framework of Space Syntax, four basic scenarios are being tested here. Later on the ecological sustainability of Keraniganj for different propositions will be evaluated.

Scenario 01: Major Spatial System: Primary and Secondary Roads only_325 Segments:

The primary network combining the national and regional highways and secondary roads at Upazila and Union level are considered here. Thus, in this scenario all the authorized urban

3 **Axial map** is the basis of layout analysis. This refers how far observer can have an uninterrupted impression of visibility and permeability as they move about town and look at distance towards the various directions. The map is derived by drawing the fewest and longest lines of uninterrupted permeability, which are necessary to cover all public open space of an area the size of the system is measured in terms of the number of lines. (Hillier and Hanson 1984)

4 Local Government Engineering Department **(LGED**) is a public sector organization under the ministry of Local Government, Rural Development & Cooperatives. The prime mandate of LGED is to plan, develop and maintain local level rural, urban and small scale water resources infrastructure throughout the country.

5 Rajdhani Unnayan Kartripakkha (**RAJUK**) is literally the Capital Development Authority of the Government of Bangladesh. RAJUK had been emerged through the ongoing crisis of planned and controlled development of Dhaka City. RAJUK established in April 30, 1987 by replacing Dhaka Improvement Trust (DIT). The prime intension of the organization was to develop, improve, extend and manage the city and the peripheral areas through a process of proper development planning and development control.

6 **Depthmap** is primarily a computer-based program to perform configurational analyses, which come under the umbrella term of `space syntax'. Space syntax analyses examine the relationships between components of space; each analysis starts with a representation of the spatial components, then makes a graph of these components, and finally analyses this graph using for the most part, conventional graph theoretical measures.

roads of Keraniganj are analyzed.

Scenario 02: Existing Spatial System: Primary, Secondary and Tertiary Roads _ 842 Segments:

In this scenario, all roads (including paved and unpaved village roads) of Keraniganj are analyzed. However, the canals or rivers are not considered here. Thereby, it holistically represents the existing land-based transportation network. Out of 842 segments, 325 belong to authorized roads (Primary and Secondary roads) and rest 517 to village roads (Tertiary Roads).

Scenario 03: Integrated System _ Major Roads and Canals _ 871 Segments:

In the recent road map of Keraniganj it has been revealed that lot of village roads are constructed in a scattered way destroying the canal system. It is argued from ecological point that the important drainage functions of this region, the lowlands to be retained and the canal system should be preserved. It is understood that the existing numerous rural roads in the low lying areas need be minimized and should be properly connected with the canal network to make an efficient spatial network. However, their present condition seems improper as being insensitive to ecology as well as for water-based transports. They need major shapeup; therefore, the scattered village roads (both pucca and kutcha) are excluded for the analysis to have an unbiased view without their interruption. The extinguished canal network, as proposed in DAP to revive, is considered as a new set of axial lines. Thus, in this construct, all authorized roads are being connected to the canal network by possible eleven ports and continuity of canals is ensured with seven segments of proposed canals. Besides, the spatial network of roads overlapping the nearby canals is disconnected at respective points to ensure natural flow of water/flood. Thus the axial structure of an integrated system, where major road network is connected with the water-based network, is constructed and analyzed by using Space Syntax.

Scenario 04: Extended Integrated System _ Major Roads with Canals & Rivers _927 Segments:

Impact of the surrounding rivers on transportation network of Keraniganj is immense for internal as well as external communications. Therefore, in this scenario a extended integrated system with all authorized roads including the rivers and canals is analyzed.

4. Integrating Land with Water routes: Analysis

Following the above mentioned frameworks, four different scenarios are tested below.

Scenario 01: Major Spatial System

This scenario with existing major roads of Keraniganj shows that global integration core (highest 1% R=n values i.e 0.4507 — 0.4490) lies along the major regional road running from Zinzira to Ruhitpur. This core is connecting Upazila Head Quarter and four local bazaars at Manda, Konakhola, Ramerkanda, Ruhitpur. Besides, an extended part of this core (highest 5% R=n values, i.e 0.4507 — 0.4129) connects this local spine with other important bazaars at Taranagar and Abdullahpur. Thus the global integration core connects directly to six important bazaars as shown on LGED map, which reflects the degree of sustainability of the spatial structure of Keraniganj in economic terms. These local bazaars have been identified as 'growth points' in DAP, therefore this primary network will have a constant importance on the future development of Keraniganj and this network may play a significant role to its economic sustainability. Besides, out of twelve Union head quarters, eight are being connected with the high value segments of global integration core (20% core). However, the accessibility to the National Highway, Dhaka-Mawa Road, and also those connecting the bridges from the internal roads are relatively poor, which indicates a weaker linkage from within to outside of Keraniganj.

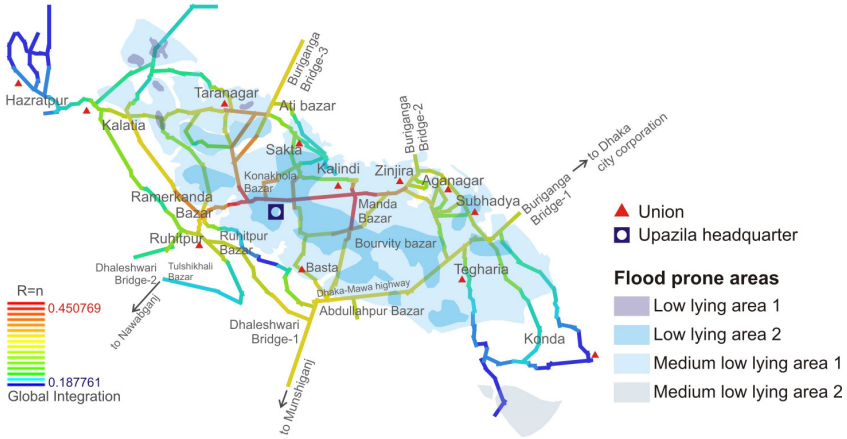

Figure.5. Global Integration (R=n) of major spatial system of Keraniganj _**Scenario – 01**

In spite of its economic and functional sustainability, a number of segments of this primary network remain scattered and also being affected by flood. Thus, in spite of land-use compatibility to a high degree, the global integration core of major spatial system is threatened by seasonal floods as lying in the flood prone area. Most importantly, the segment in front of Upazila Head Quarter is in the most affected areas and remains flooded in every year for a period. As a result, connectivity from Dhaka to Ruhitpur upto Dhaleshwari Bridge remains disrupted. Similarly, accessibility from rest of the areas to the administrative center is also remaining disrupted. It has been revealed here that the primary network of Keraniganj suffers ecologically to a considerable degree in spite of its economic as well as functional sustainability. However, social sustainability can not be assessed in this scenario devoid of its background network formed by the tertiary network of the settlement.

Scenario 02: Existing Spatial System

This scenario reveals that beside the authorized spatial network (comprising the primary and secondary roads), an unplanned network (combination of village roads) is being developed ignoring the ecological condition. Among 842 segments, Space Syntax analysis shows that 1% global integration core (R=n, 0.5949 — 0.5651; comprising 9 segments) coincides with the integration core as reveled in Scenario 01 (from Zinzira to Ruhitpur) and also includes two other branches towards Taranagar and Abdullahpur. However, global core connects Abdullahpur bazaar through a village road. Besides, Taranagar is also connected alternatively through another village road. Thus village roads, which are being developed in an unplanned manner, are affecting the spatial hierarchy of the primary network. Consequently, the economic sustainability of the primary spatial network becomes dependable on the village roads to some degree.

Figure 6. Global Integration (R=n) of existing spatial system of Keraniganj _**Scenario – 02**

Over and above, inclusion of village roads with the major spatial network of Keraniganj can not overcome the vulnerability of the global integration core of the land-based network during flood. In general, the village roads are short segments and connecting the scattered settlements on the periphery to the nearby authorized roads. Due to unauthorized land filling, in the central part the village roads also play some role to connect the primary network in an arbitrary way. These village roads are mostly segregated lines with lower range in integration. Apparently, such an order in background network is quite normal for any settlement. However, in case of Keraniganj, all these segregated lines are crossing the canals or running at certain elevation inside the low lying areas. Thus they are destroying the ecological balance and endangering the future development of Keraniganj being affected by floods during monsoon.

In this scenario the impact of National Highway is again degraded. The segments of Dhaka-Mawa Road only attain local importance (three segments become part of 5% R=3 core). Thus in this scenario accessibility to Dhaka-Mawa Road from the local roads has improved and more areas are being connected with this national highway through the village roads, which again endangers the inter-district traffic.

Scenario 03: Integrated System

In this network of 871 segments, canals comprise of 546. Here, the integrated spatial network of both the land and water routes represents a pervasive connectivity within and outside of Keraniganj. Its integration core (1% R=n: 0.4280 — 0.4134) coincides partly with the core as specified in Scenario 01 and 02 (from Zinzira to Ruhitpur); however, it also includes the national highway and regional roads in a more balanced way. Major change in this scenario is the split in the integration core, in which the regional and national highways obtain due importance. One secondary road acts as a connector of two branches of global core. Holistically, the roads of second tier plays important role by allowing accessibility to different parts of Keraniganj. The ring is formed with high value integration lines connecting the different growth centers like Zinzira to Tegharia via Ruhitpur and Abdullahpur in southern side and Subhadya in northern side. While considered for flooded situation in the centrally located low-lying areas of Keraniganj, this ring will ensure connectivity among all important land-uses of Keraniganj, both the administrative and economic centers. Moreover, this ring is constituted entirely by land routes and is connected with bridges towards Dhaka and southern part. As a result, this ring will ensure an easy access by vehicles from outside and inside of Keraniganj. It is also important to note that the low-lying areas at the central part as well as in peripheral areas, which are mostly preferred for agriculture, are also connected with other parts of Keraniganj and towards the bridges though this integrated network. This will ensure easy transportation of agricultural products to support the nearby urban areas for food security. Thus this scenario ensures sustainability of the integrated network in economic and functional terms.

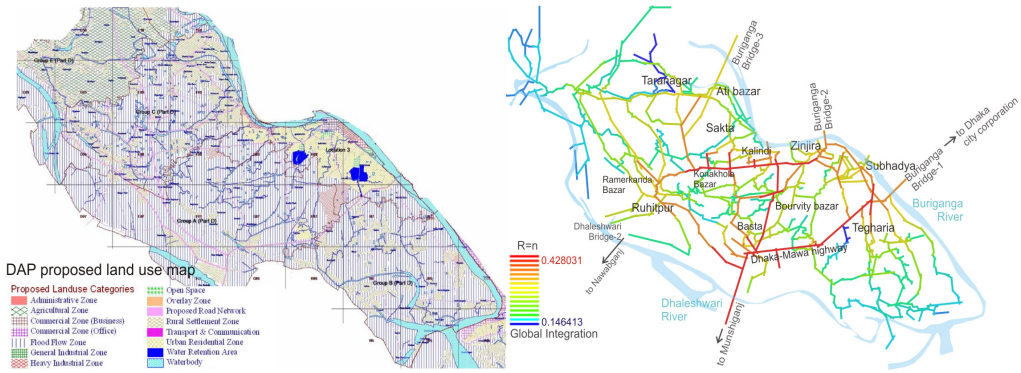

Figure7. Global Integration (R=n) of integrated system of Keraniganj **_Scenario – 03**

Besides, the ecological situation is also being addressed by the integration of canals with the land routes in a unique way. In this scenario, the local integration core (1% R=3: 1.73794 - 2.03269) is scattered and rarely coincides with high value global lines, except the national highway. It is revealed that the canals, which are mostly located in the central part of Keraniganj, obtain lower integration and remain segregated globally. Thus it can be argued that in this scenario the water-based transportation network will support the localized trips by boats and can continue their role during floods ensuring ecological sustainability of the integrated network. Moreover, the intersections of land and water routes at the proposed ports (ghats) may develop as vibrant local nodes. However, the navigability of canals, particularly during dry and wet (flood) seasons needs to be ensured by appropriate technology.

This integrated system basically integrates the existing bazaars and dispersed settlements. However, the functional core of Keraniganj, as proposed in DAP, consisting of heavy industry and mixed used zones towards north on the bank of river Buriganga will remain less integrated from the spatial core of the integrated system. This seems to happen as the traditional transport routes via the big rivers of the riverine country being disregarded in this system. Therefore, the river routes are considered to construct the next scenario to test this hypothesis.

Scenario 04: Extended Integrated System

In this scenario the major roads of Keraniganj with canals and rivers are considered. This extended integrated system consists of 927 segments, of which roads are 325; canals are 546; and major rivers (like Buriganga, Turag and Dhaleshwari) comprise of 56 segments. In this scenario, the global integration core shifts towards north close to bridges towards Dhaka, the capital. Its 1% global core (R=n: 0.5150 — 0.4935) lies along river Buriganga and partly on regional roads from Zinzira to Konakhola bazaar. Besides, an emphasis also lies on the national highway. However, this scenario generally indicates an externalized face of Karaniganj and indicates to explore the potentiality of its strategic location, which is close to national capital and being bounded by big rivers. Rivers act traditionally as the major transport routes in Bangladesh. Here rivers pick the hold on the global core and indicates their importance in the spatial network in a riverine country like Bangladesh. Besides, its local integration core (1% R=3: 1.83628 - 2.12948) picks a few segments from rivers; and they also high lights a few segments of national and regional highways.

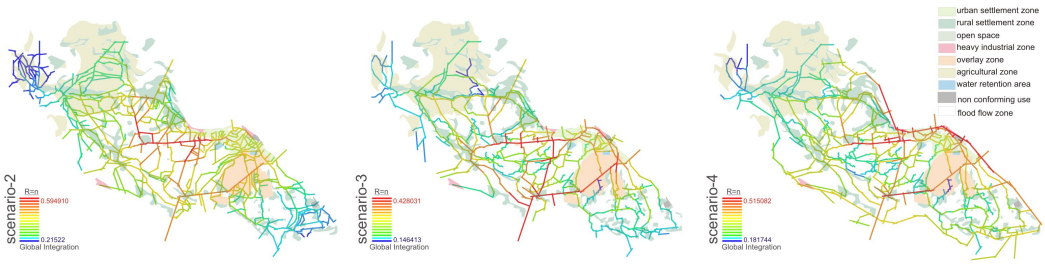

Figure 8. Different Integration (R=n) pattern of Keraniganj **_Scenarios – 02, 03 & 04**

5. Integrated System: A sustainable spatial proposition for Keranigan

The spatial sustainability focuses on the structure of the primary spatial structure of the city - the street network- which is internally derived, rather than externally imposed, descriptions. (Hillier, 2009) Thus the integration pattern derived through spatial analysis identifies the key underlying structures in the city which has a direct bearing on sustainability. Following Hillier, the spatial form of the self-organized city, like Keraniganj, can be considered as a foreground network of linked centers at all scales set into a background network of mainly residential spaces reflecting the relations among environmental, economic and social forces, that is

between three important domains of sustainability.

A comparison of different scenarios reveals the drastic change of the extended integrated system from the previous options. The compatibility of different scenarios are compared here with DAP proposed land uses in Keraniganj. (Fig: 08) In scenario 02, a large number of village roads has encroached the agriculture and flood flow zones endangering the ecological sustainability of Keraniganj. In scenario 03, the integrated spatial network shows a distributed pattern and connects the foreground network with land routes and background network with the canals. However, in scenario 04, integrated network of the land and river routes represents the foreground network; in parallel, the background network is supported by canals. However, the village roads, mostly segregated in nature, may be added to this scenario according to uses' need. Being disconnected in nature, those local roads may not hamper the spatial hierarchy in areas like Keraniganj.

Finally, it appears from scenario 01 and 02 that the present spatial network of Keraniganj suffers from a conflicting situation as the functional core gets inundated by recurring floods and sustainability of the spatial network, in environmental as well as functional terms, is being endangered. Besides, the insensible interventions of the local people though spontaneous landfills led the local network to remain disjointed and segregated. In the proposed networks of scenario 03 and 04 it have been revealed that the integrated system of water and land routes are compatible to the environmental, economic as well as social features of Keraniganj Upazila, thus presenting a sustainable spatial network for the settlement under consideration. However, these propositions can be considered as general frameworks. At this stage, the followings points can be identified as significant aspects leading to some propositions in ensuring spatial sustainability for the water-woven geography of Keraniganj responding to its existing as well as proposed land-uses.

i. All authorized roads, combining the national and regional highways and secondary roads at Upazila and Union level are to be considered as the 'primary network' in Keraniganj. Its spatial integration core coincides with the local administrative core as well as connects the local bazaars i.e the proposed 'growth points'. However, this primary network itself is not sustainable as being inundated by annual flood.

ii. For spatial sustainability, the extinguished canal network along with the present network needs to be revived. The canal system needs to be integrating with the primary spatial network through introducing ports (ghats) at some strategic points.

iii. To ensure the functioning of flood flow zones, the canal network, where ever crosses the roads, needs to be disconnected from the street network through grade separation. Thus the canal network needs to disintegrate for environmental sustainability, whereas this needs to be integrated with the primary street network at strategic points to ensure accessibility.

iv. The river based routes needs to be connected with the primary spatial network by developing the port facilities.

v. Segregated and scattered local roads need to be discouraged and local communication by boats can offer a sustainable solution for Keraniganj.

References

Dani, A. Hasan. 1956. *Dacca: A Record of it's Changing Fortune*. Dhaka: Asiatic Press.

Hanson, Julienne, and Bill Hillier. 1984. *The Social Logic of Space*. Cambridge: Cambridge University Press.

Hillier, Bill. 2009. "Spatial Sustainability in Cities Organic Patterns and Sustainable Forms." *Key Note paper published in the Proceedings of the 7th International Space Syntax Symposium,* edited by Daniel Koch. Lars Marcus and Jesper Steen. Stockholm: KTH.

Hossain, L., 2012. "Living with Water - Adaptive Housing In Lowland: Balancing Natural Process and Urban Development in lowland around Dhaka City in Bangladesh." Dissertation. B.Arch Final year. Department of Architecture. Bangladesh University of Engineering and Technology,

Islam, S., R. Rahman, Shahabuddin, and R. Ahmed. 2010. "Changes In Wetlands In Dhaka City: Trends And Physico-Environmental Consequences." *Institute of Environmental Science*. Department of Geography and Environmental Studies. University of Rajshahi, Rajshahi 6205, Bangladesh.

Jansen, Eirik G., et all. 1989. *The Country Boats of Bangladesh.* Dhaka: The University Press Limited.

Mahmud, M. S., A. Masrur, A. Ishtiaque, F. Haider, and U. Habiba. 2011. "Remote Sensing & GIS Based Spatio-Temporal Change Analysis of Wetland in Dhaka City, Bangladesh." *Dhaka: Journal of Water Resource and Protection* 3: 781-787.

Novak, J. 1994. *Reflections on The Water: Bangladesh*. Dhaka: The University Press Limited.

Government of the Peoples Republic of Bangladesh. 1993. *Final Report, Dhaka Metropolitan Development Planning (DMDP)*. Dhaka: RAJUK.

Government of the Peoples Republic of Bangladesh. 2010. *Final Plan Report, Detailed Area Plan (DAP), Group D (Keraniganj)*. Dhaka: RAJUK.