485

Urban Grid and Accessibility of Proposed Metro Stations in an Organic City: Using Space Syntax as an Analytical Tool

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ABSTRACT

Accessibility is an important influencing factor for the efficient functioning of a metro system. Among multifaceted metro accessibility indicators, this study concentrated upon the configurational analysis of the local street network to assess the accessibility condition of the proposed metro stations (Motijheel & Karwanbazar) along the MRT Line-06 in the CBD context of Dhaka city. In early-stage planning, accessibility plays a significant role in deciding the location of a metro station that facilitates the efficient transfer of passengers to local destinations. In the case of Dhaka city, it is a technical challenge here to set a strategic location of a metro station considering the organic morphology of the city and promote a pedestrian-friendly station precinct. Space syntax methods have been applied here as a scientific tool to assess the accessibility pattern of that organic urban structure in a data-scarce context concerning local pedestrian movement. A set of syntactic measures (axial and VGA) including the value of integration, connectivity, choice, and visual integration were compared to the pedestrian movement data using statistical correlation to interpret the degree of accessibility around the proposed station and recommend an accessible location of the proposed station within their morphological context.

Statistical analysis revealed that the area with a higher visual integration core and a permeable grid network shows more correspondence with the local movement. Hence, these spaces can be considered to locate the proposed station along with its major entrance points to enhance the degree of accessibility to the proposed station. In addition, the observation study suggests that land-use factors such as the location of high-rise buildings, bus stops, and street vendors also play an important role as an independent attractor to generate significant movement. Thus, it creates a multiplier effect when aligned with highly integrated lines that need a further detailed investigation in this regard for a more accurate interpretation of metro accessibility. However, this method can be used as a scientific tool for assessing the access pattern of the urban grid and

supporting the planning process when needed. In addition, this study can help the planners, design professionals and relevant authorities to focus on improving accessibility and deciding the location of the metro stations in a data-scarce organic context.

KEYWORDS

Network Accessibility, Organic City, Space Syntax, Pedestrian Movement, Metro Station Location

1 INTRODUCTION

The term accessibility used in this research is related to the pedestrian movement which is considered one of the most essential elements of contemporary cities to deal with the quality of urban life. Today, most megacities need an accessible transport network to support the increasing travel demand and improve commuting between destinations. The implementation of new public transport infrastructures such as MRT or BRT systems is supposed to significantly impact the flow of people and the built environment in cities and towns. In that case, ensuring local pedestrian accessibility around the transit stations will be a critical issue to secure a pedestrian-friendly atmosphere in the station precinct. According to the conjecture, an accessible spatial network undoubtedly provides an opportunity for seamless transfers of passengers to local destinations and helps to enhance the quality of the urban realm. It acts as a key to the sustainable mobility of a city. Moreover, an accessible street network could relieve the high-density movement in the city centre and potentially integrate many other aspects of urban development (Tsigdinos,2019, Chen, 2019, Duangporn, 2009).

For planning and designing of metro stations along MRT line-6 of Dhaka city, the feasibility study has considered a convenient inter-connection with other transportation modes, existing land use conditions like high-rise buildings, public and commercial facilities, and availability of entrance spaces (DTCA,2011). But unfortunately, very little attention has been paid to addressing the pedestrian access to the proposed metro stations considering the organic morphology of the city which requires a context-specific detailed investigation (Rahman, A. 2017, RAJUK-2015, Daily Star, 2022). This organic morphology refers to the special characteristic of the city where planned and organic areas are evident in the morphological evolution of Dhaka city and tend to exist side by side. For efficient functioning of any urban development project should consider this very inherent organic nature of the spatial system that has been developed through the ages. Hence, ensuring local level accessibility at each transit station considering this organic characteristic of local urban structure will be a critical issue to address the seamless transfer of passengers and decide on an accessible location for the metro station. Literature suggests that among multifaceted metro accessibility indicators spatial configuration of the road network significantly affects the pedestrian accessibility of the city (Duangporn, 2009). In a living context like Dhaka, it is a technical challenge to set an accessible location of a metro station considering

the organic urban structure of the city, which has developed over four hundred years of history. In addition, Dhaka being the capital of one of the fastest-growing megacities of the world the number of metro passengers and pedestrians will be so high, particularly in CBD areas due to the diversified land uses and the presence of a significant number of multi-storeyed buildings. For the efficient functioning of this new transport infrastructure, the proposed metro station needs to consider that movement and land uses in relation to the local spatial network (JICA, DTCA, 2016). Literature suggests that Space Syntax could contribute to early-stage planning as a methodological decision-making tool by gaining overall insights into the patterns of urban access (Hillier, B 1884,1993,1996; Morales, 2017, Ozturk, 2018). Therefore, this paper tried to explore the space syntax method to investigate the configurational characteristics of the organic urban structure around the selected metro stations and interpret accessible locations for the proposed metro station. The proposed approach aims to function as a decision support tool for interpreting the accessible location of the proposed metro station along with its major entrance points within their morphological context. Both axial and VGA analyses have been considered in this study to interpret the pattern of accessibility. These spatial measures helped to assess the existing spatial structure concerning local pedestrian movement and develop a context responsive planning strategy.

2 BACKGROUND AND LITERATURE REVIEW

Dhaka the capital of Bangladesh is known as one of the fastest-growing megacities in the world and one of the oldest cities in Asia. In its four years of history, Dhaka city has arisen more and less spontaneously, and the natural endowment is valued for its indigenous urban pattern. Like many other cities two primary versions of urban arrangement, the planned and organic, exist side by side in the context of Dhaka. It has some parts which have been deliberately ‘created’ in a fragmented way whereas some areas have been ‘generated’ in a natural way. Hence, the ‘created’ and the ‘generated’ areas stand side by side. The contemporary axial map of the city depicts a curious mix of these two patterns on the same canvas. (Fig 1). These pieces of areas could be identified as distinctive morphological ‘clusters and the areas within each ‘cluster’ seems to be naturally grouped (Nilufar 1999,1997). Hence, this gives an organic morphological characteristic to this city which needs to be considered in the planning and designing process of any urban development project. According to the Dhaka Structure Plan (2016-35) and Dhaka Strategic Transport Plan, in recent years the city in its process of evolution is going through a rapid transformation specially in the transport sector. Many large-scale transportation projects (like MRT, BRT lines, flyovers etc) have been initiated by the government to enhance smooth connectivity among the major transit nodes and urban centres. Therefore, assuring local level accessibility around these transit centres considering the characteristic of organic urban structure will be a critical issue to promote a pedestrian-friendly station precinct (DTCA, 2011).

According to the literature, multifaceted indicators such as land-use diversity, compact and centeredness, connectivity, affordability, and time duration are used in measuring factors

influencing metro accessibility based on the social, economic, and environmental aspects (Duangporn, 2009). Among these indicators, this research has mainly concentrated on spatial connectivity to assess the metro accessibility along the MRT Line-06 route and in the CDB context (Motijheel & Karwanbazar) of Dhaka City. Generally, the term accessibility referred to the ability of anyone to reach some part of the city by any given means (Handy & Niemeier, 1997). Among different methods of accessibility study, numerous studies have shown that space syntax analysis can predict pedestrian movement which is independent of retail and transit attractors (Hillier, 1993; Penn., 1998). 'Space Syntax', a well-recognized theory and method can be used for the configurational analysis of the spatial system in relation to the functional pattern (movement flows, land use etc) of the city. Thus, it will help to develop an insight into the study area on how different roads are connected (Fig 1) to the overall spatial system (local and global) of the city, and their effect on the functionality of the space to interpret accessibility (Hillier, B 1884,1993,1996; Morales, 2017, Ozturk, 2018) of the proposed metro station. For this research 5-10 min, walking distance (400-800meter) has been considered as a pedestrian shed which refers to a comfortable distance that people are willing to walk. The transit industry widely applies this 5-10 min walking distance (400-800meter) 0.25-mile as rules of thumb when estimating service areas around bus and rail stations." — El-Geneidy et al. (2014). This rule of thumb is used to calculate public transport catchment areas or to determine access to local destinations and it has become a tool for promoting the human scale in urban planning.

However, investigating metro accessibility cannot be limited to the above-mentioned approach. It is true that observing a city only through a top view approach lack on providing information related to the human scale. Thus, adding more "dimensions" and perspectives to this 2D approach can lead to more inclusive research. Research on other important aspects related to metro accessibility can provide a wider and more accurate representation and understanding of metro accessibility within its morphological context.

3 DATASETS AND METHODS

This research is focused to evaluate the existing situation of the local urban grid around the proposed metro stations to interpret the role of the spatial configuration in improving pedestrian access to the proposed metro stations. Both qualitative and quantitative analysis around the station area has been applied to examine the issue under study. The framework of this study is based on the following three steps: (1) Overview of the station area (2) Spatial Analysis, (3) Functional Analysis and Theoretical Interpretation.

3.1 Study Area Overview

In the first step, relevant data related to the proposed MRT line-06 routes and stations in the context of Dhaka city were collected from Dhaka Transport Coordination Authority (DTCA) and

Dhaka Mass Transit Company (DMTC). The study areas were selected based on some similar characteristics (CBD areas). For this research on-site investigation was an important factor to understand the spatial effect on the functional aspect of the study area, hence a specific catchment or influence area was selected to identify the existing pedestrian movement (flow and activity interaction with space) pattern around the stations and other physical characteristics. This part would provide a general introduction of the study area related to its morphological characteristics, and additionally, it also represents the key considerations as highlighted in the feasibility study for locating the proposed metro stations within its context.

3.2 Spatial Analysis

This section has tried to define the influence area for the spatial analysis focusing proposed metro station as the centre of the study area. The extension of the study area was limited to a 400m-800m radius or 5-10min walking distance from the proposed station centre as mentioned in section 2. This study considered a morphological analysis of the study area including street network, block pattern, land use and density to determine the characteristic of the existing urban structure around the proposed station. GIS-based resource and the open street map has been used to generate datasets including street layout, plot size, number of floors, land use and other related information for both graphic and mathematical analysis. Later, syntactic analysis has been performed for a detailed understanding of the configurational characteristics of the local urban grid. Therefore, to understand the accessibility pattern of the organic urban grid in the study area syntactic analysis has been performed as an embedded (local and global analysis) and independent (local analysis, VGA) system within the global context of Dhaka city. As an embedded system, it tried to identify the spatial properties like global integration, local integration, connectivity, control, and choice value; whereas, as an independent system the result shows the visual configurations of the existing built environment to interpret the accessibility pattern of the local urban grid. Later, this analysis provided a set of graphical and statistical evidence for interpreting the degree of accessibility of the spatial network around the proposed metro stations in relation to the local and global network of the urban structure.

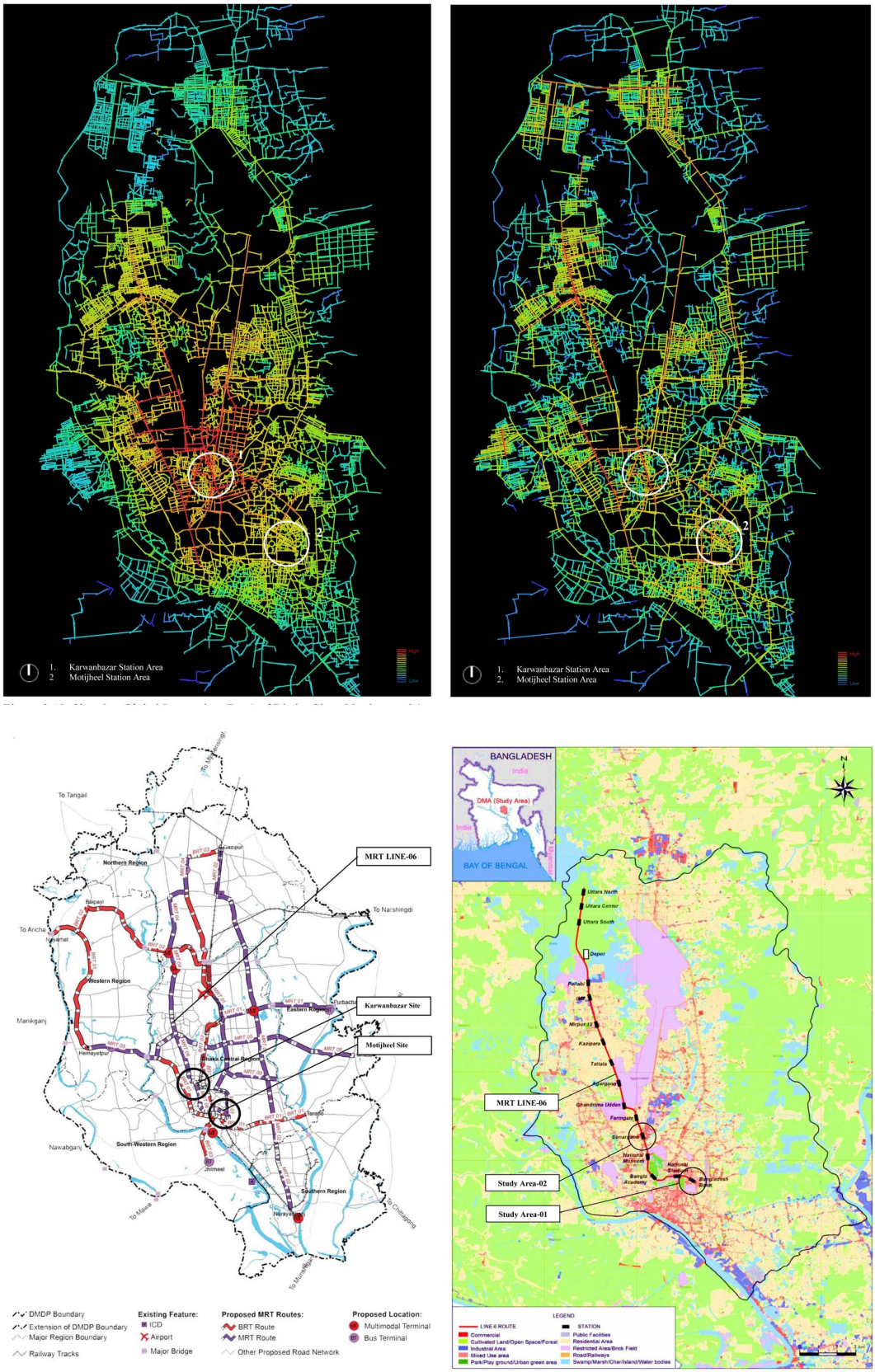

Figure 1: Top-Left Image: Global (R=N) and Top-Right Image: Local (R=4) Integration of Dhaka City; Bottom-Left Image: Proposed MRT Network in RAJUK area (left side) and Study Route of MRT LINE-06 (Bottom-Left Image).

3.3 Functional Analysis and Interpretation of Accessibility of Proposed Station

This section has tried to correlate the relevant theory of space syntax with the functional pattern of the study area to interpret the accessibility of the proposed metro station. According to the literature, configurational properties have a fundamental relationship with the urban function including movement and land use. Hillier suggests that the configuration of the urban grid itself is the main generator of the pattern of movement. In addition, in his view the location of different land uses i.e., different attractor functions are influenced by the configuration of the urban system, and they tend to locate themselves on the most integrated (most accessible) route. Hence, this group of attractors acts as a multiplier on the basic pattern of natural movement (Hillier, B 1884,1993,1996). Therefore, this study investigated the pattern of local pedestrian movement and distribution of land uses (i.e., commercial, service, educational, industrial, leisure, transportation and residential etc) around the proposed metro station to explain the relationship between the spatial configuration and the functionality of the space. Later, based on statistical correlation analysis between movement data and spatial properties of the urban grid the accessibility of the proposed metro station is interpreted. The land use (land use type, floor area and density) data were collected using a GIS map and pedestrian movement data were collected from field observation and questionnaire survey.

4 RESULTS - CASE STUDY OF MOTIJHEEL & KARWANBAZAR, DHAKA

4.1 Station Area Overview

The development of New Dhaka started in the late nineteenth century. Motijheel and Karwanbazar are among the prime commercial areas of Dhaka city. The proposed MRT Line-06 along with its major stations will go through the heart of the city (Fig-1) and will connect these two major commercial districts as well. Being a CBD of one of the fastest-growing megacities and its diversified land use pattern it is expected that these areas will attract a tremendous population from surrounding areas. Therefore, ensuring accessibility to the proposed metro stations will be a critical issue to tackle this huge flow of passengers and transfer to local destinations. Considering this issue, the study has selected two similar (pre-dominantly CBD areas) study areas (Fig-2) along the MRT Line-06 route to examine the current accessibility condition around the proposed metro stations. The sections below highlight the major morphological characteristics i, e street network, block pattern, land use and movement flow of these two-station areas. It also represents the proposed location of the metro station within the study area.

Land Use

Motijheel is a vibrant commercial centre of Dhaka city under SPZ-01 and DPZ-4: Central business district (CBD south-east) with a significant number of commercial and administrative activities. Geographical centrality of the area, greater accessibility and business activities have made this area potential for developing as a CBD area, thus rigorously influencing high movement in this area and often generating huge traffic congestion during office time (DMDP,1997). The absence of parking facilities is one of the major problems in these areas where existing most of the multi-storeyed building generates too many parking demands thus occupying the roadsides, making the movement spaces narrower (both pedestrian and vehicular) and creating congestion on the road. Apart from these most of the street remains occupied by parking carts, vehicles, hawkers, and peddlers that obstruct pedestrian movement. From GIS-based mapping and data analysis (Fig 3), it is evident that the land use pattern around the proposed station area of Motijheel has a significant commercial identity. The study represents that within a 400m radius around the proposed station the percentage of commercial, government service and service activity is quite higher which generally decreases with a certain depth.

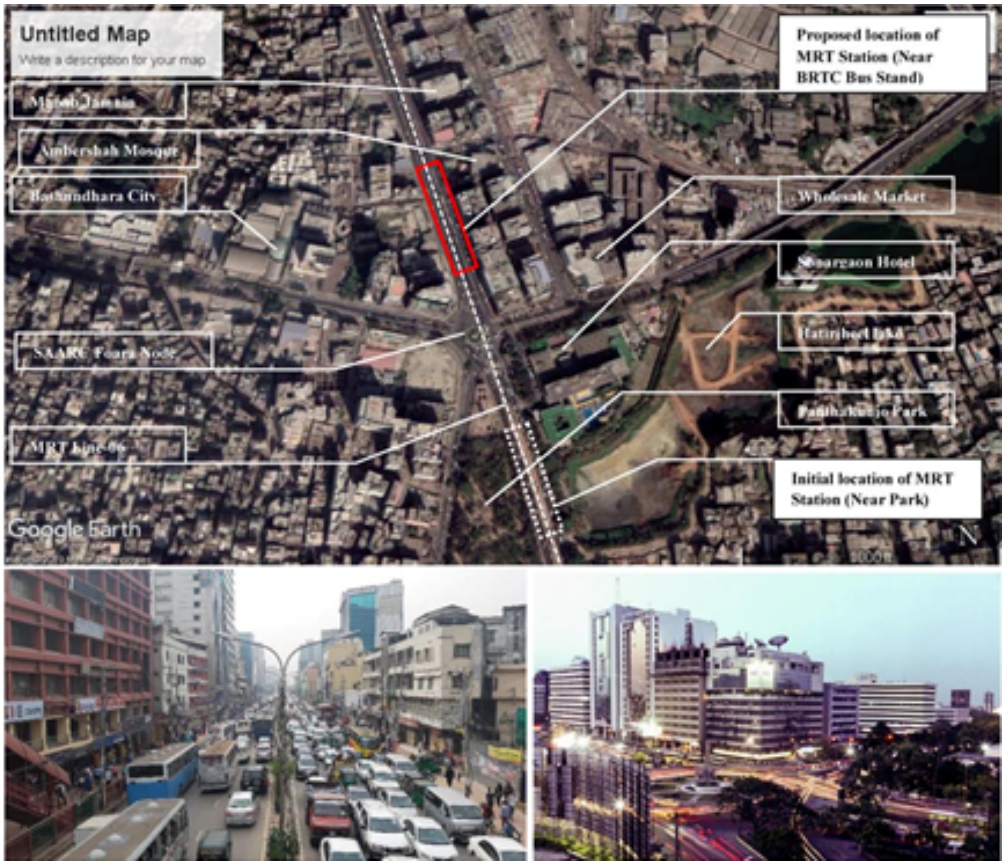

Figure 2: Figure showing Satellite image and adjacent built form around the proposed station at Motijheel (Top 3 Images) and Karwanbazar (Bottom 3 Images), Dhaka

Like Motijheel, Karwanbazar is another vibrant business district (CBD) of north Dhaka with the presence of several multi-storeyed buildings. This area acts as the heart of the city in terms of land use-activity and connectivity which connects both the north-south and east-west axis of the city and generates a huge volume of movement (both vehicular and pedestrian) in the area (DMDP,1997). Most of the existing multi-storeyed building does not have the parking facilities and generates too many parking demands, thus occupying the roadsides and making the movement spaces narrower like the Motijheel area. Another interesting feature of this site, it is naturally enriched by adjacent Panthakunjo park and Hatirjheel lake which attracts people to visit the area as well (Fig-2 &3). It also provides ample space for breathing and movement. From GIS-based land use analysis, it is evident that like Motijheel this site has also a strong commercial identity and the percentage of commercial land use is higher along the major road which generally decreases with a certain depth.

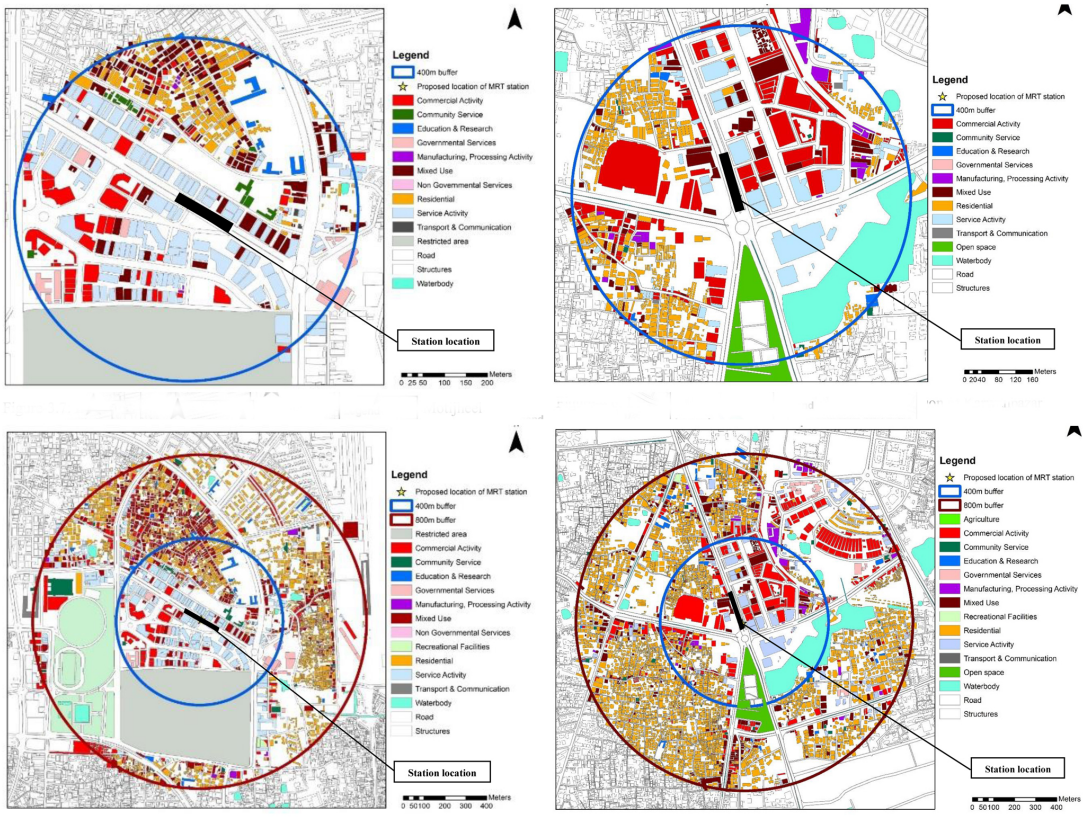

Figure 3: GIS-based land use analysis at 400m & 800m around the proposed station of the study areas (Motijheel-Top-Left & Bottom-Left Image & Kawanbazar- Top-Right & Bottm-Right Image); Source: M Tariquzzaman M, 2019.

Besides, according to the Dhaka Structure Plan 206-35, the future sub-centres of Dhaka city focusing on these major transit centres (BRT/MRT Stations) are going to be transformed soon following the Transit-Oriented Development principle. Hence, these types of land development processes and geographical locations will attract more people to visit the area and proper access needs to be ensured for both sites for sustainable urban development.

Street Network and Block Size

The street network around the proposed metro stations of Motijheel and Karwanbazar area both shows (Fig 4) a combination and co-existence of the grid pattern and spontaneous organic character in general. In addition, different sized (coarse grain and fine grain) of the urban block has been found in both areas where some are smaller, and some are larger, hence, controlling the pattern of access to the station area.

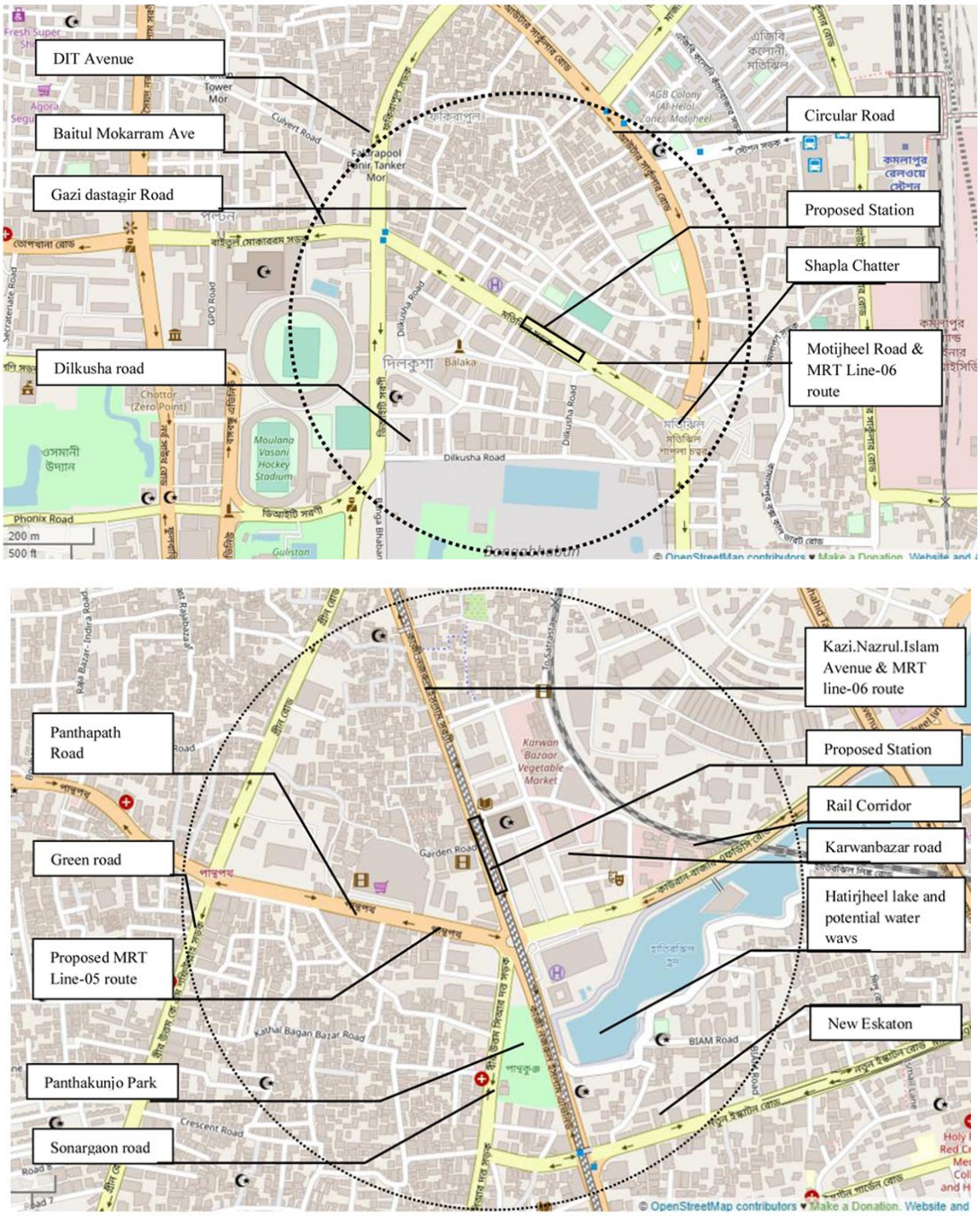

Figure 4.: Open Streetmap (Motijheel-Top Image & Karwanbazar-Bottom Image) showing major roads and plot configuration in the study area (Source: Open Streetmap).

In the case of the Motijheel site, the street network close to the station area is dominantly grid pattern whereas an organic character has been found away from the station area. The grid pattern has been found on sides side (at Dilkusha & City Centre near station areas) of Motijheel Road which creates a lattice-like network. The road width in the northern residential part is much narrower than the road width in the southern commercial part (Dilkusha) which allows ample space for large movement. For block size, the area near the proposed station is smaller than the area away from the station which makes the station area more permeable and well connected. The presence of these large blocks around the station area like some commercial blocks in Dilkusha,

the Playground of BFFC and Notre Dame College campus at Arambag, Office area of Bangladesh Bank makes the route lengthy for the pedestrians to reach local destinations.

In the case of the karwanbazar site, the street network close to the karwanbazar wholesale market area mostly follows the grid pattern whereas an organic character has been found in the adjacent residential areas like west Tejtury para, Kathalbagan and New Eskaton area. Grid pattern road network near karwanbazar wholesale market offers a better permeability with the adjacent major artery (Kazi Nazrul Islam Avenue). Despite these, few dead-end roads restrict thoroughfare movement within local destinations. Like Motijheel, the presence of some large urban blocks (like near Bashundhara commercial complex) has made the movement route longer for the pedestrians to reach local destinations. From the above study, it can be said that the area near the karwanbazar wholesale market road network shows a fine grain character whereas there are areas that show less permeability and affects the access pattern to the station precinct.

However, only looking at the maps can't help to understand the inner logic of the inter-relationship of movement pattern and accessibility in the study area Therefore, in the latter part the spatial structure of the study area is analysed by employing space syntax theory to reveal the spatial logic of accessibility and it has been compared with movement data to find out the relationship between the movement and space.

Movement Flows

According to Hillier, the measures of the spatial structure thus the integration of each line describes a fundamental relationship with movement (Hillier, B 1993). To find out this relationship, movement patterns around (5-10min walking distance) the proposed station areas are studied to reveal the fact that if there any relation exists between movement and the integration pattern in the study area. In this research, the Gate method has been used to study the pedestrian movement rate in the study area with a stationary observer counting all the pedestrian movement crossing a notional gate (Fig-5) three times (at peak hours 9 am-10 am, 1 pm-2 pm and 5 pm-6 pm) of the day and each set of observation lasting five minutes and converted to movement rate per hour. In the latter part, this movement pattern (Fig 9) has been compared with the spatial measures to find out the relationship and interpret the degree of local accessibility.

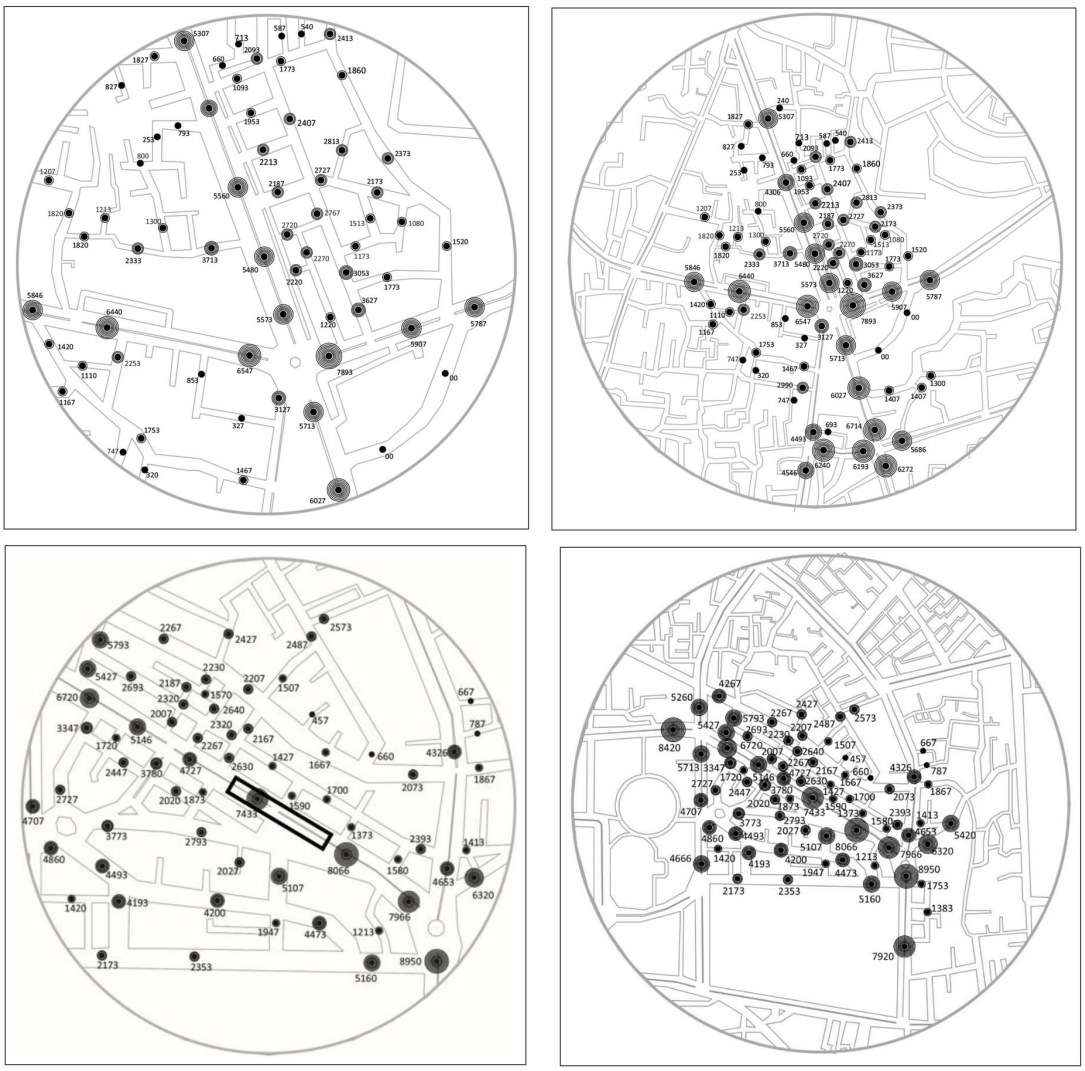

Figure 5: Pedestrian flow density at 400m & 800m radius around the proposed station of the study areas (Kawanbazar-Top Left & Right; Motijheel-Bottom Left & Right Images; Source: M Tariquzzaman M, 2019

A detailed set of pedestrian movement data (fig 5) has been prepared based on observation and field survey in the study area of Motijheel. Observations were taken at 80 gates (Fig 5), with maximum coverage of incoming or outgoing routes towards the station area within its pedestrian shed. It has covered a range of heavily used, moderately used, and poorly used streets by pedestrians. Figure-5 shows the location of the study gates for the pedestrian count and later average movement data has been plotted on the street map to show the movement volume (from heavy to low) in different gates. Large dots represent higher pedestrian movement across the gate whereas small dots represent lower pedestrian movement.

In the case of karwanbazar, figure-5 shows the location of the study gates for the pedestrian count and later average movement data has been plotted on the street map to show the movement volume in different gates. It represents the movement rate (heavy to low) in different streets. Higher pedestrian movement on both peak hours (morning and evening) has found near the intersections (Banglamotor Node and SAARC Foara Node) and along the major arterial road

(Panthapath, Kazi Nazrul Islam Avenue and Hatirjheel link road) due to the adjacent land use and common movement route to reach local destinations (bus stoppage, office, bank, and other business activity). A moderate pedestrian movement rate has been found in the karwanbazar wholesale market area and the branching streets close to the major arterial roads. The stair landing of the foot over the bridge also creates an obstruction at the footpath during mass pedestrian movement. Besides, some landing stairs (entry/exit) of the foot over the bridge occupy the major width of the available footpath thus interrupting the mass pedestrian flow.

Proposed Station Location

The Feasibility Study shows that the proposed MRT Line-06 will carry at least 61,000 passengers from different stations in both directions in the year 2025. It has considered convenient inter-connection with other transportation modes, existing land use conditions and availability of entrance spaces to decide the locations of the proposed metro station (JICA, DTCA, 2011). However, in its process of execution, Dhaka Transport Co-ordination Authority (DTCA) stated that there are significant challenges in mobility management and accessibility improvement for ensuring the efficiency of the metro system which needs a detailed investigation (Rahman, 2011).

As per the feasibility study, the alighting & boarding passenger volume for Motijheel Station will be 14,000 per hour (JICA, DTCA, 2011). In addition to that, there will be a higher movement of regular pedestrians at the ground level for other activities. Figure-6 illustrates the proposed station location near the existing filling station or BRTC bus stand at Motijheel. It also shows the proposed entrance locations around the station, and they are E01 to E08 as mentioned in the figure (Fig-6 & 10). Among the entrances E01, E02, E06, and E07 are located along the major arterial road occupying the effective width of the existing footpath that may create conflict and congestion between the metro passengers and pedestrians which needs to be taken care of. During early-stage planning, there was an elevated walkway connection with the Shapla Chatter node to connect passengers from adjacent areas, but it has not found in the current station layout. No detailed layout has been found to connect the existing multi-storeyed buildings like the city centre, Bangladesh Bank or Other important buildings which generate a significant movement in the area. However, near the proposed location at the southern part of the station (near Pubail filling station), there is ample space (Fig-4 & 5) that can accommodate a large movement.

In the case of Karwanbazar station, the alighting & boarding passenger volume will be 8,000 per hour (JICA, DTCA, 2011). In addition to that, there will be a higher movement of regular pedestrians at the ground level for other activities. Figure-6 illustrates the proposed station location near the existing underpass at Karwanbazar. It also shows the proposed entrance locations around the station, and they are E01 to E05 as mentioned in the figure (Fig-6 & 10). Among them except E06, all other entrances are located along the major arterial road (Kazi Nazrul Islam Avenue), hence, occupying the effective width of the existing footpath that might

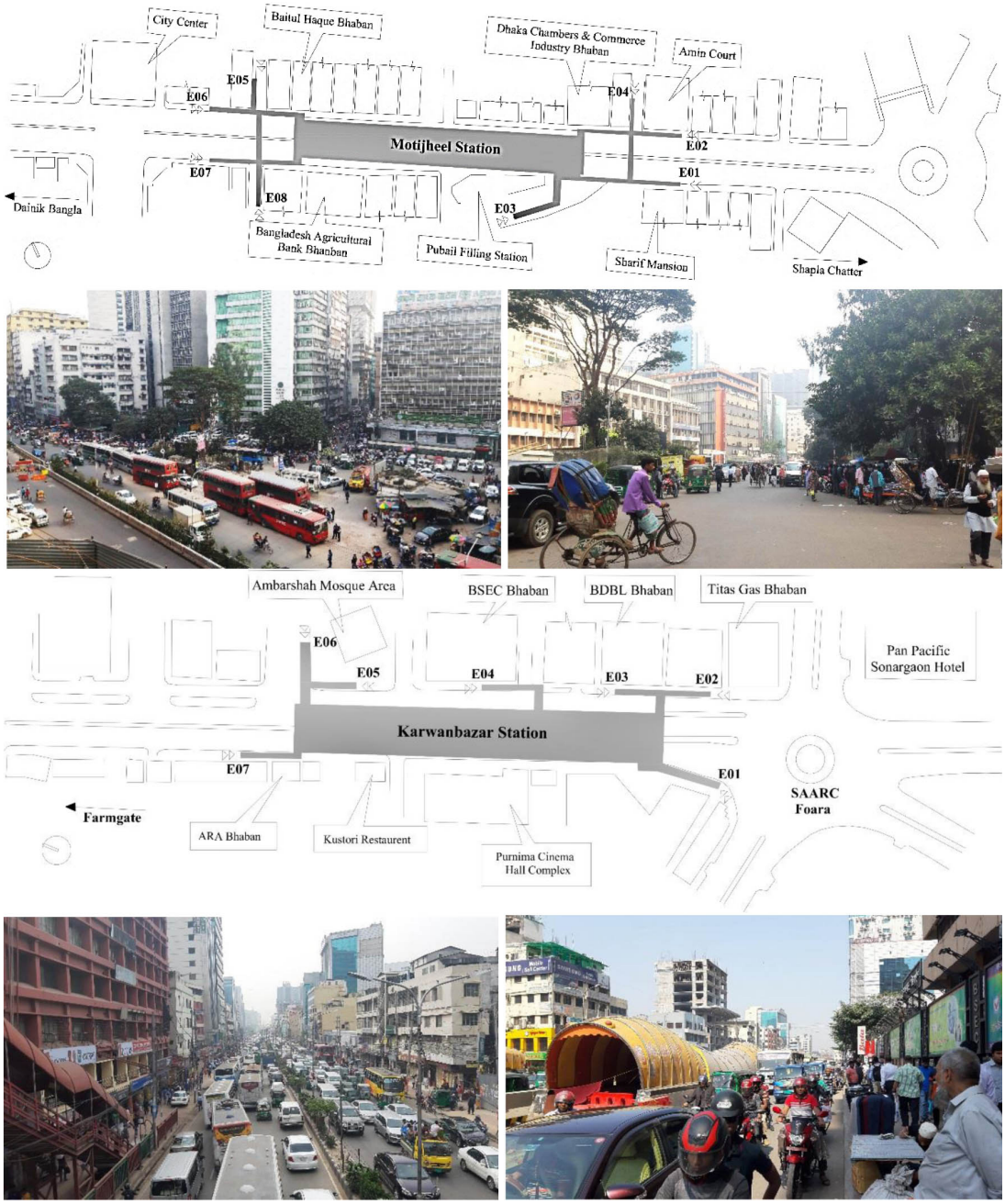

Figure 6: Proposed Station Layout at Motijheel (Top 3 Images) and Karwanbazar (Bottom 3 Images) and adjacent built form and available spaces. Station Layout Source; www.dmtc.gov.bd

create conflict and congestion between the metro passengers and pedestrians which needs to be taken care of. However, near the proposed location at the eastern part of the station (near the Ambershah mosque Area), the presence of a connected network of streets can ease the access to the station area but the entrance location of the proposed station along the major road might create serious congestion with regular pedestrians which needs to be considered.

4.2 Syntactic Interpretation of Accessibility

To interpret the accessible condition, axial properties and VGA properties have been analyzed separately for a better understanding of the characteristic of the urban spatial structure under study. Literature suggests that Hiller's concept of accessibility refers to the most integrated route in an urban grid configuration. The higher the integration value the more it is accessible and vice-versa. From axial analysis, it is found that within the spatial structure of the city Karwanbazar site is more globally integrated (Fig-1 &7) in relation to the overall city grid and is a more integrated part of the whole urban structure. Within this spatial structure major Arterial Roads (Kazi Nazrul Islam Avenue) and some Link Roads (Panthapath, Panthapath-Tejgaon Link Road, Link Road at Banglamotor, New Eskaton Road (Fig-1 &7) have gained a higher integration value and global importance, thus refers to higher accessibility. On the other hand, in the Motijheel area, the study area remains outside of the global core of the city and acts as a locally important area; and the major primary arterial roads like DIT Avenue, and Motijheel Road, Circular road have gained a higher integration value (Fig-1&7). In both areas, these highly integrated lines also act as a point of attraction for vehicular movement thus affecting pedestrian movement and crossing. Besides, in both areas, a moderate correlation (Fig-8) has been found between global integration and connectivity which refers to a moderate 'intelligibility' i.e., a sense of readability of the grid from the local scale towards a larger context which influences movement. As more integrated lines are crossed by equal more other lines in the spatial system the more intelligible the structure (Hillier, B 1996). Therefore, in both areas, part of the area represents a lattice-like permeable network (Fig-7) of streets (with a significant integration value) around the proposed station whereas some organically developed parts remain outside of this network. This might be the resultant effect of the co-presence of planned and spontaneously grown areas being developed side-by-side over the years. Hence, this 'lattice like' spatial feature strengthens the candidacy of the location within the spatial network to ease access from adjacent areas.

Accessibility measures of VGA analysis suggest that the visual integration core within the spatial structure can accommodate a higher density of movement to result in a shallow and well-connected circulation space (kinda, S.A 2013, Parvin, 2007). Therefore, this local area effect of the spatial measures helps to understand the degree of integration and accessibility of the local urban grid and gives a direction to interpret an accessible location for the metro station that can afford a mass movement within the spatial system. The VGA analysis at a 400m radius around the Motijheel station area shows that along the MRT Line-06 route the visibility integration (VGA) core lies near the BRTC Bus stand (near the proposed station location) and Shapla chatter node (Fig-7). At 800m radius, the visual integration (VGA) core shifted from the BRTC bus stand towathe rds Shapla chatter node and Dainik Bangla node. The Karwanbazar Station area shows that the obvious visibility integration (VGA) core lies in the SAARC foara node for both 400m radius and 800m radius (Fig 7). The only exception at an 800m radius is that the core tends to extend towards the north (near the proposed station location) and south side (Panthakunjo Park at the initial station location).

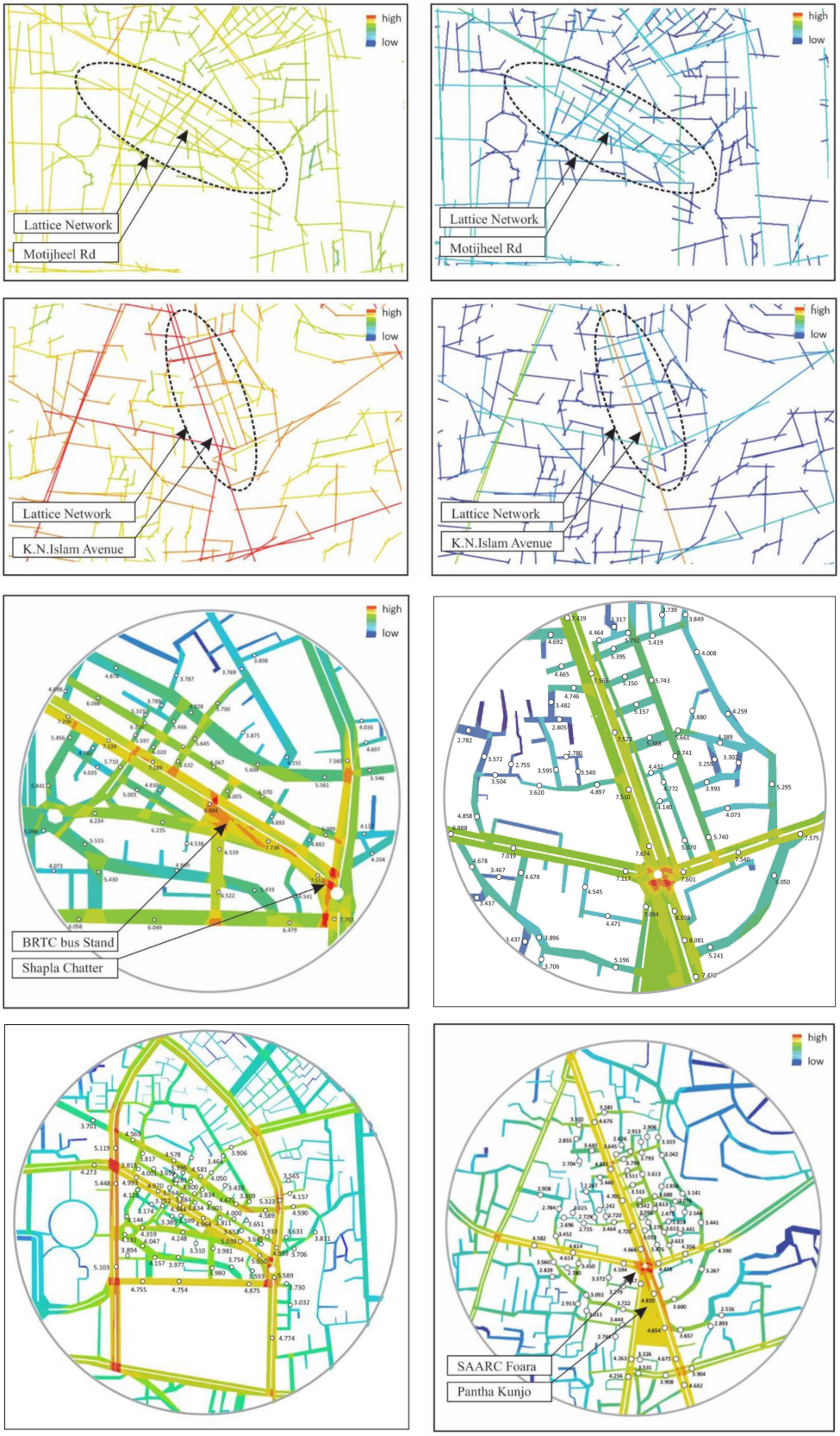

Figure 7: Global Integration (R=n) (Top-Left), Connectivity (CN) (Top-Right) and VGA analysis (Middle-left, Bottom-Left) of Motijheel and Global Integration (R=n) (Middle-Left), Connectivity (CN) (Middle-Right) and VGA analysis (Middle-Right, Bottom-Right) karwanbazar (Top-right & Bottom-Right images) Area; Source: M Tariquzzaman M, 2019

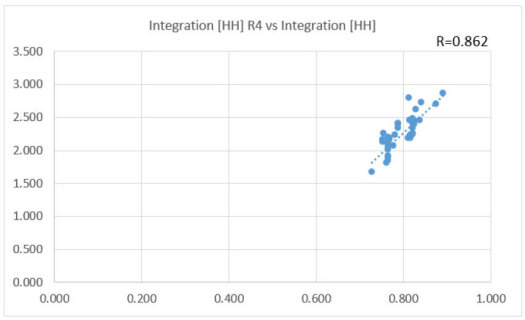

Figure: Correlation between Local Integration (R4) and Global Integration

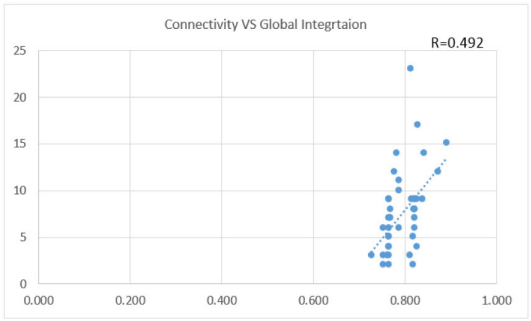

Figure: Correlation between Connectivity and Global Integration

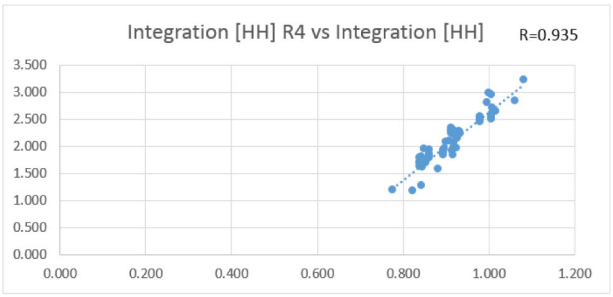

Figure: Correlation between Local Integration (R4) and Global Integration

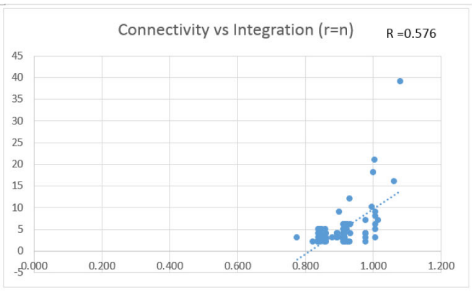

Figure-: Correlation between Local Integration (r=n) and Connectivity

Figure 8: Correlation among syntactic measures of Motijheel (Top-Left & Top-Right) & Karwanbazar (Bottom-Left & Bottom-Right).

4.3 Effect of Spatial Configuration on Movement and Land use

According to Hillier, B 1993, configurational properties have a fundamental relationship with the urban function including movement and land use. Hence, this study tried to interpret the above hypothesis for both cases by comparing the spatial properties in relation to the local pedestrian movement. The correlation (R/\) measure between spatial properties and movement data (Fig 9) represents the relationship between two different variables and tries to comprehend the effect of spatial configuration on movement. From scattergram analysis (Appendix-1&2) the most significant correlation (R/\) (global integration and movement) that governs predicting pedestrian movement shows a low or moderate value (0.352 & 0.508) and does not develop any strong relationship to predict movement in both cases. The other correlation (R/\) result with local integration and segment choice is also so insignificant to predict local movement. On the other hand, correlation (R/\) with VGA properties comparatively shows a significant value (0.847 & 0.636) and represents a substantial correspondence with the local movement pattern (Tariquzzaman, M. 2019).

Therefore, in both cases, the effect of spatial configuration on local movement is more associated with VGA properties than axial properties. So, the result of the spatial analysis in relation to the local movement does not represent any significant correspondence with Hiller's spatial theory of accessibility to predict local movement which means other attractors (land use or other factors) might also play a vital role to influence movement in the study areas. However, from the field

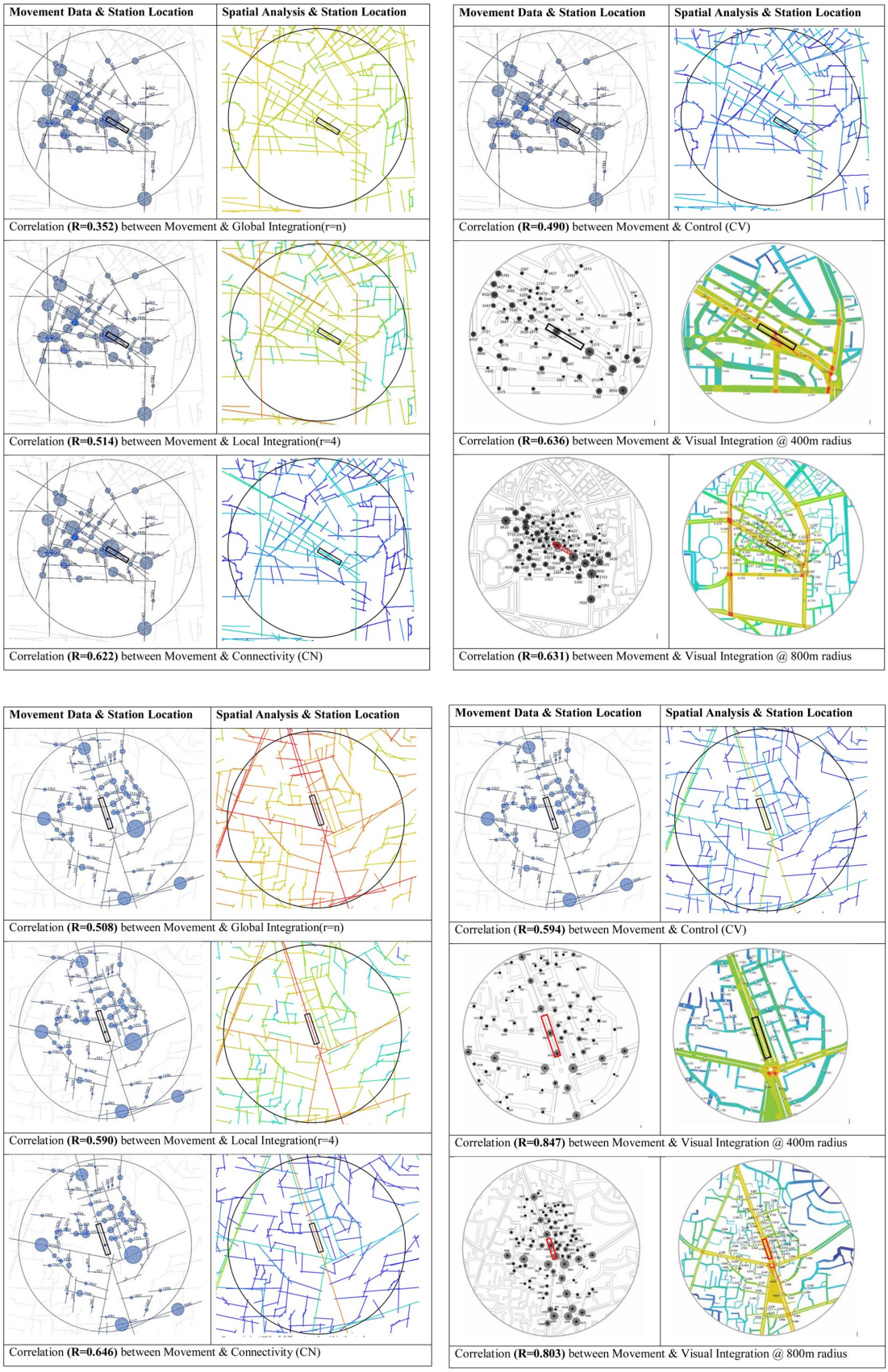

Figure 9: Correlational analysis (spatial data vs movement data) at Motijheel (Top-Left & Top-Right Images) & Karwanbazar (Bottom-Left & Bottom-Right Images); Source: M Tariquzzaman M, 2019

observation, it is found that in both CBD areas a noteworthy number of multi-storeyed commercial and office buildings are located along the major arterial and secondary roads of the study area of Motijheel and Karwanbazar thus attracting a significant amount of movement from different parts of the city. Hence, these act as a multiplier when aligned with highly integrated lines (Hillier, B 1993, 1996) and might eventually enhance the overall pedestrian movement in the area which requires further detailed investigation from a land-use perspective (Tariquzzaman, M. 2019).

4.4 Interpreting Accessibility of the Proposed Metro Station

This section aims to summarize and interpret the accessibility of the proposed metro station concerning the configurational analysis of the local urban grid and its effect on the functional pattern of the study area. For this evaluation, the result of different syntactic measures (both axial and VGA properties) have been considered and compared with local pedestrian movement only. It presents that among different syntactic measures of configurational analysis VGA properties show comparatively significant correspondence with the local movement in both cases (Motijheel and Karwanbazar) than axial properties. The resultant effect of this phenomenon can shed some light on interpreting the accessibility (Fig 4&10) of the proposed metro station in the study area. Hence, the area with a higher integration value (VGA) can be considered for locating the proposed metro station along with its major entrance points like lift, escalator, and stairs to facilitate the high flow of passengers to local destinations. In this perspective, the area near the BRTC bus stand in Motijheel and Panthakunjo Park in Karwanbazar (Fig 4&10) has better candidacy to accommodate a mass movement and enhance accessibility in the station precinct.

In the case of axial analysis and its correlation study with local movement, the result reveals an insignificant relationship in both cases (Motijheel and Karwanbazar) and does not represent any significant correspondence to predict local movement and interpret accessibility. Besides, the statistical analysis represents a good correlation between the local and global integration measures which indicates locally important roads are mostly in correspondence to the roads which are globally important too and the spatial network is well integrated both at the local and global scale around the proposed station. In addition, a moderate correlation is found between global integration and connectivity which refers to the degree of ‘intelligibility’ of the area i.e., a sense of readability of the grid which influences the local movement (Fig-7 & 8). Therefore, the area with the permeable grid network (Fig-7 & 8) can ease the access from adjacent areas and strengthen the candidacy of the area to decide on locating the station along with its major entrances.

On the other hand, the proposed station location at both sites falls (Fig-1 & 7) within a permeable grid and lies within a highly integrated line that attracts a heavy movement (both vehicular and

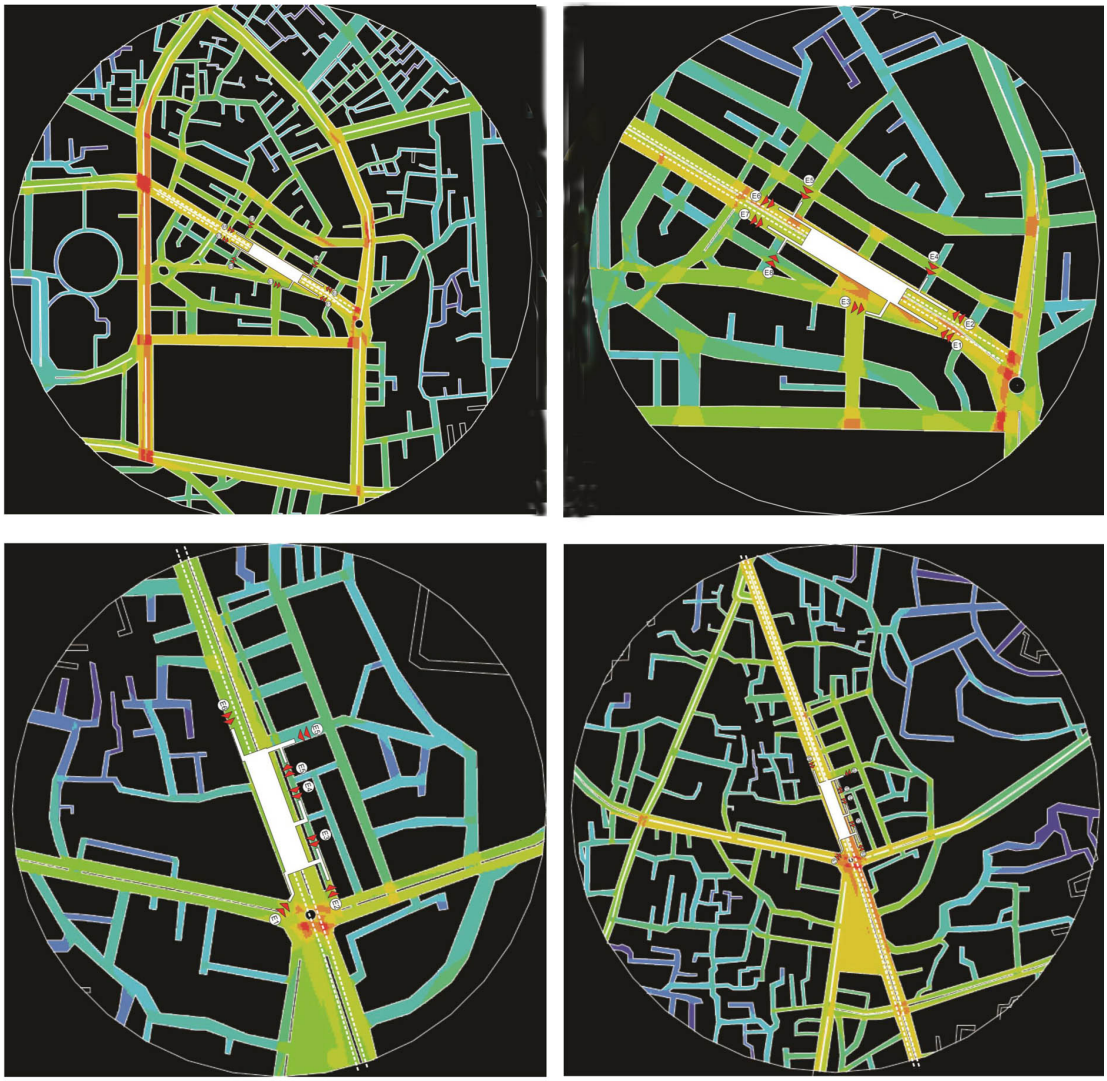

Figure 10: VGA graph analysis at 400- 800m radius of Motijheel (Top-Left & Top-Right Images) & Karwanbazar (Bottom-Left & Bottom-Right Images) Station area with station entrances; Source: M Tariquzzaman M, 2019.

pedestrians) to the study area and this often segregates the pedestrian movement on both sides of the street. In addition, some of the entrance points (like lift, escalator, and stair landings) of the proposed stations might affect the passenger dispersal as well as regular pedestrian flow, as these entrance points are occupying a significant portion of the main footpath. The entrance locations (Fig- 6 &10) of E01, E02, E03, E06, E07 in Motijheel station and E01, E02, E03, E04, E05, E07 in Karwanbazar station may create this situation. In that case, the area with a higher visual integration core resulted in a shallow and well-connected circulation space within the spatial structure which might be effective to absorb the high flow of movement and ease the dispersal of passengers to local destinations. Findings from the field study show that being part of the CBD area a significant number of multi-storeyed buildings along the major arterial and secondary roads attracts a major movement (both vehicular and pedestrians) in the area. In addition, it acts as a multiplier when aligned with highly integrated lines within the spatial system. Therefore, this also needed a detailed investigation for an accurate interpretation of metro accessibility considering transit-land use integration.

5 CONCLUSIONS

A crucial part of this research framework is the application of the space syntax method for investigating pedestrian accessibility of the urban structure around the proposed metro station in an organic context where planned and unplanned areas coexist side by side. The advantage of this approach is that the analysis includes both local area characteristics and investigates the area's connection with the broader urban environment toward a better understanding of the problem and planning for such issues. The methodological steps considered here highlight the crucial issues concerning the accessibility of the proposed metro station in an organic context in relation to the local pedestrian movement. For example, from spatial and movement study it is identified that to accommodate a mass movement the area with higher visual integration and permeable grid network would be able to enhance the degree of accessibility and ease the passenger's dispersal. So, for locating the proposed stations along with its major entrances, the area having these characteristics is desired to enhance the degree of accessibility to the station area.

However, the accessibility of metro stations is a complex issue that cannot be fully analyzed by one single research. The proposed framework presented in this paper can function as a scientific method for decision support tool in a data scare context. Further research in this area might also include the investigation of other measures such as land-use factors or other metro accessibility indicators. The extension of research studies in the field of accessibility issues can contribute to making more sustainable and social cities in the future.

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APPENDIX 1

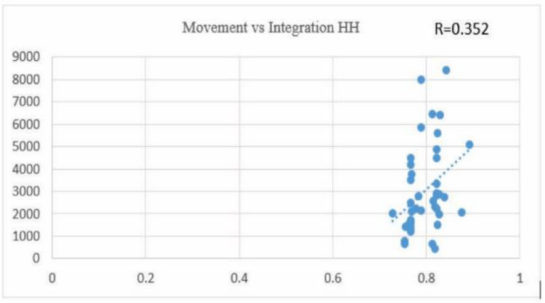

Figure: Correlation of between Global Integration and Movement Pattern

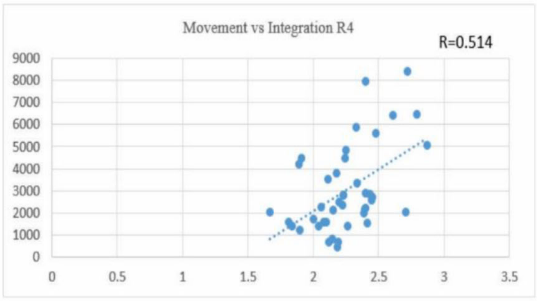

Figure: Correlation of between Local Integration and Movement Pattern

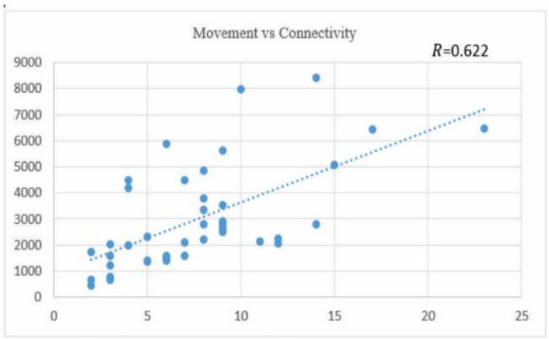

Figure: Correlation of between Connectivity and Movement Pattern

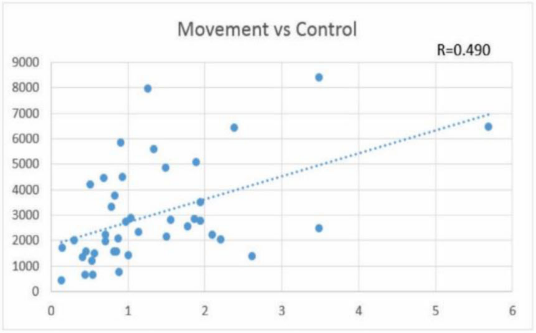

Figure: Correlation of between Control and Movement Pattern

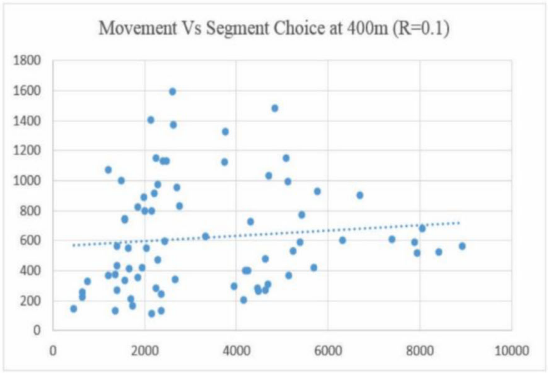

Fig: Correlation of between choice and movement at 400m radius

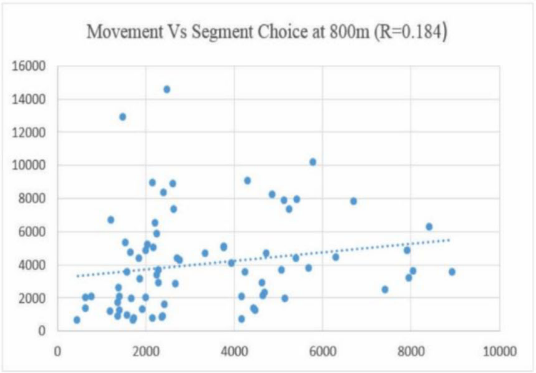

Fig: Correlation of between choice and movement at 800m radius

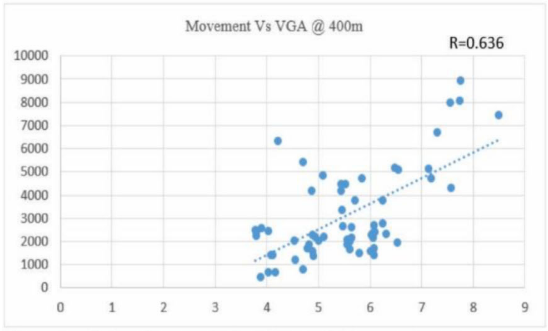

Figure: Correlation of between VGA @400m and Movement Pattern

Figure-: Correlation of between VGA @800m and Movement Pattern

Figure 11: Correlational analysis (spatial data vs movement data) at Motijheel

APPENDIX 2

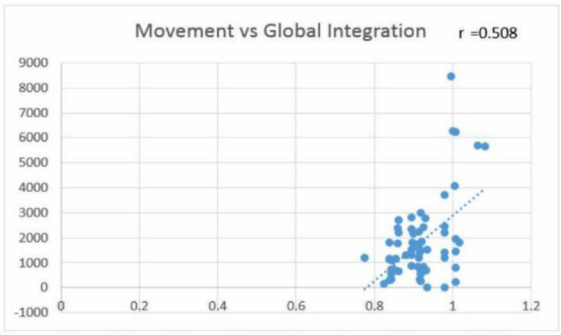

Figure-: Correlation of between Global Integration and Movement Pattern

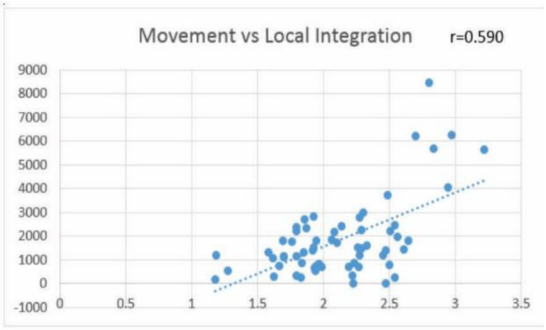

Figure: Correlation of between Local Integration and Movement Pattern

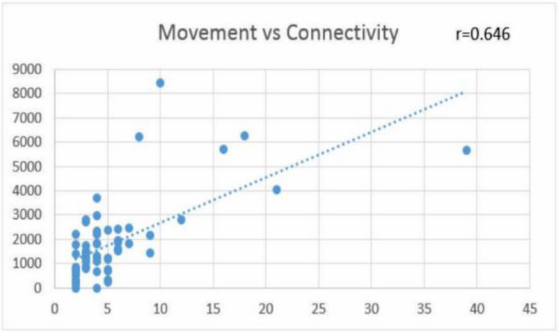

Figure: Correlation of between Connectivity and Movement Pattern

Figure-: Correlation of between Control and Movement Pattern

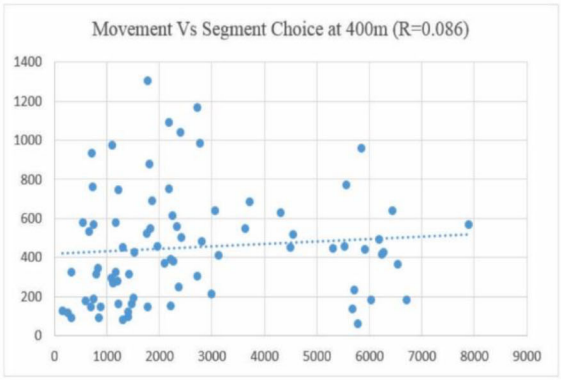

Fig: Correlation of between choice and movement at 400m radius

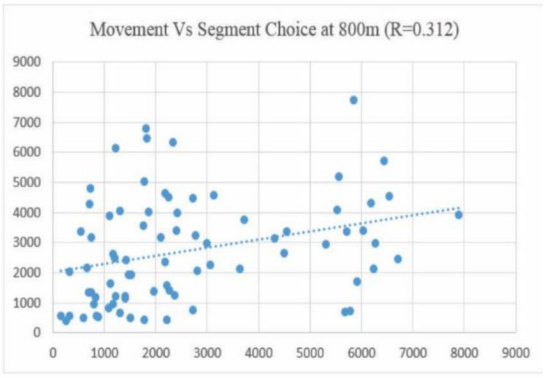

Fig: Correlation of between choice and movement at 800m radius

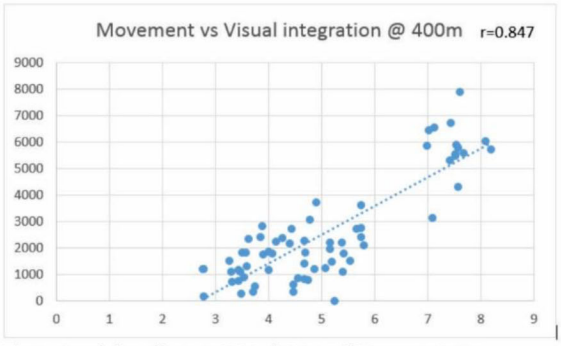

Figure: Correlation of between VGA @400m and Movement Pattern

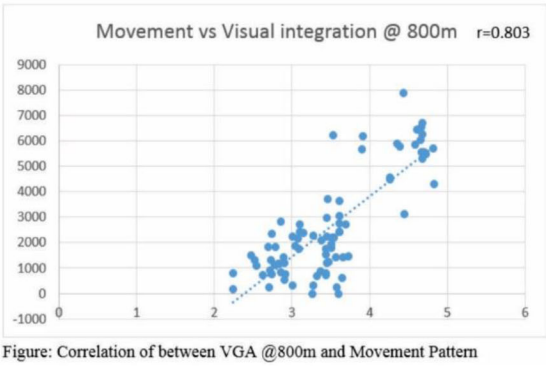

Figure: Correlation of between VGA @800m and Movement Pattern

Figure 12: Correlational analysis (spatial data vs movement data) at Karwanbazar