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Land-Use, Street Configuration and Pedestrian Volume:

The Case of a Historic Town, Mymensingh, Bangladesh

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ABSTRACT

This study explores the relative connections among pedestrian movement patterns, land use and street configurations by analyzing the pedestrian volume, existing land use patterns as well as the street configuration of Mymensingh. Mymensingh is a historic town in Bangladesh which was established by the British Colonists more than 200 years ago along the river Brahmaputra. The street patterns of Mymensingh was developed by the fusion of the wide streets made by British Colonists and the narrow streets made by the local inhabitants. The juxtaposition of these street patterns created a unique type of street configuration in Mymensingh.

According to Space Syntax, urban street configuration is considered as the most dominant factor on pedestrian movements as well as the patterns of using the land and there exists a co-relation among these. In this study, pedestrian movements and land-use patterns are observed and compared with the configurational values of street segments within the street network by the simulation method of Space Syntax. By comparing the real-life and simulation data, the study result shows that the co-relation between urban street configuration and the distribution of pedestrians is not so strong at present. But extremely high volume of pedestrians is observed in the highly integrated streets where there exists spontaneous retail and commercial developments. On the contrary, where there are other implanted land-uses other than retail or commercial areas in the highly integrated streets, the volume of pedestrians is found to be lower. So, spontaneously grown land-uses like retail depends upon the spatial configurations which have very strong impact on the movement of pedestrians. The study results also suggest that, while planning for enhancing pedestrians' mobility in historic towns like Mymensingh both the spatial configuration and existing land-use patterns need to be considered.

Keywords: *land use, street configuration, pedestrian movement, Mymensingh*

INTRODUCTION AND BACKGROUND

Even today, walking is the only mode of transport to a large percentage of the population especially in the developing world (World Bank 2008). In urban areas of many developing countries where population density and the number of poor populations are very high, walking is the only option available to a considerable number of people (World Bank 2008). Asian cities have been termed traditionally as '*cities of walkers'* as in many cities over Asia a large number of people rely on walking or cycling for their daily commuting (Asian Development Bank 2011). But due to the unprecedented economic growth, Asian countries are facing the challenges of rapid urbanization and urban transport becomes a burning issue (Asian Development Bank 2011). Therefore, the use and number of private vehicles are increasing in an alarming rate. As a result, severe traffic congestion, higher accident rates, air pollution and emission of greenhouse gases are very common phenomenon in a large number of Asian cities (Asian Development Bank 2011). These adverse incidents are also happening not only in Asian cities but also in most of the cities in developing countries all over the world. According to a census by World Bank (2000), "Within a generation the majority of the developing world's population will live in urban areas and the number of urban residents in developing countries will double, increasing by over 2 billion inhabitants." To cope with the transportation demands of an increasing urban population, particularly in low to middle income countries, there is an emerging need for low cost and sustainable transportation mode (World Bank 2008).

According to World Bank (2008), in the developing world, walkers still comprise over a third of the modal share of all trips made and even those affording public transport depend on walking to access to the stoppage points. Walking is also popular in many developed countries like United States and United Kingdom (Hu & Reuscher 2004). But due to the aggression of motorization, walking rates have declined progressively over the last several decades (Hu & Reuscher 2004). In a study it is seen that, in United States the percentage of primary school children who walk or bicycle to school decreases from 48 to 13 percent between 1969 to 2009 and in United Kingdom the percentage decreased from 62 to 50 percent between 1989 to 2004 (National Center for Safe Routes to School 2011)

To resolve the traffic congestion, the most common response is to focus on expanding road capacity rather looking for a more sustainable solution (Asian Development Bank 2011). But, a large number of evidence from different international consensus termed this approach as a 'short-term' process. This process eases traffic flow for the time being but also stimulates the growth of motorized vehicle numbers and use, that will also play a role for creating congestion again (Asian Development Bank 2011). In studies conducted by Asian Development Bank (2011), in a number of Asian cities focused on current pedestrian infrastructure, suggested pedestrian oriented solutions for Asian cities. Unfortunately, while the walking share is still high, it is declining across Asian cities day by day (Asian Development Bank 2011). Most city authorities seem to provide more incentives to private motorized transport rather than promoting non-motorized means like walking or cycling. As a result, a large number of people has already shifted to motorized vehicles as their main choice for transportation and consequently have contributed to deteriorating traffic conditions and the overall urban environment (Asian Development Bank 2011). Considering the degradation of pedestrian facilities and the migration of people to motorized transport, it is said that "… pedestrians are victims of policy neglect." (World Health Organization 2009). A recent study conducted by the World Health Organization (2009), on global road safety concluded that "… 68% of countries in the world don't have national or local level policies that promote walking and cycling." The absence of such policies will contribute to the shifts to private motorized modes and continued decline of pedestrian trips (Asian Development Bank 2011). According to World Bank (2008), as walking trips are highly unpredictable and pedestrian activity is not conducive to measurement, this mode is neglected repeatedly. Though a few projects in various regions throughout the world have recently initiated pedestrian projects, there is a severe necessity to give more attention to the urban pedestrian environment (World Bank 2008).

Bangladesh, a developing country of South Asia, is one of the most densely populated (976/sq.km, BBS Census 2011) and climate change vulnerable country in the world, with an area of 147,570 square kilometers (Bangladesh Bureau of Statistics 2015). In Bangladesh, though a large number of people are observed to walk in urban areas, pedestrians are the most vulnerable and neglected among all other road users. Still, vehicular traffic is getting much more concentration and priority than the pedestrians in urban planning policies (Emtenan & Shahid 2017).

REVIEW OF LITERATURE

This section investigates the significance of walking and the relevancy of enhancing the movements of pedestrians. It will also address factors of the built environment that directly affects the pedestrian movement, and the basic theories and concepts of Space Syntax that deals with street configuration and pedestrian movement.

Significance of walking research

Overall support for pedestrian environment has grown increasingly important as the world urbanizes and motorization threatens to displace or constrain foot travel. Replacing walking and public transit trips with those made by the private automobile significantly deteriorates the walking environment as well as the air quality in both developed and developing cities (World Bank 2008). The exponential increase of motorization and the inadequate concentration given to pedestrian facilities have inadvertently reduced the pedestrian share overall. As a result, pedestrian fatalities and accident rates have increased exponentially over the past decades. Not only this, rapid growth of motorization has led to higher levels of air pollution that directly affects pedestrians (Asian Development Bank 2011). Recently, one of the commonly shared aim of city planning and urban design is to reduce automobile dependency and encourage non-auto commuting (Ozbil et al. 2011). Usually, increments of walking reduces the dependence on vehicular travel and thus minimizes air pollution levels and also contributes to public health. As a result, a pedestrian friendly urban environment is considered as a key factor for urban sustainability and environmental welfare that also affects public health (World Health Organization 1997).

Being able to easily walk on city streets acts as a significant factor for improving the overall livability of the city. On the other hand, walking is indispensable for supporting public transport facilities and also provides an alternative to private vehicles for short distance trips. Short distance trips are common in Asian cities that are characterized by very high density of population and mixed land use development (Asian Development Bank 2011). Walking is gaining attention as a key factor for supporting healthier, environmentally friendly and socially active communities (Cambra et al. 2017). In the past decades, the research from various fields like architecture, urban planning, transportation and especially public health are focusing on walking for a number of influential reasons (Cambra et al. 2017). According to Siegel et al. (1995), walking is one of the least costly and widely available forms among all physical activities, and people of all ages can easily adopt walking (Westby, 2001). Simpson et al. (2003) argued that currently walking is the most accepted form of physical activity in the world.

Different studies from United States and United Kingdom shows that the pervasiveness of walking is several times higher than other most commonly reported physical activities (Organization for Economic Co-operation and Development 2010). The number of benefits of walking are continuously found in different research being conducted throughout the world. Amongst all of the research the most commonly found benefit of walking is the improvement of public health. Walking also ensures traffic safety, neighborhood security and attractive urban environment (Lindelow et al. 2014).

Recently a new term 'walkability' has gained significance due to the benefits of walking. It is found in a number of health researches (Lindelow et al. 2014). Walkability reflects overall walking environments in an area that takes into account the quality of pedestrian facilities, roadway conditions, land use patterns, community support, security and ease of walking. In sustainable urban design walkability is considered as a significant concept which directly affects human health, urban environments and socio-economic conditions (TDM Encyclopedia 2017). Currently walkability is considered as one of the important subjects not only in the urban design arena but also in the field of public health (Ozer & Kubat 2013). With the escalating awareness of the benefits of walking, the meaning of the term 'walk-able' has been newly termed as 'encouraging physical activity' (Kubat et al. 2013). As an indicator of the physical quality of urban environments, walkability it is also being measured as an 'environmental justice issue' (Greenberg and Renne 2005; Ozer & Kubat 2013).

Density, land-use and pedestrian movement

Different research regarding the relationship between walking behavior and built environment show that different physical properties of built environment affect walking activities and the number of pedestrians. Among all of the components of a built environment that influence pedestrian behavior positively, three factors have been proven consistent. These three factors are; mix of land-use, connectivity and density (Ozbil et al. 2011). In general, the studies reviewed in this section looked at how population density, land use pattern and connectivity of streets (street configuration) affects walking behavior and controls the number of pedestrians. In various research taken from the fields of urban design and planning, transportation and also from public health there is are similar findings. It has been advised that a higher rate of pedestrians is observed where there exists neighborhoods with higher residential and employment densities, more connected street patterns, and a variety of destinations (Cervero & Kockelman 1997; Frank & Pivo 1994; Handy et al. 2002; Saelens et al. 2003, Choi, 2013). According to Agarwal and Schimek (2007), higher population densities are usually linked with more walking. Vehicular trips can be degenerated through compact developments with higher densities and by reducing the distance between origins and destinations. It offers a diversity of choices for commuting by triggering changes in the overall travel pattern (Ewing et al. 1994; Holtzclaw 1994; Cervero and Kockelman 1997). Recent policy initiatives also encourage denser developments for reducing auto-dependence rates (Washington State Growth Management Act, 1990).

Additionally, other researchers recommend that land use patterns act as a considerable factor for encouraging walks. The existence of retail within neighborhoods has stronger impact on choices for non-work trips than density (Cervero and Kockelman1997). Patterns of development have a significant effect on household travel beyond their relationships with the socio-demographic characteristics of households (Ewing et al. 1996). Higher levels of mix-use development and the presence of activities near residences increase non-work trips and encourage non-auto commuting (Holtzclaw 1994; Cervero 1996). Increased levels of mixed land use at the trip origins and destinations capitulate increase in walking (Frank and Pivo 1994). Likewise, mixed land use neighborhoods that help to increase walking were affiliated with a population with a reduction in body mass index (Frank et al. 2006).

Space Syntax, street configuration and pedestrian movement

Conceptualizing and measuring the built environment are significant steps for understanding the role of street configuration in shaping physical activity like walking. These types of methods for measuring the built environment have advanced considerably in the past decade (Sallis, 2009, Koohsari et al. 2014). Space Syntax is a concept and analytical method developed primarily in the arena of architecture and urban design for understanding the morphological logic of urban grids (Hillier 1996; Hillier & Hanson, 1984). Within the past several years the practical use of Space Syntax has been more familiar in architecture and urban design disciplines (Koohsari et al. 2014). Hillier and Hanson (1984), introduced the method of Space Syntax in their seminal book titled *The Social Logic of Space*. According to Hillier et al. (1987, p. 363),

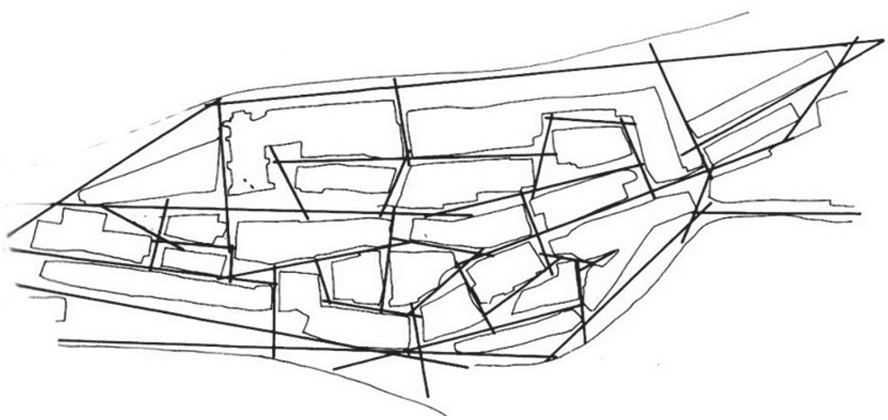


Figure 1:
The axial map as a representation of spatial form (Hillier & Hanson, 1984)

> *"Space syntax . . . is a set of techniques for the representation, quantification, and interpretation of spatial configuration in buildings and settlements. Configuration is defined in general as, at least, the relation between two spaces taking into account a third, and, at most, as the relations among spaces in a complex taking into account all other spaces in the complex."*

Space Syntax investigates the spatial structure of cities by first modeling their network of spaces or non- built up areas (Koohsari et al. 2014). Space Syntax quantifies spatial layout of spaces using a set of spatial descriptors that are generally calculated on the notion of 'axial map' (Figure 1). An axial map comprises the 'longest and fewest ' lines that covers all the spaces in an urban layout and connects them with each other (Koohsari et al. 2014). Additionally, axial lines are "… the longest visibility lines for representing individual linear spaces in urban environments" (Liu & Jiang, 2012) and they are assumed to be "… the sight lines for people moving in a spatial network" (Koohsari et al. 2014).

The Space Syntax method involves measuring the accessibility of all parts of an urban network from each individual street segment. The intent is to "… provide a comprehensive description of spatial structure and the hierarchy of connectedness without evoking information about land use or making assumptions about desirable or typical trips."(Ozbil et al. 2015) In the Space Syntax method, the particular concentration is specified as to the number of directional changes required for moving from one location to another (Ozbil et al. 2015). The theory of Space Syntax argues that the amount of movement on each street is influenced by its configuration and by the relationship each street establishes with other streets within the urban network. The spatial distribution of pedestrian flows within the system is therefore fundamentally morphological and topological, being a functional result of the configuration of the urban street network (Pereira et al. 2012; Cambra et al. 2017). A positive and substantial degree of correlation was found between the volumes of pedestrian and Space Syntax indicators (Connectivity, Integration, control and Global Choice) amongst which 'integration' was found to have the strongest correlation. Integration is a static global measure that describes the average depth of a space to all other spaces in the system. The higher integration value of the axial line, the less is the depth (Peponis & Wineman 2002). For reaching a highly integrated street, one has to make fewer turns, whereas more changes of direction are required to arrive at less integrated streets (Kostakos 2010). The spaces of a system can be ranked from the most integrated to the most segregated (Klarqvist 1993). The global integration index (Rn) reflects the average topological distance in a network, that is to say the number of directional changes from each line segment. The local integration (R3) index (with a radius of 3) which reflects the topological proximity of a line to its nearby axial lines (two turns away from a given axial line) to all the other lines in a network (Cambra et al. 2017).

In Space Syntax, the configuration of a network is considered to be the "… primary generator of pedestrian movement." (Hillier et al. 1993, p. 31). This means the direct impact of street configuration on pedestrian movement is independent of other variables of built environment such as land use. It is hypothesized that "… the more a space is integrated, the greater the chances that it will be more densely occupied by moving people." (Peponis et al., 1997, p. 344).

Different studies show a positive association between volume of pedestrians and connectedness of street segments. Hillier et al. (1993), examined the relationship between the configurational values of the King's Cross area in London and observed the movement of pedestrians. A coefficient of determination (R^2) of 0.238 was found by using simple linear regression analysis between the pedestrians' volume and integration values. By using the natural logarithm of pedestrian flows a higher degree of R^2(0.547) was found. The degree of correlation also amplified when each of the 10 subareas of the whole study area was analyzed independently, ranging from 0.617 to 0.789 that means almost 60% to 80% of the variation of the pedestrian movement could be explained just by analyzing the configurational aspects (Hillier et al. 1993, Cambra et al. 2017). Pedestrian movement densities were also found to be interrelated with the integration values of streets within the adjacent street network in traditional residential areas in London. Whereas, this correlation broke down in housing estates where the internal path structure was excessively fragmented and labyrinthine (Hillier et al. 1987). The connection between pedestrian movement densities and integration was consequently found in different cities around the world. The relationships were found in extensive studies in London (Hillier et al.1993), in Greek Cities

(Peponis et al.1989), in Dutch cities (Read, 1999), in Istanbul (Kubat et al. 2005) or in Atlanta (Peponis et al. 1997).
It is argued that streets which attract more movement by virtue of their syntactic accessibility also attract land-uses, such as retail, depending on movement, which in turn multiplies their attraction value, turning an otherwise linear relationship into a logarithmic one (Hillier et al. 1993, Ozbil et al. 2011). It is also revealed that, at least in some cases, streets with commercial uses continue to attract proportionately higher levels of movement even at the times of the day or the week when retail premises are closed, which indicates that the correlation holds, independent of the functional impact of land use (Peponis 1989, Ozbil et al. 2011).

The case of the town Mymensingh, Bangladesh

Bangladesh is a developing country of south Asia which is undergoing urbanization at a remarkable pace. Its cities are growing more than twice the rate of rural areas, and this rapid growth of urbanization is expected to continue until Bangladesh transitions from a low income to a middle-income country (Bangladesh Urban Forum 2011). Since independence in 1971, the urban population has grown at a yearly average rate of 6 percent whereas at the same time period, the national population growth was only 2.2 percent. Therefore, urban population has grown six-fold, compared with a 70 percent increase in rural population (World Bank 2007). According to recent UN data, about 35 million people, which is almost 25 percent of the total population of Bangladesh, presently live in urban areas, compared to only 8 percent at the time of independence. By the year 2030, the number is predicted to increase to more than 80 million (World Bank 2007). At the moment, the fast pace of unplanned and uncontrolled urban growth is posing enormous challenges to the sustainable development of the country (Bangladesh Urban Forum 2011).

Mymensingh is one of the historic towns in Bangladesh that was established by the British East India Company in 1787 C.E. (Bangladesh Bureau of Statistics 2011). The town was established along the river Brahmaputra (Figure 3), as the river was the most significant mode of transport in that time. At present, Mymensingh, one of the divisional headquarters of Bangladesh, is located about 118 Km north of the capital Dhaka (BRAC 2015). The population density of Mymensingh City is 5493/sq km (Bangladesh Bureau of Statistics 2011).

The major streets were built during the colonial period to connect different administrative purposes. Later, a number of organic street patterns evolved to connect local neighborhoods within the colonial urban grid (Aziz 2016). Colonial administrative structures like the Court House, Civil lines, the Town Hall, a Hospital and the Railway station were constructed by the colonial rulers for specific purposes within proximity. Afterwards the local land lords, Zamindars, established their lavish villas near the river. The villas had large open spaces and were enclosed by high walls. Zamindars also developed

Figure 2 (A & B):
Different street side activities along Swadeshi bazaar
Source: Field Survey 2014

a number of educational institutions within the town. Local bazaars were also established within the near proximity to the river as that was how goods were transported. Later on, different commercial and residential areas were developed spontaneously in different sections of the town. The spontaneously grown streets were narrow and crooked as they were not built for motorized vehicles. During the colonial period it was unimaginable for any local to afford a car. Hence, the streets of the town were initially determined by the colonists, later, streets evolved by the local land lords and finally by local inhabitants. As a result, there exists a mixture of different land uses both implanted and spontaneously increased that intermingle with each other, all within near proximity (Figure 3). On the northern part the river and on the southern part the rail tracks act as two bold edges of the 'Historic part' of the linear town (Aziz 2016).

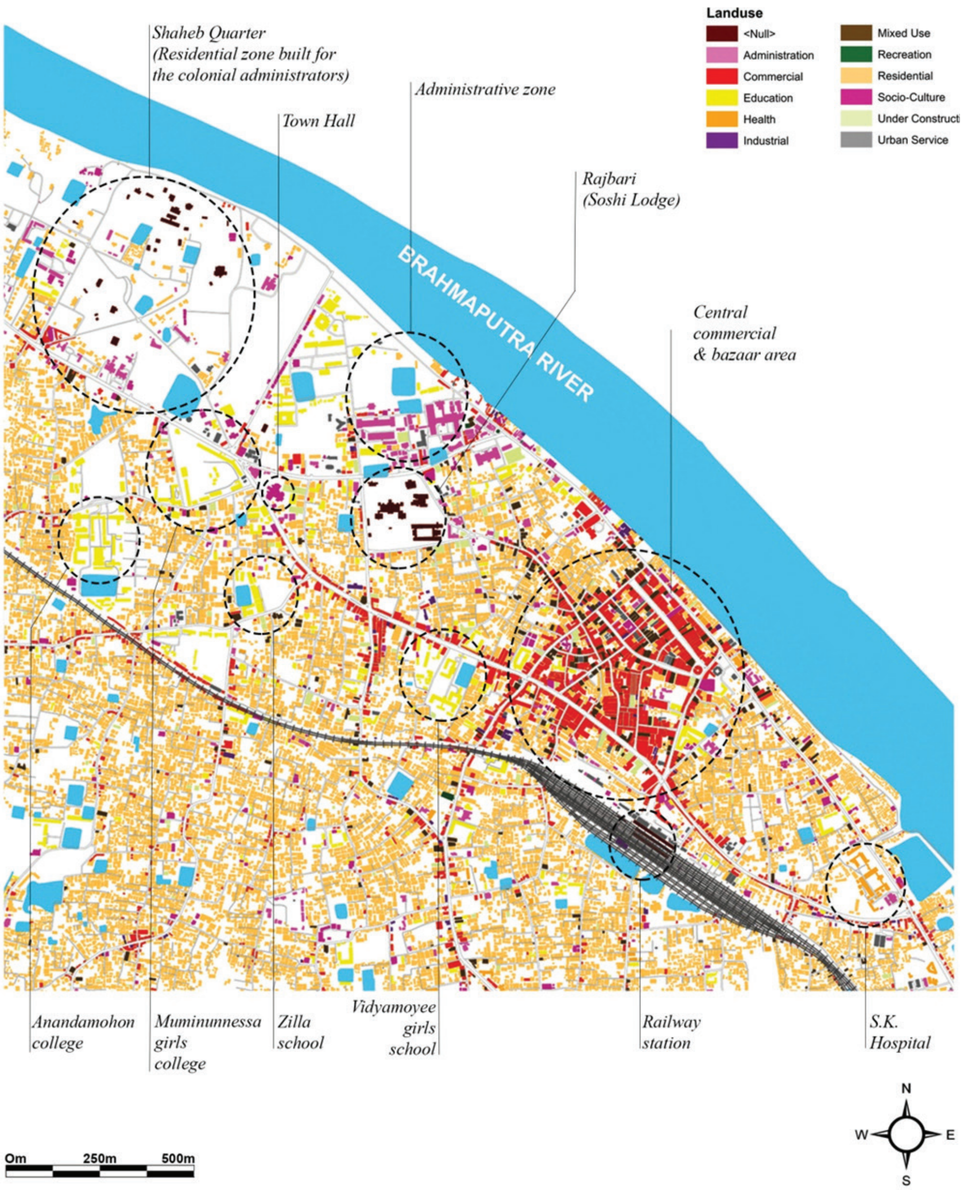


Figure 3:
Significant land-uses in the historic part of Mymensingh
Source: Field Survey 2014, Source of base map: Urban Development Directorate (UDD) 2014

METHODOLOGY

This study was conducted in a number of sequential stages. In the first stage, data on actual moving pedestrian flows were recorded by conducting on site observations through the Gate method within the study area. Though there are other recently developed sophisticated and automated methods, the Gate method is still the most used method to obtain pedestrian flows (Cambra et al. 2017). According to the Space Syntax Observation Manual (Vaughan & Grajewski 2001),

> *"… the gate method is the workhorse of spatial observing techniques". "It is a simple and widely adopted method consisting of observing the people (or vehicles) passing through an imaginary screen line crossing the street space at a right angle, being suitable for recording moving people but not for stationary people" (Cambra et al., 2017).*

By using this simple and straightforward technique, the Space Syntax research community has contributed significantly to the understanding of the relationship between built environment attributes and pedestrian volumes. It provides consistent evidence of a positive and significant relationship between the network connectivity and the pedestrian activity (Hillier et al. 1993; Hillier & Iida 2005; Kalakou & Moura 2014; Hajrasouliha, 2015; Cambra et al. 2017).

In stage two, detail field surveys were conducted to assess the existing land use pattern. In stage three, a GIS based map, collected from the secondary source, was used to verify existing land use patterns. In the fourth stage, spatial measures of different street segments were made through the software Depthmap X, which is a single software platform to perform a set of spatial network analyses designed to understand social processes within the built environment. In the final stage of this research, the association between distributions of pedestrians and spatial measures were studied using linear statistical analysis.

Pedestrian observations and data collection

Due to resource limitations, only the historic part of Mymensingh that was developed during the Colonial period was observed for counting pedestrians. The streets surveyed were selected based on the

Figure 4:
Street side temporary shops and pedestrians along the west wall of Vidyamoyee Girls School, Mymensingh.
(Source: Field Survey 2014)

following criteria: (1) not a dead-end street, (2) representative of a wide range of configurations and qualities of the street network, (3) observation points were determined within the streets that vary in types of land use, like bazaars, schools, religious buildings, residential areas, and mixed-use buildings. In this study, a number of street segments were chosen that cover a wide range of well-used, moderately used and poorly used street segments. The Gate method, developed by Space Syntax, is followed in this study to collect pedestrian data. Three times within a day, all the moving pedestrians are counted crossing a notional gate. From a reconnaissance survey three rush hours, morning peak hour (8.00 to 10.00 AM), midday peak hour (12.00-2.00 PM) and afternoon peak hour (4.00-6.00 PM) are considered for the study. Each set of pedestrian observations lasted for 2.5 minutes. Each set of is converted to generate the movement per hour for analysis. For counting pedestrians, observations are taken at 112 points by three observers during 5 five weekdays within the 'Historic Part' of Mymensingh Town. Amongst the 112 observation points, counts of 82 points were found valid. In sunny and moderate weather, the fieldwork was done during the month of September 2014, starting on Sunday and ending on Thursday as Friday and Saturday are holy days in Bangladesh,

Land-use pattern within the study area

Land use data were acquired from the 2014 GIS based map provided by the Urban Development Directorate (UDD) and was used to select the observation points. After selecting the observation points, real life and detail land-use distribution patterns adjacent to the observation points were observed on a street by street basis. The central portion of the historic district is occupied by the commercial and retail zones which are in in close proximity to the railway station (Figure 3). A number of bazaar zones, Mechua bazar, Boro bazaar, and Choto bazaar, are situated within this zone. These bazaars are mainly shopping streets. Generally, the ground floor is used for retail shops, whereas the upper floors accommodate commercial uses like banks or other offices. In some cases, the upper floors of the retail buildings are used as residential areas. In many cases the owner of the shop resides on the upper floors. Within this central retail, commercial and mixed-use zone there are several mosques and temples. In the nearby residential zone, the Kalibari area, there also exists a few small retail shops at the ground level. In between the residential and central commercial zones there is a large school, the Mukul Niketon School, and a large mosque locally famous as Boro Masjid. Most of the administrative buildings like the Judge's court, district commissioner's office, etc. are situated near the river Brahmaputa. The lavish villa, Soshi Lodge, built by the local Zamindar, is situated in between the administrative zone and the central commercial zone. Retail and commercial developments are restricted in the administrative zones, though there are some temporary shops existing along the walkways of the restricted zone (Figure 4). During the field survey, pedestrians are observed and counted at different streets situated in different zones of activity during different time periods.

Figure 5:
Street side activities at Ganginarpar Road and Station Road (Retail and Commercial Area) Source: Field Survey 2014

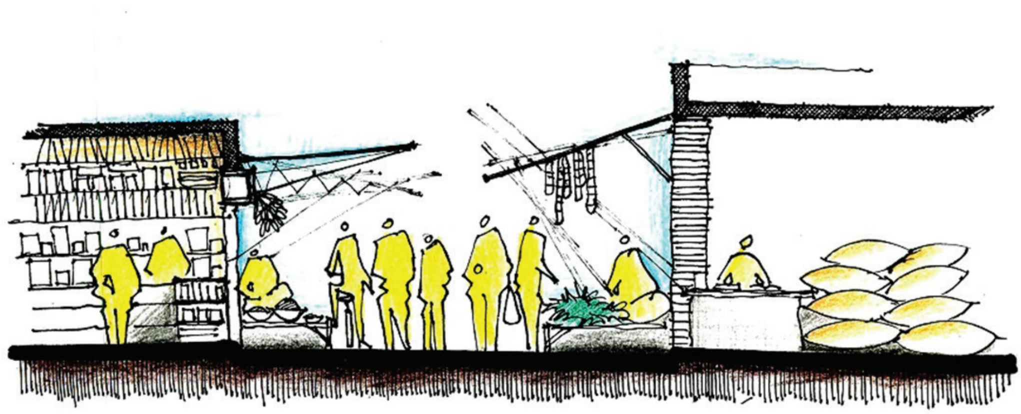


Figure 6:
Section through Mechua Bazaar Street

Spatial analysis

The axial map for Mymensingh was drawn based on the GIS map of Mymensingh (2014), collected from Urban Development Directorate (UDD). The axial map was analyzed through the software Depthmap X for space syntax (spatial) measures of the study area. In the analysed axial map warm colored, red to orange, axial lines are highly integrated (more accessible) whereas cool colored, blue to sky-blue, are most segregated (less accessible) streets (Figure 7). The analyzed axial map of Mymensingh, determined that the central area (Boro Bazaar Street, Choto Bazaar Street, Swadeshi Bazaar, Mechua Bazaar) is still within the most integrated part of the town. The two major historic streets, one along the river and one is parallel to the rail track, connecting Rally to the Town Hall area is within the highly accessible/integrated part of the town. The most significant spatial measures global integration (Rn) and local integration (R3) values of the corresponding street segments (at which pedestrians were counted) were recorded.

Statistical Analysis

Multivariate regression analyses were conducted to examine the associations between pedestrian counts with global (Rn) and local (R3) integration values of the corresponding street segments. Regression analysis of Pedestrian count (log) and global integration values considering the whole town are shown in Table 3. The value of R^2 was found .0893 that means a very poor correlation. In case of the regression analysis between Pedestrian count (log) and local integration (R3) the value of R^2 were found.14 which also indicates a poor interrelation (Table 1 & 2).

FINDINGS AND ANALYSIS

The analysis and findings of the research are discussed in the following sections.

Analysis of the variations in pedestrian volumes during different time slots

Table 3 notes the volume differences of pedestrian travel at various gates during different time slots. At some gates the volume was 16 gate points higher than at others.

From table 3, it is observed that in most of the cases, the highest pedestrian counts are found in commercial streets whether the pedestrian facilities exist or not. In almost all the cases, the volume of pedestrians is comparatively lower in the morning hours and with time it increases and at midday and afternoon the counts are found to be significantly higher. The variations between midday and afternoon are not so significant. An exception is the Mechua bazaar, where the highest pedestrian count is found in the morning hours compared to midday and afternoon, but the difference is not very significant (Table 3).

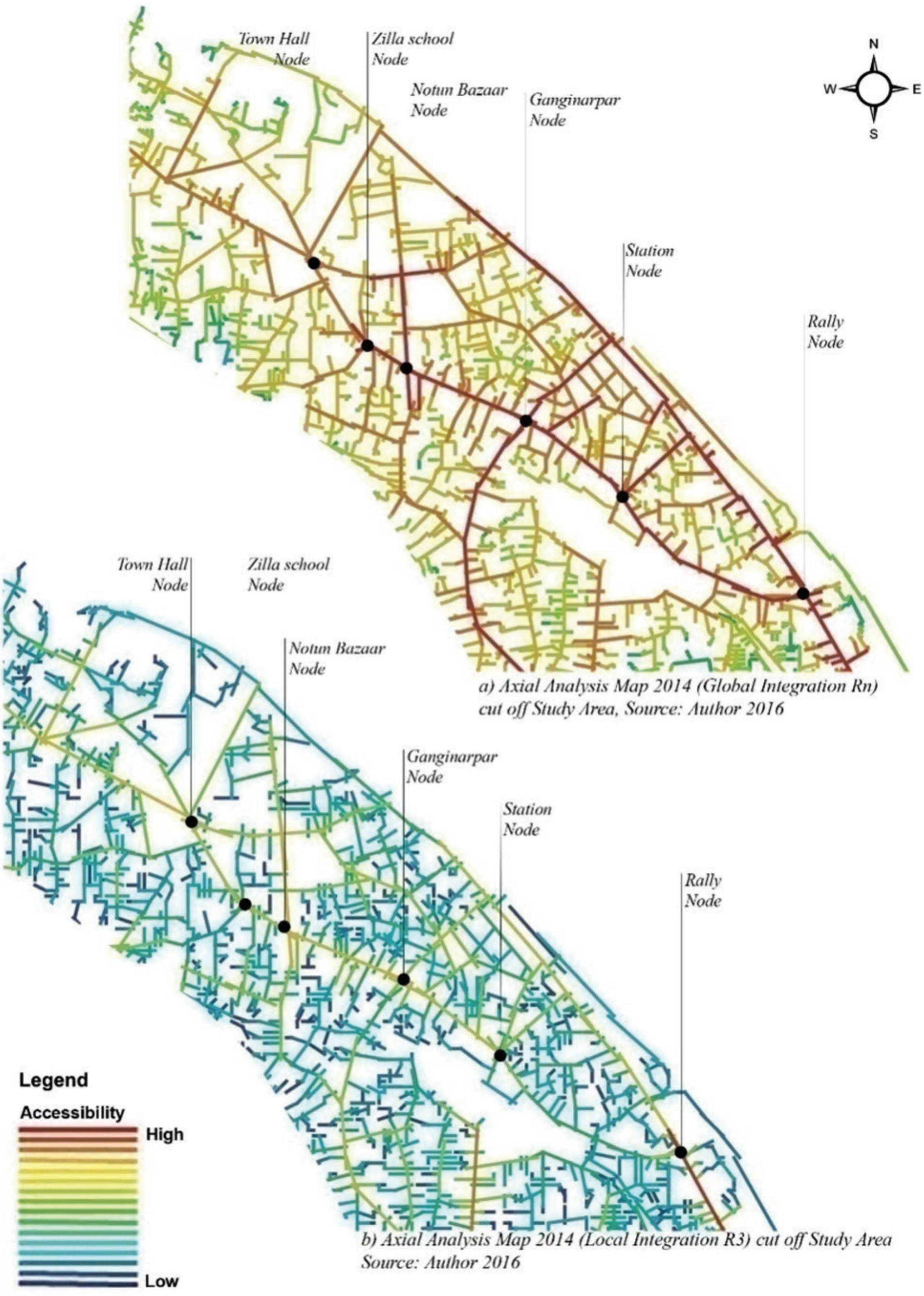


Figure 7:
Axial map of Mymensingh Town 2014 (Study Area) analyzed through Depthmap X.

Table 1: Regression analysis between pedestrian count (log) and Global integration (Rn)

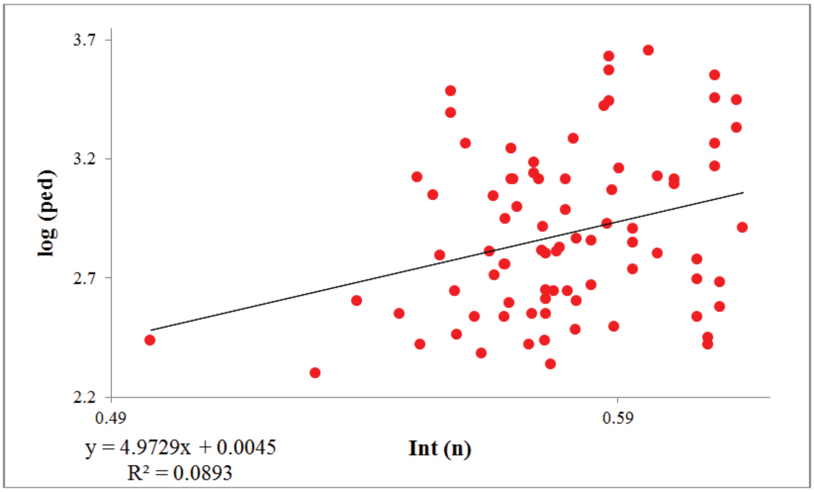


Table 2: Regression analysis between pedestrian count (log) and Local integration (R3)

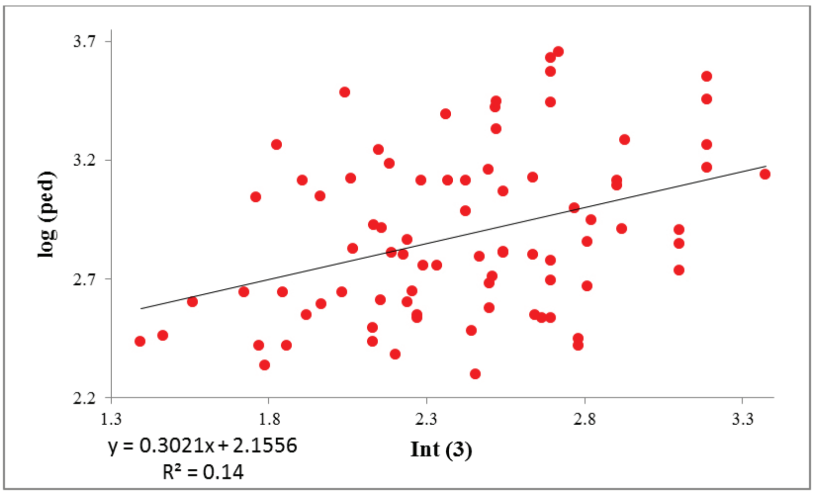


Table 4 records the variation of pedestrian volumes during different time slots. It indicates that the lowest pedestrian counts were found at residential and mixed-use streets. In some cases, the morning counts are higher whereas in other cases midday and afternoon counts are higher. So, it is difficult to trace any trend within the areas of the lowest count. The variations of pedestrian counts in different time slots at different residential streets are unpredictable. In some residential streets pedestrian counts are higher in the morning than other time slots; whereas, at other locations the higher counts are found in the evening. Even in some cases, it is found that in less integrated streets, pedestrian traffic is found to be comparatively higher due to the proximity of the central commercial zone (Table 4).

Table 3: The average highest pedestrian counts in different time slots (From high to low)
Source: Field Survey 2014

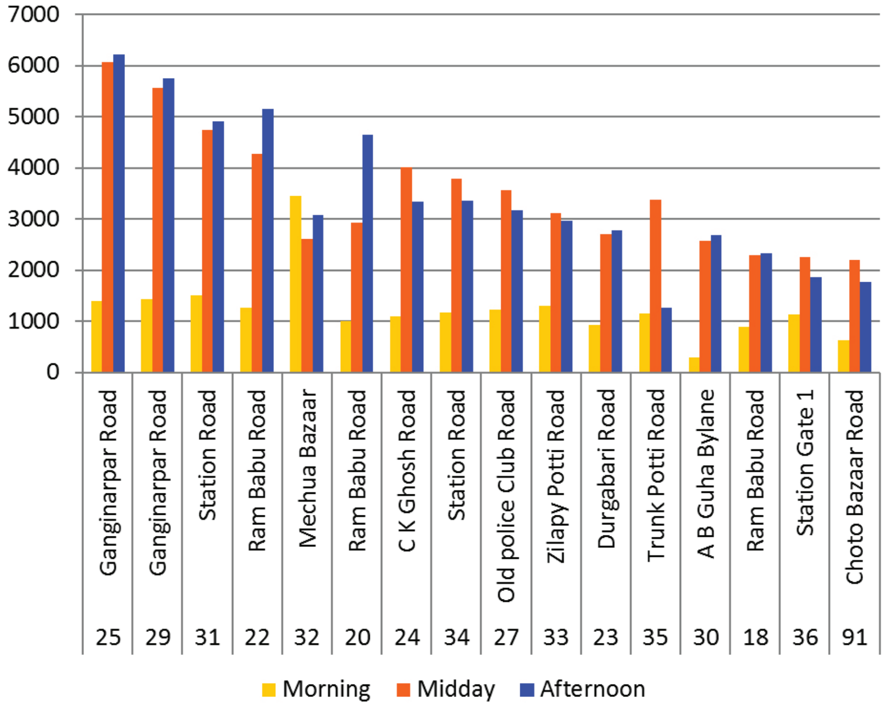
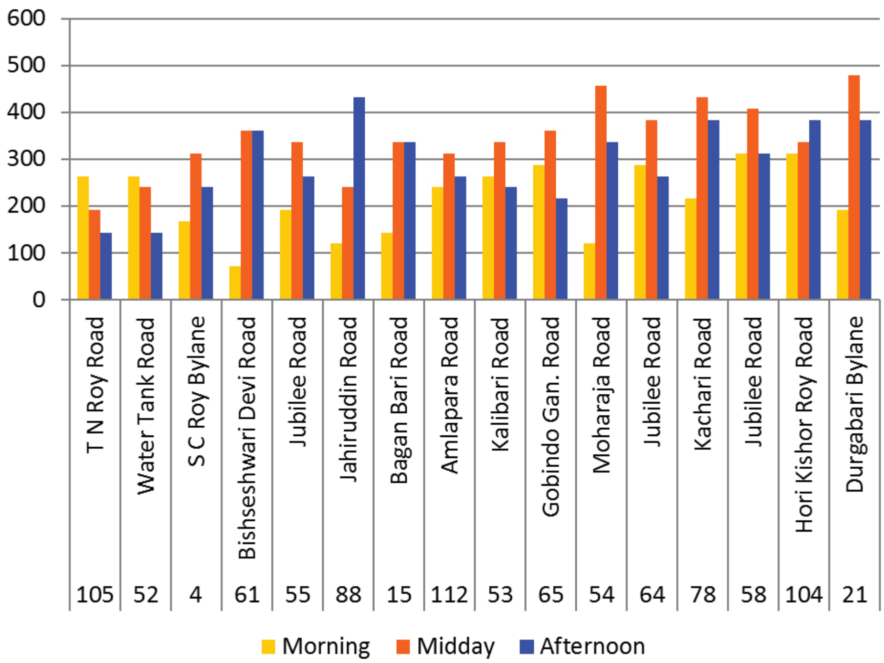


Table 4: The average lowest pedestrian counts in different time slots (From low to High)
Source: Field Survey 2014



Analysis of highest and lowest pedestrian counts according to land-use

While observing the pedestrians in the field survey, it is seen that in morning hours between 8.00 AM to 10.00 AM the pedestrians are mainly those who are going to school or to work. Most of the retail areas (except the bazaar for fish, meat and vegetables) are closed. Only the local bazaars are open in morning hours. During the morning hours a high volume of pedestrians are found in the streets in front of different schools and in the local bazaars. Whereas at midday between 12.00 to 2.00PM a very high number of pedestrians are observed in the retail and commercial streets, Station Road and Ganginarpar Road. The pedestrians going to the retail and commercial areas, and those going home from schools occupy these streets.

In afternoon hours from 4.00 to 6.00PM the numbers of pedestrians are higher in the retail and commercial areas, especially in Ganginarpar Road, Station Road and Ram Babu Road (Table 3). Thus, in the retail and commercial areas pedestrian traffic is found to be higher in the midday and afternoon hours compared to the morning hours. In contrast, at the Mechua bazaar, (Figure 6) which is a local *kancha* bazaar (the local term of a bazaar for daily commodities like vegetables, fishes, meats and fruits), the number of pedestrians during the morning is found to be slightly higher as many people go there before going to work. Another exception is found at Trunk Potti Road where the midday count was comparatively higher than other counts due to the presence of the Mukul Niketon School.

At the gates on Ganginarpar road, which is the main road, the numbers of pedestrians were extremely high. The observed pedestrian flow is much higher here than in any other streets of town. Different kinds of retail shopping centers and residential hotels are found along this street. The proximity of the railway station and other commercial streets also act as a pedestrian generator. From the analyses, it is very clear that the pedestrian flow along the Ganginarpar road and Station road is significantly higher than in all other streets studied. These streets are also found to be the busiest part of the town in respect to spontaneous retail and commercial development and for vehicular traffic congestion. In most of the cases the numbers of pedestrians are very low in residential streets like T N Roy Road, Water Tank Road, S C Roy lane. Although most of the administrative functions are along the Jubilee road, pedestrians are found in lower numbers. (Table 4)

Spatial analysis of Mymensingh town

By analyzing the axial map of Mymensingh 2014 (Figure 5) through Depthmap X, it is seen that the central part of the town is still within the highly integrated area. Although the centrally integrated core extends in different directions, the major streets of the historic section, the rail station to Town Hall, is within the most integrated part of the town as shown by the red colored line in Figure 7. The historic streets within this area are Ganginarpar Road, Station Road, Ram Babu Road and Shama Choron Rai Road. According to the Space Syntax Analysis, this part of the town is the most integrated part the town. which means anyone who wants to travel from one part from another part of the town need to cross this section. Other historic peripheral roads along the river, like Kalibari road, Jubilee road, Kachari road and Strand road, are also located within the highly integrated part of the town. Even the parallel connecting roads, like Moharaja Road, Trunk Potti Road, Durgabari Road, also belong within the highly integrated part of the town. Almost all of the roads found in the highly integrated part are the historic roads that were built by the British Colonists. On the other hand, the labyrinthine and crooked streets that were organically integrated by the local inhabitants still belongs to the segregated and less integrated part of town.

Comparative analysis between pedestrian counts, Space Syntax measures and land-use

The results of the regression analysis (Value of $R^{2)}$ between the pedestrian count and the mixed-use integration areas, the values were found very low, meaning a very poor relationship. The streets where higher volumes of pedestrians are found have high integration values. On the other hand, low numbers of pedestrians are found in less integrated streets. It is suggested that there might exist a relationship between these two.

The presence of some implanted land uses restricts the spontaneous growth of retail and commercial development. Examples of this restriction are the administrative buildings constructed during the Colonial Period along some of the highly integrated streets, like Kachari Road. As the land-uses like retail acts as a significant attractor of pedestrians, the number of pedestrians along these administrative streets are limited in spite of having higher integration values.

On the other hand, spontaneous retail and commercial growth in some highly integrated streets like Ganginarpar Road, Station Road and Rambabu Road, attracts more people. Pedestrians attract more retail which again attracts more people. As a result, within these highly integrated and commercially significant streets pedestrians are found in extremely high numbers compared to all other streets in town. Even then, due to the proximity of the highly integrated and commercially significant streets like Ganginarpar Road and Station Road, the comparatively high volume of pedestrians, as well as spontaneous retail growth, was observed at some of the less integrated streets.

Generally, the less integrated streets are residential in nature. Also, some land uses like schools along highly integrated streets (Vidyamoyee School along Rambabu Road) affects pedestrians and retail growth in different ways. A large number of pedestrians, the majority being students, are attracted to the school at specific times, but the blank wall of the school restricts large scale retail development. This restriction limits pedestrian traffic to some extent. Although the temporary shops along the blank walls of Vidyamoyee school, attracts some pedestrians, the volume is not very high like the retail shopping streets of Ganginarpar Road or Station road.

CONCLUSION

The findings of this research lend specific support for a number of key findings that may have implications for urban planning and urban design decisions aimed at encouraging pedestrians and reducing automobile dependency.

Analyzing the correlation between pedestrian volume and spatial measures, integration both on a local and global scale, are found to be poor. But there might be relationships between them, as many highly integrated streets have higher pedestrian volume; whereas segregated, less integrated streets have low pedestrian volumes. Integration values are also related to land-use patterns. In most cases, retail and commercial developments were found in highly integrated streets, whereas residential developments were seen in less integrated streets.

Exceptions are found in the streets where there are some implanted land-use, like administrative or educational institutes, within highly integrated zones. These land-uses restrict the spontaneous growth of retail development, but a number of pedestrians are attracted for specific purposes to these zones. Though there are flows of pedestrians within these zones, the volume is not as high as in the retail areas.

Where there is scope for retail developments in highly integrated streets, the volume of pedestrians is found to be extremely high compared to other highly integrated streets where retail development is restricted. Therefore, the movement of pedestrians and the development of different land-uses initially depend upon the spatial configuration. But eventually land-uses having specific attractions also have significant impact on pedestrian movements.

In case of the historic part of Mymensingh the effect of land-uses, both implanted and spontaneously grown, breaks down the initial relationships between spatial configuration and pedestrian volume. So, in the urban planning process in historic towns like Mymensingh, both the spatial configuration and the existing land-use patterns should be considered in providing pedestrian facilities, hence encouraging pedestrians and enhancing the volume of pedestrians.

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