Social Sciences
2016; 5(6): 77-85
http://www.sciencepublishinggroup.com/j/ss
doi: 10.11648/j.ss.20160506.11
ISSN: 2326-9863 (Print); ISSN: 2326-988X (Online)

Evaluation of Bicycling Environment for Urban Mobility: A Case of Selected Roads in Khulna Metropolitan City

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To cite this article:

Md. Sohel Rana, Muhammad Salaha Uddin, Md. Abu Saeed Al Azad. Evaluation of Bicycling Environment for Urban Mobility: A Case of Selected Roads in Khulna Metropolitan City. *Social Sciences.* Vol. 5, No. 6, 2016, pp. 77-85. doi: 10.11648/j.ss.20160506.11

Received: November 20, 2016; **Accepted**: December 12, 2016; **Published**: January 5, 2017

Abstract: Bicycle is considered as one of the sustainable, and active modes of transportation. However, in the urban milieu bicycling has not been prioritized yet, and not been integrated with the other forms of transportation modes. This scenario is more ubiquities for a developing country like Bangladesh. Khulna is the third largest city, and with industrial setup has noticeable number of bicycle users. Unfortunately, the bicycling environment for this particular group of travelers in the city is not up to the standard. From this realization, this study has been conducted to explore the bicycling environment of selected roads on the basis of fourteen established criteria of evaluating bicycling environment. Six roads have been studied for this purpose. It has been found that all of the roads are not up to the standard for bicycling, though numbers of bicyclists have been observed in all of the roads. Each of the roads has been critically assessed by conducting physical, and user opinion survey. Scores have been compared of the selected six roads to give the ranks of the roads. The results from user perspective, and evaluation criteria slightly differ in outcomes. According to the assessment of evaluation criteria Ahsan Ahmed Road is only providing 17% suitable environment to the bicyclists. On the other hand, according to user opinion Municipal road is providing better services than the rest five roads. Evaluation of bicycling environment has given a detail scenario of how different roads are serving to bicyclists. It has been cleared that none of the roads (studied roads) has been giving optimum services to the bicycle user. To promote, and improve the situation for bicycling planned intervention is mandatory according to the situational analysis. This study is providing an insight to think about the bicycling planning at city level.

Keywords: Bicycling Environment, Evaluation Criteria, User Perspective, Bicycling Planning

1. Introduction and Background

Humans are mobile in nature, and in modern urban life people move from here to there on a regular basis such as from home to work, school, office, and others. The nature of mobility differs from place to place, and characteristic pattern of physical development influences the mobility in urban context. The mobility of some people (fast drivers) is undoubtedly very high in sprawling city where most streets are designed for fast traffic. The tendency of pedestrians to speedy car, and automobiles are increased while alternative modes of transportation such as walking, and bicycling decreased. However, Bicycle is considered as one of the sustainable modes in transportation system. It is a universally accepted contemporary mode of transportation. There is no parallel competitor of bicycle considering its non-polluting, space-saving, resource conserving, and health enhancing characteristics. In city context for urban mobility bicycle is usually acceptable to planners, and policy makers as a part of promoting multi-modal transportation system. Politicians endorse it, and there are dedicated support groups that vocally promote bicycle system as the solution for almost all city mobility problems [1].

As a sustainable mode of urban transportation bicycle has become a popular phenomenon over the world to ensure sustainable urban mobility. Denmark, Germany and Netherlands have made their cities bicycle friendly, and car unfriendly. A range of taxes, restrictions on car ownership, parking, and use have made driving expensive and

inconvenient. Car ownership is still very high in these countries, and mentioned measures, together with policies have encouraged more people to use their bicycles when they can [2]. However, for advocating pure bike system in cities the people would have to be socially responsible, and physically fit. Moreover, choosing the bicycle as a mode of transportation is a very special process at individual level. Besides all of the issues, Bicycle could be dominant urban transportation in complex urban setup for its unique characteristics. There are subliminal reasons behind the non uses as well as non popularity of bicycle as mode of transportation for urban mobility. Apparently, and perceptually it is assumed that Bicycle is not a firm mode of transportation because of the lack of security in this vehicular mode, and also it is a mode quite unlike from cars in relation to conveniences. Insecurity, and inconvenience are often considered important barriers for cycling. Due to this negative perception bicycle is not considered as a mode of transportation for urban mobility. In this mobile society there is potentiality of bicycles to be useful from mobility concern. Especially, from the point of short urban mobility concern bicycle can be a good option in a specific situation. The promotion of bicycle for the mobility purposes demands a friendly environment. This environment can only be possible to ensure through proper planning. Opportunities to provide accessible, safe, convenient and inviting environments for walking and bicycling should include adoption of effective land use planning and design standards [3]. For instance, Danish, Dutch, and German authorities have actively worked to provide friendly environment for bicycling [2]. Where separate paths and lanes are not possible, traffic calming measures play an important role for safe cycling. For example, the speed limit in most residential areas in Denmark, Germany and Netherlands has been reduced to 30 km/hr (19 mph). Road junctions have also been extensively modified to make them safer, and more convenient for cyclists. Extensive bike parking facilities, especially at train and tram station, and bus stops have increased cyclist's convenience, and encouraged 'bike and ride' travelling. These are the formal forms of the usage of bicycle. Self-service rental bicycle, power assisted bicycles, development of cycle paths, pedestrian priority zones, secure bicycle parking, and other services: more and more initiatives are reinforcing the bicycle's position in town and improving mobility and security.

People can experience safe bicycling environment in a properly planned area. Usually, in case of the cities of developing countries this environment is not in favour of bicycling due to the lack of planning intervention. Taking this hypothesis this study is conducted to assess the bicycling environment of some selected roads in Khulna city which is the third largest city of Bangladesh. Bicycle is an important mode of transportation at individual level in Khulna city. This is the mode that is easily available to people of almost every age, and socio-economic level. Khulna is an industrial city, and its growth pattern is linear. Public transit system is not yet developed according to demand. There is only one bus route of 22 Km that runs from Fultola to Rupsha. In Khulna city trips are generated from different production point such as home, work, education, shopping, recreation and other purposes. All of these trips are produced by different types of modes. Here, 17.1% trips are motorized but the bicycles users are limited to 5.9% [4]. Only 6% home to work trip was produced by bus because most of the people are Khulna were not interested in bus service as most of the time town service buses neither maintained a schedule nor available [5]. Majority of the city dwellers belong to the low income group. About 50% of the city dwellers made trips on foot [6]. On an average, people travelled one kilometer daily to reach their work places [6]. People usually depend on the para-transit like modes such as Three Wheeler Battery Bike, Three Wheeler Motorized Bike (local Name *Autul*, *CNG, Baby Taxi*) for mobility purposes. Due to the undeveloped public transit system as well as for socio-economic condition of the people bicycling as a mode of transport has a great potentiality in Khulna city. This study is the pre-assessment of bicycling environment for the formalization of this mode in city's transportation system. No formalized form of cycling, and lack of infrastructure is just the tip of the problem in Khulna city. To induce bicycling for urban mobility purposes there will require separate lane, safety, marking, and signal, bicycle parking site, limited speed of motorized vehicle, and appropriate governmental policy. Bike lanes, and better bicycle infrastructure can help to better organize the flows of traffic and reduce the chance that motorists will stray into cyclist's path of travel. In reality for many cities in Bangladesh this situation is not imaginable. This is also true for Khulna city.

Bicycle has become a simple, and efficient mode of transportation service. If bicycle using will increase, there arise a question that how it will support the existing transportation network in developing countries like Bangladesh. Especially, in urban environment many people experience considerable challenges riding their bicycles within the existing infrastructural setup. Realizing this phenomenon this study conducted to understand the bicycling environment of khulna city area. Assessment of bicycling environment is necessary steps to promote bicycling in urban environment in planned way. This study will help to determine which streets should receive highest priority for introducing new bicycling facilities.

2. Methodology of the Study

The study is conducted with an object to assess and evaluate the bicycling environment in some selected roads of Khulna city, Bangladesh. To obtain the study objective sequential and systematic steps are adopted. Firstly, six roads are selected including a major part of Khulna city where the concerned part is from Upper Jessore to Rupsha Ghat route (Figure 1).

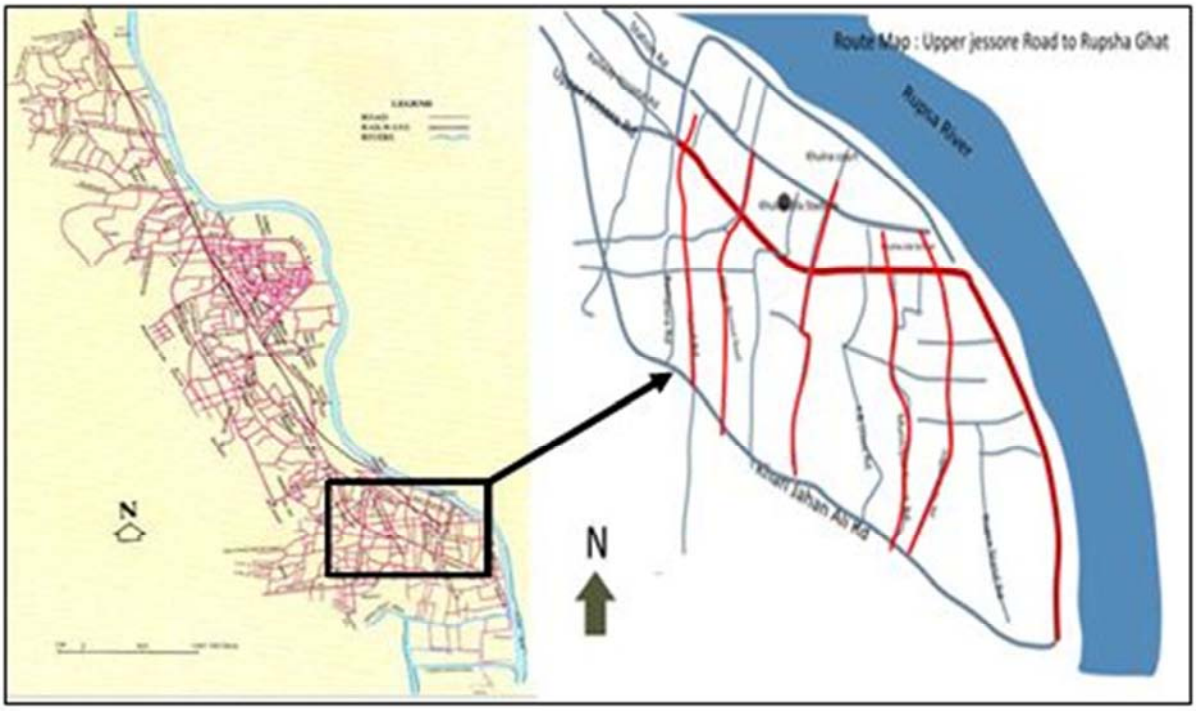

Figure 1. *Route map of the study area.*

The main focus has been given to those roads where significant numbers of road users has been found in bicycle operation. All of these roads are not experiencing heavy traffic flow, and more suitable for bicycling as heavy vehicles are constraints for bicycle users. The slope is almost zero of all the roads, and people are used these roads for short trips. Most of the short trips are generated by bicycle for different purposes i.e. home to school, home to workplace etc. Due to industrial location in this selected part of the city it has been observed that, workers prefer bicycle to reduce their travel cost. The total length of the selected six roads is 5.25 km. The list selected roads is given below:

Table 1. *Name of Selected roads.*

Road No.	Road Name	Length (Km)	Road No.	Road Name	Length (Km)
Road 1	Yusuf road	0.83	Road 4	Gagon Babu road	1.30
Road 2	Municipal road	0.57	Road 5	Ahsan Ahmed road	0.72
Road 3	T. B Cross road	0.52	Road 6	Rupsha Ghat road	1.31

Next after the selection of the roads the bicycling environment has been evaluated following the 14 criteria **(**Table 2). These criteria which were developed by various studies such as Gold [7], Holmes et al. [8], GFTC [9], Meenar [10], Boulter [11] and Durham and Gallagher [12] included physical, environmental and social features. Criteria have been redefined after a reconnaissance survey and applied to each road of upper Jessore to Rupsha Ghat route. Bicycling environments of the selected roads have been evaluated in terms of each criterion. However, to avoid misleading results by giving equal importance to each criterion a coefficient ranging from 1 to 3 has been determined for each criterion (Table 2). 10 professionals were approached for this purpose, and a mean value was obtained by averaging the value of each criterion. Field level data were collected on each of the criterion by conducting physical survey. Besides, Bicycle user survey was conducted through questionnaire to assign score to 4 criteria (No. of intersection, recreational facility of the route; connection with recreational facilities, and route use enjoyment) among the fourteen criteria.

Table 2. *Bicycling Environment Evaluation Criteria.*

Bicycle Evaluation Criteria	Coefficient	Evaluation Criteria	Score
No. of Intersection	02	No. of Intersection per km	
		0.00-2.00	3
		2.00-4.00	2
		4.00-6.00	1
		6.00-8.00	-1
		8.00-10.00	-2
		10.00-20.00	-3

Bicycle Evaluation Criteria	Coefficient	Evaluation Criteria	Score
Environmental impacts (Tolerance Level to activities relating to adjacent environmental setup)	2	Very high	3
		High	2
		Medium	1
		Low	-1
		Very Low	-2
		Absent	-3
Road width	3	Wide, suitable for separated bicycle way (more than 100 ft)	3
		Wide, suitable for separated bicycle lane (80-99 ft)	2
		Suitable for separated bicycle lane (60-79 ft)	1
		Wide, suitable for motor vehicle lane (40-59 ft)	-1
		Narrow, suitable for motor vehicle lane (20-39ft m)	-2
		Narrow, difficulty riding alongside motor vehicles (10-19 ft)	-3
Traffic density	2	Low-density all day long (all week)	3
		High-density on weekends	2
		High-density in peak hours on weekdays	1
		Continuous high-density on weekdays	-1
		High-density all day (all week)	-2
		Very high-density all day long (all week)	-3
Topographic feature (Maximum Slope along the route)	2	1%	3
		3%	2
		5%	1
		7%	-1
		9%	-2
		More than 10%	-3
Physical condition	2	Appropriate surface, sufficient drainage & lighting, secure physical environment	3
		Appropriate surface, insufficient drainage, lighting, secure physical environment	2
		Appropriate surface, insufficient drainage and lighting, insecure physical environment	1
		Rough surface, sufficient drainage and lighting	-1
		Rough surface, insufficient drainage and lighting, secure physical environment	-2
		Rough surface, insufficient drainage and lighting, insecure physical environment	-3
Seeing quality	2	Very High	3
		High	2
		Rather High	1
		Moderate	-1
		Low	-2
		Very Low	-3
Recreation Facility on the Route	2	Parks, playground and theater	3
		Parks, playground/ theater	2
		Only playground/parks/theater	1
		School field	-1
		River bank	-2
		No recreational facility	-3
Connection with Recreational Facility	2	Directly connected/ Beside road	3
		At the end of route	2
		1 km away from the road	1
		2 km away from the road	-1
		3 km away from the road	-2
		>4 km away from the road	-3
Route Use Enjoyment	2	Excellent	3
		Very good	2
		Good	1
		Moderate	-1
		Bad	-2
		Worst	-3
Land use type	2	Public area, development area, park or play ground	3
		Mostly public area	2
		Restricted public area	1
		Mostly Privately owned (residence or agriculture)	-1
		Dense Agricultural Area	-2
		Priority area under protection	-3
Number of proprietorship (Land or Real Estate) Proprietorship per km	1	10 and below	3
		11-25	2
		26-50	1
		51-100	-1
		101-200	-2
		Above 200	-3

Bicycle Evaluation Criteria	Coefficient	Evaluation Criteria	Score
Potential number of users	2	High-density residential region	3
		Medium-density residential region	2
		Low-density residential region	1
		Widely dispersed residential region	-1
		Outside but connected to the residential region	-2
		No connection with residential regions	-3
Composition of users	2	Dense user group that has a high variability in age and position	3
		Dense user group that has a moderate variability in age and position	2
		Dense user group that has a low variability in age and position	1
		Rare user group that has a high-to-moderate variability	-1
		Rare user group that has a low variability	-2
		Seldom user group, invariable or solely in special situations	-3

These four criteria had been described based on the route conditions before going at user level. After that a user survey was conducted to find out the score of each criterion for the selected roads. Users assigned their priority score for each road based on their own perspectives, and observation. Users were asked to assign the score within the range of + 3 to - 3 for the four criteria according to the prevailing condition of the selected roads.

After the user survey, the scores of the other 10 criteria were assigned on the basis of standard practices, and physical conditions of the roads. On the basis of road characteristics of the selected route for each criterion -3 to 3 value was assigned. Finally, Score for each criterion was calculated by multiplying the coefficient of each criteria & physical and user survey score. After summation of each criterion score for each road represents final score. An example of the whole procedure is given bellow:

- Route Score=Σ Criteria Score
- Criteria Score=Coefficient * (Score of 1st section * its' length percentage + Score of 2nd section * its' length percentage + - - - + Score of last section * its' length percentage)

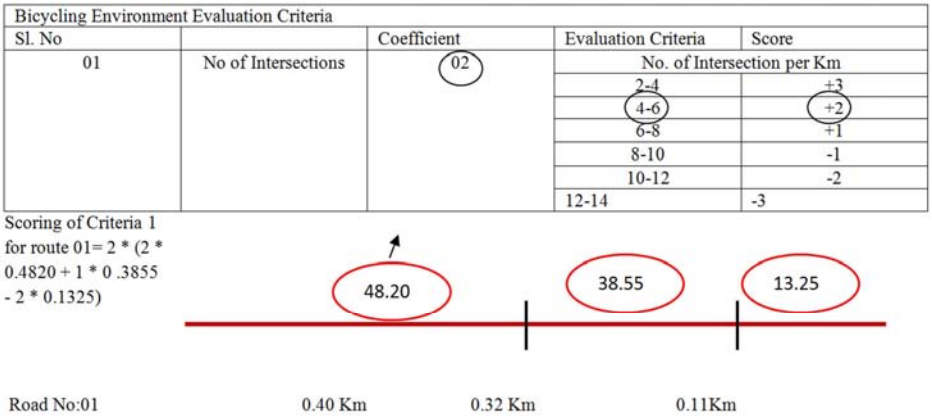

Figure 2. *Scoring Procedure for Road No 01 with Varying Nos of Intersection*

Rank on the basis of suitability criteria are represented on map. To check the acceptability of this calculated rank, user perspectives were also analyzed, and ranked for each road accordingly. The comparison between two ranks of all roads is presented on two different maps.

3. Findings and Discussion

Bicycling environment of the selected roads are evaluated based on the 14 criteria. The situational analysis of each of the criteria for the selected roads were done, and scored according to their level of service, and characteristic conditions of the roads based on fourteen criteria. Among the mentioned criteria (Table 2) three: environmental impacts, traffic density and road width got negative scores for all of the roads. Negative scores indicate that environmental setups of the selected road surroundings', traffic density, and road width are not satisfactory for bicycling. Associated activities of the adjacent land use of the selected roads are not favouring the bicyclists. Surrounding lands of the roads are mostly used for commercial, and residential purposes. There are observed large number of commercial activities beside Rupsha Ghat road and Ahsan Ahmed road (Figure 3). Due to the presence of commercial activities, goods carrying vehicles such as pick up, truck etc. are plying on those roads regularly. This situation is not amiable for bicycling. Consequently, all of the roads got negative score in terms of environmental impacts. On the other hand, traffic density of different roads varies on peak and off-peak hour. During peak hour traffic volume becomes very high in Rupsha Ghat road, Ahsan Ahmed road, and traffic density of other roads doesn't significantly change in different time period of a typical day. Considering this homogeneous high traffic density all of the roads scored negatively. The road width is an important criterion to ensure safe, and smooth bicycling environment as well as to provide separate bicycle lane. All of the roads are

not up to the standards to provide separate bicycle lane (Figure 2). Among the six roads only Rupsha ghat road is providing limited space for bicycling with the other motorized vehicles. Rests of the roads are not serving any extra spaces for bicyclists. On the contrary, for the criterion No. of intersections all of the roads got positive score except Rupsha Ghat Road. Most of the roads have 3-5 intersections per Km. Municipal, and Yousuf road have least number of intersections than the rest five roads. Based on the number of road intersections, and associated user compatibility the score for each road is assigned. Similar, scoring results found for topographic features as all of the roads in terms of slope percentage are providing favourable situation for cycling. Any kind of undulation is not observed on the roads of study area. For all of the roads slope (%) found between 1% - 2%. Physical condition of road is evaluated based on surface condition, sufficient drainage, lighting, and secure physical environment. Ahsan Ahmed road is only providing satisfactory physical condition, and scored 3. Next to Ahsan Ahmed road Rupsha Ghat road is in better physical condition and scored 1. Rests of the roads are not up to the standard for bicycling, and got negative score. Significantly, the Municipal road is in worst physical condition and scored the lowest -3.

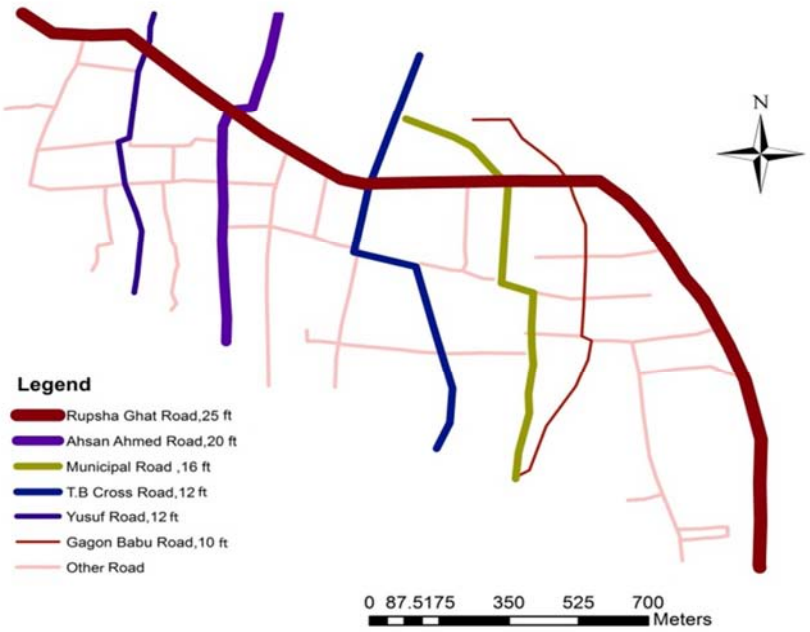

Figure 3. *Road Width of the Selected Road.*

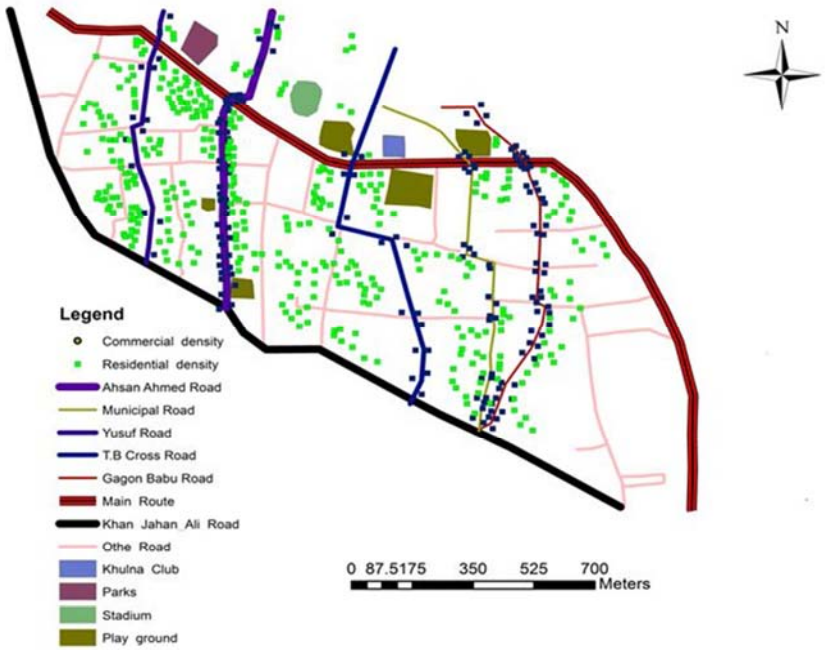

Figure 4. *Recreational Facilities around the selected roads.*

Seeing/visual quality of the selected roads is not up to the standard. Within a very short distance all of the roads have noticeable curvatures that are alienating the visual environment for bicycling. Gagan Babu and Rupsha roads' visual quality is slightly better than other roads and considered as rather high in quality whereas other roads are considered as moderate in terms of offering the appropriate visual environment to the bicyclists.

Recreational facilities around the selected roads are also considered to evaluate the bicycling environment. It is found that there exist sufficient recreational activities beside the selected roads of Khulna city. Municipal road, and Ahsan Ahmed road is more connected to recreational facility (Figure 3). Due to well connectivity with the recreational facilities these two roads got good score than the other roads. Number of proprietorship beside Ahsan Ahmed road and Yusuf road is very high in comparison of other roads, so score of these roads are less in case of proprietorship number. Compositions of residential, and commercial uses are observed in the study area. The route use enjoyment during the bicycling is not satisfactory to the user. Only the Ahshan Ahmed road got positive score in terms of route use enjoyment.

Based on the physical, and user opinion survey the collected scores of different roads are multiplied by the coefficient (given by 10 professionals). After adding scores of all of the criteria the composite score for each individual road was calculated (Table 3). It was found that only three roads Municipal, Ahsan Ahmed, and Rupsha Ghat Road got positive scores whereas the rest three roads got negative scores. However, the positive score is very low that indicates the low level bicycling environment. Ahsan Ahmed road got the highest score of 15 out of 84. If it is converted in % then the suitability percentage of bicycling is only about 18%. In compare with the scale of San Francisco Department of Public Health's [13] Bicycle Environmental Quality Index (BEQI) the road belongs to poor quality for bicycling. Similarly, the Municipal road is only 6% suitable for bicycling considering all of the criteria and also indicating the absent of friendly bicycling environment. Rupsha ghat road belongs to the same category with Municipal road. Rest three roads are not comparable for bicycling environment as all got negative scores.

The obtained ranks of the roads are shown in map differentiating the width of the road lines. The highest ranked road is Ahsan Ahmed Road, and then Municipal Road. Although Ahsan Ahmed road is a very busy road, and have large number of proprietorship beside the road, but considering all suitability criteria, it gains the highest score among the others.

Table 3. *Composite Score of the Selected Roads.*

	User/Physical Survey Score						Coefficient for	Coefficient*Survey score					
Road Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**Each Criterion**	**1**	**2**	**3**	**4**	**5**	**6**
No. of Intersection	2	2	1	1	1	-1	2	4	4	2	2	2	-2
Environmental impacts	-2	-1	-1	-2	-3	-1	2	-4	-2	-2	-4	-6	-2
Road width	-3	-3	-3	-3	-2	-2	3	-9	-9	-9	-9	-6	-6
Traffic density	-2	-2	-2	-2	-3	-3	2	-4	-4	-4	-4	-6	-6
Topographic feature	3	3	3	3	3	3	2	6	6	6	6	6	6
Physical condition	-1	-3	-2	-1	3	1	2	-2	-6	-4	-2	6	2
Seeing Quality	-1	-1	-1	1	-1	1	2	-2	-2	-2	2	-2	2
Recreational Facility on route	-1	1	-2	-2	1	1	2	-2	2	-4	-4	2	2
Connection with Recreational Facility	1	2	1	-2	1	1	2	2	4	2	-4	2	2
Route use enjoyment	-1	-1	-1	-1	2	-2	2	-2	-2	-2	-2	4	-4
Land use type	2	2	2	2	3	1	2	4	4	4	4	6	2
Number of proprietorship	2	2	3	1	1	-1	1	2	2	3	1	1	-1
Potential number of users	2	2	3	3	2	1	2	4	4	6	6	4	2
Composition of user	1	2	1	2	1	2	2	2	4	2	4	2	4
							Total	-1	5	-2	-4	15	1
							Rank	4	2	5	6	1	3

Source: Author's Calculation

Road Rank on the Basis of User Opinion

To justify the resulted road rank from the evaluation criteria user opinion survey was conducted. Users gave score to these roads according to the route services, and form their own perspective. 60 bicyclists (10 from each road) were asked to give the rank to corresponding roads according to their experience of bicycling on those roads. Finally, a single and composite rank was developed for each of the roads from the user opinion. It is found that calculated suitability rank slightly differs from the user rank. In giving priority of a road the bicycle user mostly considered the vehicle volume of road, and road width. People don't think about other characteristics of the roads. They judge the roads on the basis of their priority requirement. The comparative ranking of the six roads are shown in the following figures (figure 4 & figure 5).

Figure 5. *Road Rank based on Bicycling Evaluation.*

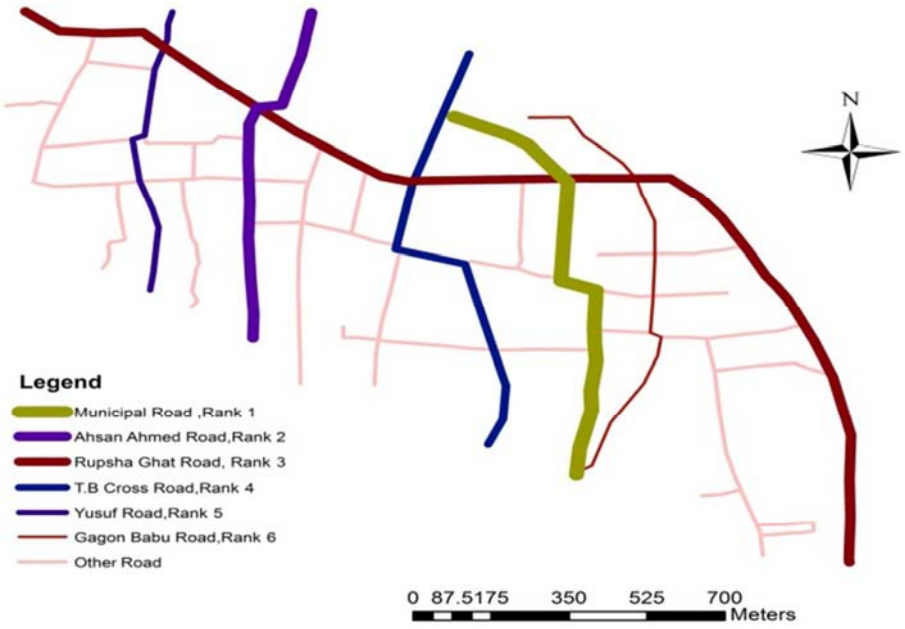

Figure 6. *Road Rank based on User Perspective Criteria.*

According to evaluation criteria, and assessment Ahsan Ahmed road placed first rank whereas according to user perspective Municipal road got the first rank. They differ in terms of rank in one position. Gagun Babu and Rupsha Ghat roads hold same rank in both cases.

4. Conclusion

Evaluation of bicycling environment is an important tool to assess the bicycling environment. Service and physical condition of the route are the determinants for promoting bicycle as an urban mobility. A number of factors are considered for physical assessment of the route i.e. no. of intersection, road width, traffic density, slope, drainage, lighting, recreational facility, land use type and proprietorship of the surroundings.

In Khulna city, there is no formal route to induce bicycling but the bicycle trips are increasing as rapid rates. The numbers of increasing bicycle demand are creating pressure in the existing road network. In this case, there has a chance to develop suitable bicycle network by improving the roads with appropriate planning intervention. This study will provide a foundation for evaluating bicycling environment in other parts of the city, and accordingly the guideline for planning intervention on priority basis. The bicycling environment evaluation method that is described here may

become a guide to city development authority to prepare a bikeway network plan and associated planning intervention.

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