INTERNATIONAL JOURNAL OF SCIENTIFIC & ENGINEERING RESEARCH, VOLUME 4, ISSUE 11, NOVEMBER-2013
ISSN 2229-5518

# Measuring Accessibility to Punctiform Urban Services using Space-Time Prisms: a Study on the Planned Residential areas of Khulna City

S.M. Waliuzzaman, Mohammed Shariful Islam

**Abstract**—Accessibility indicates the relative easy to access of a certain opportunity & actually it is the result of interaction of land use & transportation system. For urban planning practice a number of methods so far has been developed, but in recent time space-time accessibility measurement technique has been developed by different geographer which considers space constrain of human activity along with the time constrain unlike the traditional methods. Recently, urban planners are also contributing to the space-time concepts with proper application of this concept to the real world accessibility problem of the urban area. This paper shows how the concepts of space-time prisms can be applied to measuring accessibility to punctiform urban services where punctiform services are those, which delivered from a specific point & has a spatial dimension. Besides measuring the accessibility, this paper also shows the gap between the existing land uses of Khulna City in respect of supply of services with the accessibility of the residents for the selected residential areas. In case of selecting the location of punctiform urban services delivering, this type of accessibility measurement is necessary to reduce the waste of resource like time, money, energy for both service suppliers & service consumers.

**Index Terms**—**Accessibility, Spatio-temporal, GIS, Punctiform Services, Daily Potential path**

## 1 INTRODUCTION:

Human lives involve various activities in a space–time context. As social beings, people cannot avoid interacting with others in activities. These interactions enable flows of information and material among people and keeps the society functioning. Because activities are distributed at different locations, travel is usually used to help people participate in activities and complete interactions. Transportation systems are designed to help people to participate in these activities, distributed over space and time & hence accessibility indicates the collective performance of land use and transportation systems & determines how well that complex system serves its residents.

Generally people travel from one place to another to consume a certain service & facilities as a part of his daily life. These service & facilities are often treated as opportunities that are accessible to a person physically. Considering travel as a derived demand, transportation researchers have recognized that the spatial and temporal distribution of activities can determine where and when people travel (Damn, 1983).

So, it is very important to consider the time constraint of an individual to access the opportunities in case of measuring accessibility. Individuals need to perform various activities to maintain existence in society. Although certain activities may occur simultaneously, more often they exclude each other and are executed in a sequence in which each activity has to be carried out within a given duration, at a certain place, and in presence of other individuals. Because spatial movement consumes time and due to the specific time budge of the individual, activities which have fixed execution time or locations limit him from physically participating in events elsewhere. Therefore, a better grasp of spatial and temporal characteristics of human activities and interactions can help researchers gain a better understanding of the land use and thus accessibility to urban opportunities.

## 2 CONCEPTS OF ACCESSIBILITY AND MOBILITY:

The concept of "accessibility" has been coin in the transportation planning field for more than 40 years. Improving accessibility is a common element in the goals section in almost all transportation plans in the US (Handy,

INTERNATIONAL JOURNAL OF SCIENTIFIC & ENGINEERING RESEARCH, VOLUME 4, ISSUE 11, NOVEMBER-2013
ISSN 2229-5518

2002). However, the term accessibility is often misused and confused with other terms such as mobility. In order to have a common language in this paper, these terms are defined and introduced in this section. Mobility measures the ability to move from one place to another (Burns, 1979 in Weber, 2003). For example,, assuming both are part of a connected network, a person who owns a car has a higher level of mobility than one who doesn't. The word accessibility is derived from the words "access" and "ability", thus meaning ability to access, where "access" is the act of approaching something. Here it is concerned with ease of reaching destinations or activities rather than ease of traveling along the network itself. One of the first definitions of accessibility in the planning field was suggested by Hansen (1959) in Jones et al (1990), who defines accessibility as a measure of potential opportunities for interaction. High levels of mobility can, but do not necessarily reflect high levels of accessibility. High levels of accessibility can be present with low levels of mobility. Because activities take place over space, accessibility cannot be present without some mobility. An origin and a destination combined with potential activity at the destination and travel time or cost are the main parts of any accessibility measure (Kwan, 1998).

## 3 CONTEXT:

The present study is aimd to measure the accessibility to punctiform urbanservices considering space-time prisms of the residences of planned residential areas of Khulna city where punctiform urban services are those, which describe the point characteristic of the service delivering system & these services need to consume after travelling a certain distance as well the service delivering locations are fixed. In general it can be said that punctiform services are those services which are served from a specific point, like Medical facilities (Hospital, clinic, dispensaries, etc), shopping centers, recreational centers etc. The accessibility on these service & facilities depends up on both the location of these service -facilities & existing transportation system along with the time budge of the individual & operating time limits of these service & facilities.

Khulna is the third largest city of Bangladesh & here authority like Khulna City Corporation deals with the service delivering process where accessibility issues of the residents are less considered. In case of the allocation process of services & facilities there are very fewer research has been conducted so far considering the space-time accessibility of the residents. Due to the lack of planning initiatives, research & proper guideline, distribution of services & facilities has been occurred in unplanned way & hence the residents need to spread their radius of activity throughout the city. But if the location of services & facilities could be arranged in such a manner where the activity of the residents could be clustered into some specific locations, the extra travelling which indicates waste of energy, money as well as time could be minimized. For this purpose it is necessary to identify the accessibility of the residents considering the present location of services & facilities with corresponds of the activity pattern.

In order to measure the accessibility to punctiform urban services of the residents, three residential areas have been selected for the present study. Mujgunni Residential Area (RA), Sonadanga RA (1st & 2nd phase) and Nirala RA are those areas of study jurisdiction. Mujgunni RA is in ward no. 09, and maintains a 4 km. distance with the CBD. Sonadanga RA 1st and 2nd phase stand pretty adjacent, though in two different wards: ward no. 17 & 18, respectively. Both these areas are quite close to the heart of the city (not more than 2.2 km. away from the CBD) and they are little denser (in terms of number of plots and population) than the others concerned. Nirala RA is

developed in the south-western block of Khulna city. This area in ward no. 24 is especially distinguished by the trait of providing accommodation for a large number of teachers and students of Khulna University which is a little more westward from Nirala RA, just outside the Khulna City Corporation (KCC) boundary.

Only planned residential areas have been taken into account as to selecting the operation area of this study because they offer greater choice and opportunities to the dwellers in performing fixed and desired activities. Of course, there are other planned areas for residential use in Khulna city other than the selected three; Khulna Development Authority (KDA) has so far developed 8 residential areas (site and services scheme) (Hafiz & Hossain, 2005). The reasoning for "why only these, not others or not more" is conceptualized up to considering the relative reduction of homogeneity in the target population in terms of opportunities and constraints for the individuals to perform activities, exactly what the constraint-based time geographic framework seeks to analyze.

All these areas have a common trait i.e., they all cater for only the middle, upper middle and higher income group people (more in terms of size and price of the plots they acquire rather than based on income). Hence, socio-economic status of the target population can be assumed fairly homogeneous; they have more or less similar kind of economic opportunities and constraints and infrastructural provision which can affect their activity participation.

## 4 Conceptual Framework:

Actually there are three major components for measuring accessibility to punctiform urban services and the total analytical process are based on this three major component. They are (1) Residents, (2) Transportation System & (3) Punctiform services where the general relationship among these three components are as follows- Residents use existing transportation system in order to get certain punctiform urban services. The conceptual frame-work for measuring accessibility is given separately for the three components below.

Residents: From the residents their daily activity data for fixed & flexible activity has been collected through questionnaire survey. From the list of daily activity data, their time budge to perform a certain activity has been identified that refers maximum allowable time for the individual to perform a certain activity. For different residents, their time budge may vary according to the socio-economic characteristics like employment, income, etc.

Transportation System: The existing transportation system gives a clear image of that how quick an individual can reach to his destination. Through analysing the road connectivity as well as the availability of modes, the maximum feasible travel speed can be identified considering waiting time as well as other delays (though for Khulna City, the delay time due to traffic congestion & signal has been assumed nil). From the time budge of an individual & optimum travel speed, the space-time prism of an individual can be constructed which present the reachable region for a residents or individual within his time budge.

Punctiform services: Punctiform urban services do contain locational attribute (latitude, longitude or address) & a minimum performing time. These service & facilities are also limited within certain time-frame beyond which they are not operated any more. So in order to get the service, an individual must reach to the location of the services within its operating time as well as the service must be located within the accessible region of the individual. If these criterias are fulfilled the service will be accessible to that individual or residents.

INTERNATIONAL JOURNAL OF SCIENTIFIC & ENGINEERING RESEARCH, VOLUME 4, ISSUE 11, NOVEMBER-2013
ISSN 2229-5518

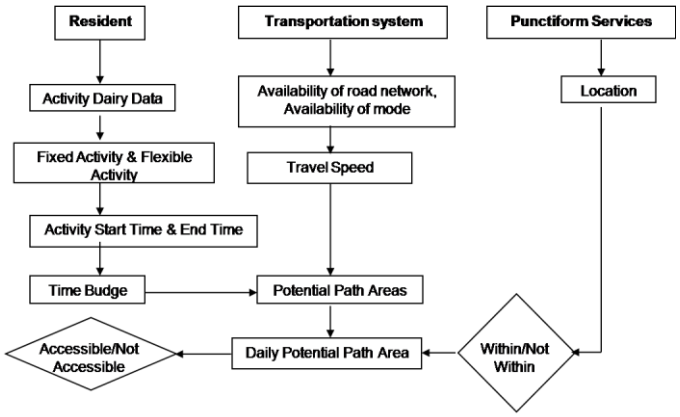



**Figure 1: Conceptual Framework of the Analytical Procedure**

## 5 DATABASE PREPARATION:

Database preparation is the most important & difficult task of the present study which deals with the activity dairy data of a large number of sample & to relate this database with the spatial database of road network & location of service & facilities. So to conduct the present study three types of data are required. They are listed below-

| Data requirement | | |
|---|---|---|
| Individual | Transportation network | Service-facilities |
| •List of daily out-home activities (fixed & flexible)<br>•Location of performing activities<br>•Start time & end time of activities<br>•Mode used to reach the destination | • Length of road<br>• Road connectivity<br>• Average speed of different mode | • Opening time<br>• Closing time<br>• Location |

Reconnaissance survey on the three selected planned residential areas has revealed that a lot of plots are still not structured, not in use, and lying vacant. Besides, buildings of varied capacities, ranging from one storey to five storeys, are erected on the structured plots. Hence generalization on the accurate count of existing number of households residing in the five PRAs is quite difficult.

The situation is further aggravated with the fact that concerned organizations like KDA does not have any account on how many households live in these PRAs; they are only interested in plot level data i.e., how many plots are developed, how many are distributed etc. These limitations have therefore lead to some compromise with the account of household number. It has been assumed for convenience that, each plot will accommodate two households on an average. The considered total of household has been thus obtained as 1622. From the total number of household the sample size has been derived as 966 which are approximately 59% of the total respondent.

Collection of digital land use data and digital road network data is meant for the proper functioning of the conceptual framework that has been developed the present study. Delineation of individuals' activity performance locations & route has been based on digital land use & road network data. However, digital land use map and digital road network has been collected from both Khulna City Corporation (KCC) and Khulna Development Authority (KDA).

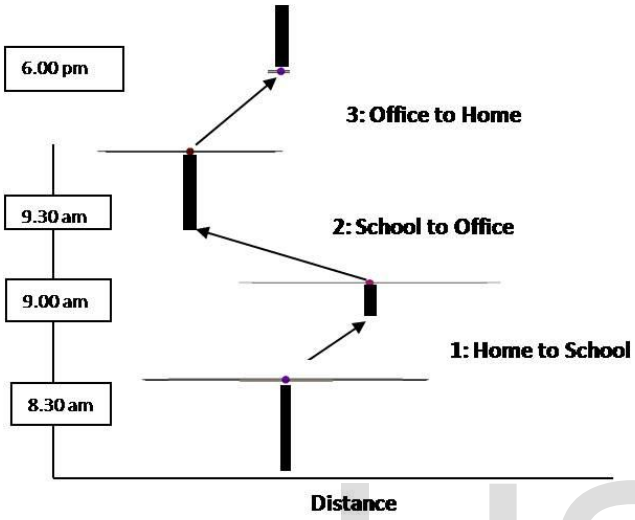
## 6 ANALYTICAL PROCEDURE:

The activities of an individual can be categorized as fixed & flexible activities where fixed activities are those activities of fixed start time, end time or fixed activity performing duration & difficult to reschedule & flexible activities are those, which can be rescheduled according to the need or choice of an individual.

For example if an individual has two out of home fixed activity then the individual has three activity performing point. The first activity is dropping the child at the school before 9.00am, then going to the office before 9.30am and coming back to the home at 6pm. In this case there are three

INTERNATIONAL JOURNAL OF SCIENTIFIC & ENGINEERING RESEARCH, VOLUME 4, ISSUE 11, NOVEMBER-2013
ISSN 2229-5518

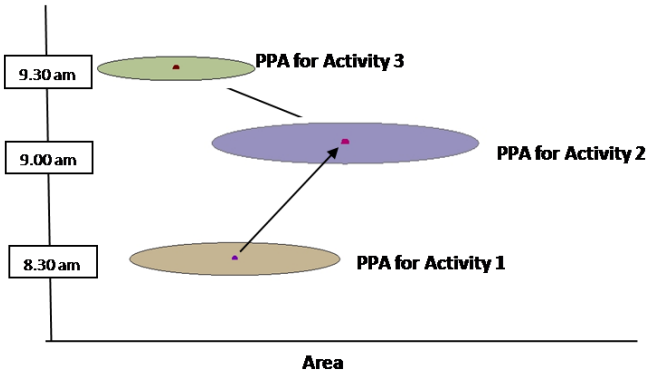
activity points (School, Office & Home) & three activity path. Hence the time budget of the individual for each activity (Home to School, School to Office, and Office to Home) can be derived from minimum activity duration subtracting from total activity duration.




Source: Field survey, 2009

**Figure 2: Potential Path of a Respondent**

After generating the time budge for each activity, it is required to determine the average travel speed of that individual. For example if the individual use Rickshaw to reach all his three destination according to the above figure, then the average travel speed of a rickshaw can be identified and by multiplying the time budge with the travel speed for each activity, the potential path area (PPA)




Source: Field survey, 2009

**Figure 3: Potential Path Area of a Respondent**

For that activity can be constructed (figure 3).

If an individual has two out of home activities, that mean there are three PPAs for each pair of fixed activity for the individual. The Daily Potential Path Area can be derived thus aggregating all the PPAs of an individual of a day.

Source: Field survey, 2009

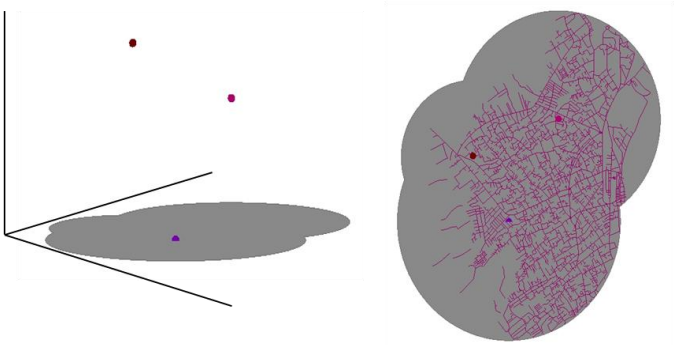
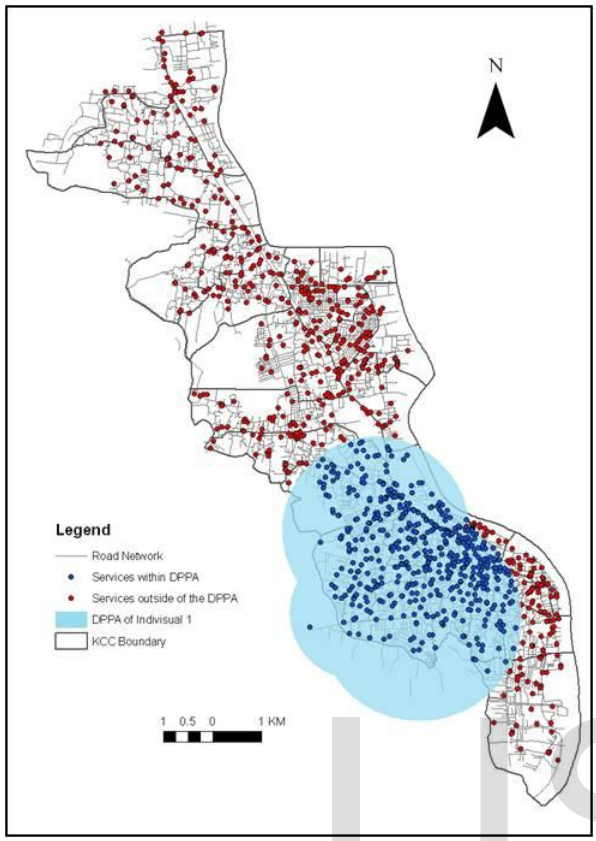


**Figure 4: presented above shows the DPPA of an individual according to above example**.

The prime objective for determining the DPPAs of the respondents from four residential areas is to measure the accessibility of the residents to urban punctiform opportunities. According to the time-geographic framework the accessibility can be measured through identifying the number of service & facilities that falls within the DPPAs of an individual. If an individual has large number of service & facilities within his DPPA more than another person, it denotes that first individual has better accessibility to urban services than the second one.

The figure presented below (figure 5) shows the DPPA of a respondent of Nirala & the service & facilities that are within his DPPA. The red dots are those service & facilities, which are not accessible to the individual & blue dots are those, which are accessible through out participating his daily activity as far as the space-time prism of that individual is concern.

INTERNATIONAL JOURNAL OF SCIENTIFIC & ENGINEERING RESEARCH, VOLUME 4, ISSUE 11, NOVEMBER-2013
ISSN 2229-5518




Source: Field survey, 2009

**Figure 5: Accessible services within a DPPA**

## 7 Result & Discussion:

***Number of Punctiform services within the DPPAs:*** Accessibility to different punctiform urban services & facilities differs from area to area and table 1 presented below shows the average frequency of different selected services that contained within the DPPA of an individual for four different residential areas. Beside this table 1 also shows the total average frequency of different services as well as the total number of services contained within the Khulna City Corporation (KCC) area.

On average DPPAs of the individuals of Mujgunni residential area contained 419 numbers of services where the average number of services is 394 among a total of 1062 selected services of Khulna City Corporation. The individuals of Sonadanga residential area 2, has the minimum number of services (377) among the four residential areas & it is almost35% of the total services. Beside this individual of Nirala & Sonadanga residential area 1, has accessibility to 38.5% & 38.04% services of the Khulna City Corporation as far as the their DPPAs are concern.

Table 1: Number of services accessible to the residents from different residential areas

| *Services* | *Nirala* | *Sonadanga 1* | *Sonadanga 2* | *Mujgunni* | *Average Frequency* | *Total Frequency in KCC* |
|---|---|---|---|---|---|---|
| *Bank* | *18* | *28* | *26* | *21* | *24* | *81* |
| *Bazar* | *23* | *15* | *22* | *9* | *18* | *75* |
| *Clinic/Hospital* | *30* | *18* | *23* | *24* | *21* | *84* |
| *Club* | *35* | *16* | *28* | *28* | *30* | *57* |
| *College / Technical Institute* | *11* | *15* | *16* | *26* | *14* | *84* |
| *Community Center* | *3* | *2* | *3* | *2* | *2* | *5* |
| *Fire brigade* | *2* | *3* | *2* | *2* | *2* | *4* |
| *High School* | *85* | *65* | *72* | *74* | *75* | *124* |
| *Madrasa* | *56* | *65* | *40* | *56* | *46* | *102* |

INTERNATIONAL JOURNAL OF SCIENTIFIC & ENGINEERING RESEARCH, VOLUME 4, ISSUE 11, NOVEMBER-2013
ISSN 2229-5518

| | | | | | | |
|---|---|---|---|---|---|---|
| *Market* | *23* | *45* | *38* | *42* | *36* | *68* |
| *Park* | *4* | *3* | *5* | *2* | *4* | *17* |
| *Petrol Pump* | *8* | *16* | *12* | *14* | *10* | *28* |
| *Play Ground* | *6* | *2* | *3* | *3* | *4* | *42* |
| *Primary School* | *62* | *42* | *52* | *63* | *53* | *154* |
| *Public Library* | *2* | *1* | *1* | *1* | *1* | *4* |
| *UPHCC* | *41* | *68* | *34* | *52* | *54* | *133* |
| *Total* | *409* | *404* | *377* | *419* | *394* | *1062* |

*Source: Khulna City Corporation & DPPA calculation (based field survey), 2009*

***Accessibility Index*:** Accessibility Index assigns a respective value to different activity location over the space which represents the respective accessibility of that location over other locations. In order to prepare an accessibility index first of all the total Khulna City Corporation area has been divided in to 1769 equal hexagon each consisting of 100m edge.

For developing the accessibility index two parameters has been selected & they are the proximity of road & percentage of DPPAs contained by. A scaling technique of equal weight has been done within a scale of one to five. Some brief on the selected parameters and their scaling range has been discussed below.

1. **Proximity of road:** The proximity of road-network is an important indicator for measuring accessibility. If a certain location or space is within the accessible region of an individual but the road-connectivity is missing, this will largely affect the accessibility of that individual despite of being the accessible region of that individual. Thus the hexagons has been differentiated according to the proximity of road network.

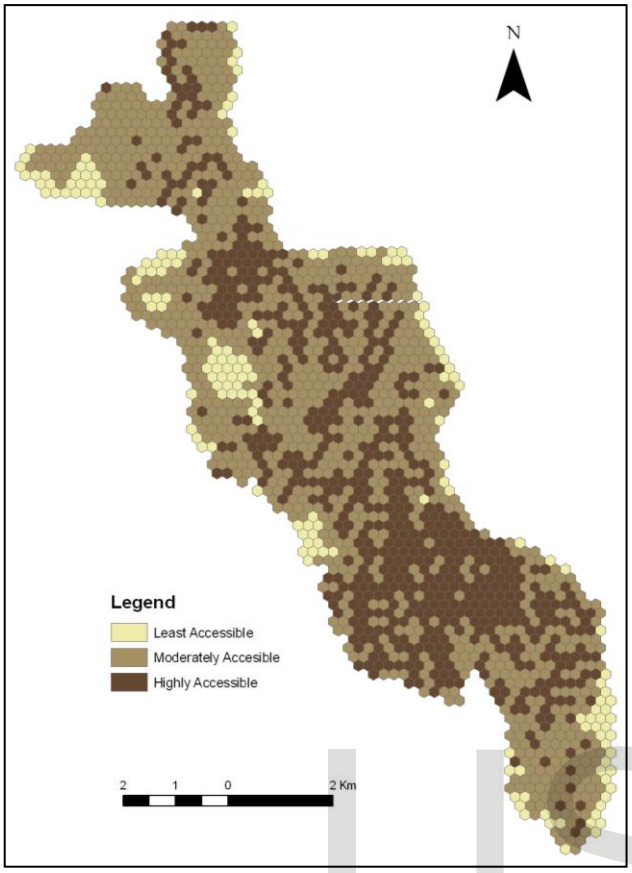
| Distance of Road-Network | | | | |
|---|---|---|---|---|
| Below 50 m | 50 m to 100m | 100 m to 200 m | 200 m to 500 m | Above 500 m |
| 5 | 4 | 3 | 2 | 1 |
| ← | | | | → |

**2. Number of DPPAs contained by:** Another parameter to determine the accessibility index is based on the percentage of DPPAs that contain a certain hexagon. For example, if a hexagon is within the DPPAs of 80% of the individual, then it can be said that this location (hexagonal shape) is much accessible than another one that is within 30% DPPAs of the individuals. Thus again the hexagons has been differentiated according to the percentage of DPPAs, they contained by.

| Percentage of DPPAs, contained by | | | | |
|---|---|---|---|---|
| Above 70% | 50% to 70% | 30% to 50% | 15% to 30% | Less than 15% |
| 5 | 4 | 3 | 2 | 1 |
| | ← | | → | |

After identifying the score of each hexagon for two different parameters, the total score for each hexagon has been calculated. The total score has been identified within a range of 2 to 10 for each hexagon & then based on the final score (or index), the total KCC area has been divided into three categories to Less accessible (score 2 to 4.66), Moderately accessible (score 4.66 to7.32) & Highly accessible (score 7.32 to 10) shown in figure 6.

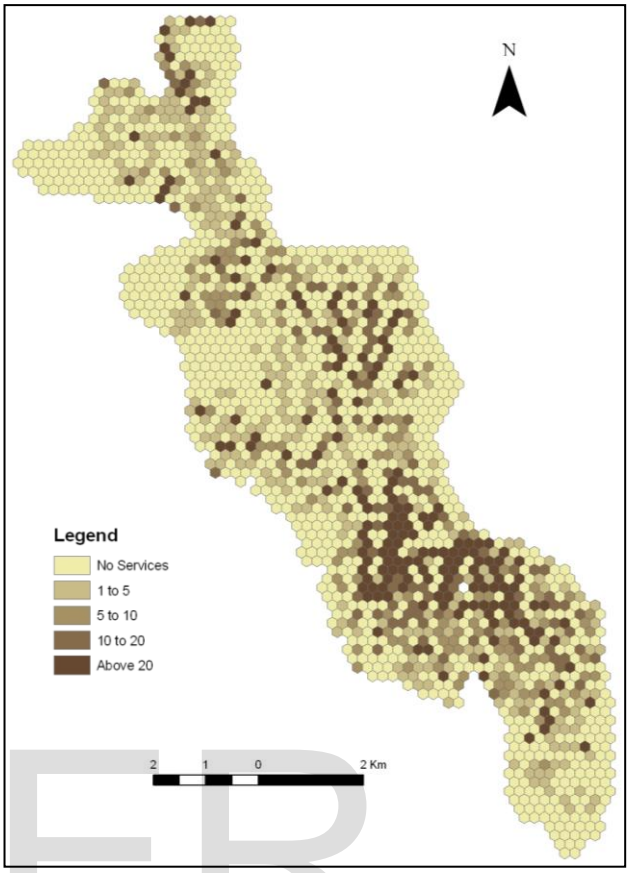
INTERNATIONAL JOURNAL OF SCIENTIFIC & ENGINEERING RESEARCH, VOLUME 4, ISSUE 11, NOVEMBER-2013
ISSN 2229-5518




*Source: KCC & individual manipulation by ARC MAP (version 9.2)*

**Figure 6: Distribution of hexagons according to the accessibility index**

Like the determination of accessibility index for each hexagon, it is also important to identify the supply of different services for each hexagon which enable to prepare a comparative visualization of supply of services with the accessibility of the individuals. In order to determine the supply side, the hexagons have been classified based on the number of services they contain & figure 7 shows the findings. The above figure (7) shows the dark areas where services & facilities are highly densed & light areas with low density of services & facilities. The major limitation of this approach is the lacks of consideration of relative importance of the services & only consideration of the number of services regardless with its importance or weight.




*Source: KCC & individual manipulation by ARC MAP (version 9.2)*

**Figure 7: Distribution of hexagons according to the number of services & faculties**

According to the accessibility index map (Figure 6) and the supply of services map (Figure 7), a table has been prepared that shows the number of services & facilities within different hexagon for different accessibility. This table is of vital importance as far as the gap between supply of services & accessibility to services are concern. This table (table 2) gives an ideal picture of the efficiency of existing service allocation situation.

INTERNATIONAL JOURNAL OF SCIENTIFIC & ENGINEERING RESEARCH, VOLUME 4, ISSUE 11, NOVEMBER-2013
ISSN 2229-5518

Table 2: Gap between supply & accessibility

| | Highly accessible | | Moderately accessible | | Less accessible | | Total | |
|---|---|---|---|---|---|---|---|---|
| | F | % | F | % | F | % | F | % |
| No services | 385 | 44.51 | 220 | 40.37 | 105 | 29.25 | 710 | 40.14 |
| 1 to 5 | 212 | 24.51 | 110 | 20.18 | 53 | 14.76 | 375 | 21.20 |
| 5 to 10 | 56 | 6.47 | 91 | 16.70 | 35 | 9.75 | 182 | 10.29 |
| 10 to 20 | 72 | 8.32 | 39 | 7.16 | 48 | 13.37 | 159 | 8.99 |
| Above 20 | 140 | 16.18 | 85 | 15.60 | 118 | 32.87 | 343 | 19.39 |
| Total | 865 | 100.00 | 545 | 100.00 | 359 | 100.00 | 1769 | 100.00 |

*Source: KCC & individual calculation (Field Survey, 2009)*

The table 2 shows that about 44.51% of the hexagons, which are highly accessible to the residents of these four residential areas, have not a single service. This could be an important consideration for further services allocation procedure. Again about 32.87% of the hexagon, which is less accessible, contains more than 20 services which indicate a mismatch between supply & demand for services. About 40.37% of the moderately accessible hexagons has no service contains within its boundary but about 20.18% of this type of hexagon has services in between one to five. Overall, about 40.14% of the total Khulna City Corporation areas are unserved in terms of punctiform urban services & about 359 hexagons among the 1769 (20.29%) has been derived as less accessible to the residents of these four residential areas.

## 8 CONCLUSION:

A framework has been developed here that applies the concept of space-time prisms at the measurement of accessibility to urban punctiform services & facilities at both aggregate and individual levels. At the aggregate level, practitioners at City Corporation are currently engaged in the search for a practical way to include accessibility assessment as a formal step in their planning processes (Miller JH, 2005). The case study in Khulna City illustrates how the proposed framework can be implemented within a GIS to accomplish this. The procedure avoids a large level of effort in data preparation and programming, which is usually the obstacle in bridging the gap between research and practice. Although two databases, individual activity dairy data & digital land use data, have to be created for this analysis, such databases are becoming common in practice (Munshi T, 2005). The activity dairy data of other areas of Khulna city can be incorporated as an additional step in the current framework to get the accessibility scenario of the whole city. This provides an alternative performance to measure the accessibility of urban services for evaluating various transportation/land-use policies and indicate potential ways for improvement.In the past decade, conventional distance based accessibility measures experienced difficulties to present the actual level of accessibility. Activity-based models, which originated from Hagerstrand's initial proposal, have emerged as a potential basis for the next generation of accessibility measurement (Weber J, 2005). The present study also shows that being

INTERNATIONAL JOURNAL OF SCIENTIFIC & ENGINEERING RESEARCH, VOLUME 4, ISSUE 11, NOVEMBER-2013
ISSN 2229-5518

close proximate to the residence of an individual; a service may not be accessible to that person because of the time constraints that limits him to access the service.

So, the term accessibility is the collective impact of the location of residence, location of work, location of services as well as the time budgets of an individual which is comprised of his occupation, income & other socio-economic factors. Thus in a metropolitan city like Khulna there are a varity of people with different socio-economic background but their daily activity patterns are quite similar in terms of activity location, duration as well as number of activity performed. From the present study it has been found that some activity locations like Dackbanglow, Shibbari & Newmarket are within the DPPAs of more than 70% of the individuals of the four residential areas. So any services & facilities in these areas will be accessible to the residences of the four residential areas studied if other things remain normal. Thus incorporating all the areas in the current framework the gap of supply side of services & demand side of services can be identified as well as this can be a guideline for provision of providing punctiform services & facilities for the city dwellers.

## REFERENCES

[1] Axhausen KW & Gärling T (1992), "Activity-based approaches to travel analysis: Conceptual frameworks, models, and research problems". Transport Reviews 12: 323-341.

[2] Burns LD (1979), "Transportation, Temporal, and Spatial Components of Accessibility." Lexington Books,Lexington.

[3] Damm D (1983), "Theory and empirical results: a comparison of recent activity-based research", in Carpenter, S. and P.M. Jones (eds.), "Recent Advances in Travel Demand." Aldershot, UK: Gower.

[4] Hägerstrand T (1970), "What about people in regional science?" Papers of the Regional Science Association 24:7-21.

[5] Jones PM (1983), "The practical application of activity-based approaches in transport planning: An assessment." In Carpenter, S.M. and P.M. Jones (eds.) "Recent Advances in Travel Demand Analysis." Aldershot, U.K.: Gower.

[6] Kitamura R (1988), "An evaluation of activity-based travel analysis." Transportation 15: 9-34.

[7] Kwan MP (1998), "Space-time and integral measures of individual accessibility: A comparative analysis using a point-based framework." Geographical Analysis 30:191-216

[8] Kwan MP (1999), "Gender and individual access to urban opportunities: A study using space-time measures." The Professional Geographer 51:210-227

[9] Kwan MP & Hong XD (1998), "Network-based constraints-oriented choice set formation using GIS." Geographical Systems 5:139-162.

[10] Islam M (2009), "Measuring people's space–time accessibility to urban opportunities – an activity-based spatial search algorithm in a GIS" International Journal of Urban Sustainable Development.

[11] Ming S. Lee and Michael G. McNally (2000), "Application of Space-Time Prisms for the Measurement of Accessibility", Institute of Transportation Studies & Department of Civil and Environmental Engineering, University of California, Irvine.

[12] Miller HJ (1999), "Measuring space-time accessibility benefits within transportation networks: Basic theory and computational methods." Geographical Analysis 31:187-212.

[13] Miller HJ & Wu Y (2000), "GIS software for measuring space-time accessibility in transportation planning and analysis." GeoInformatica 4:141-159

[14] Miller HJ & Wu Y (2005), "A measurement theory for time geography." Geographical Analysis 37, pp. 17-45.

[15] Munshi, T. and Brussel, M., (2005), "Use of geo-information to determine the work place accessibility using public transport in Ahmedabad city, India." Dept. of Urban and Regional Planning and geo-information management, International Institute of Geo-information Science and Earth Observation, The Netherlands.

[16] Weber J (2001), "Evaluating the effects of context and scale on individual accessibility: A multilevel approach" Ph.D. Dissertation, Department of Geography, The Ohio State University.

[17] Weber J (2003), "Individual accessibility and distance from major employment centers: An examination using space-time measures." Journal of Geographical Systems.

[18] Weber J & Kwan MP (2002), "Bringing time back in: a study on the influence of travel time variations and facility opening hours on individual accessibility." The Professional Geographer 54:226-240

[19] Weber J & Kwan MP (2003), "Evaluating the effects of geographic contexts on individual accessibility: A multilevel approach." Urban Geography.

[20] Hafiz, D. R. & Hossain, M. M. (2005), "KDA Housing Projects: An Investigation of Problems and Prospects of Development." Nagar Shoilee, 03.