ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

'Centrality Measures' as a tool to identify the Transit Demand at Public Transit Stops; A Case of Ahmedabad City, India

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Manuscript Info

Manuscript History:

Received: 15 May 2014
Final Accepted: 29 June 2014
Published Online: July 2014

Key words:
Centrality Measures, Network Analysis, Public Transport, Transit Demand, Transit Stops

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Abstract

This paper presents a simplified method to measure transit demand of public transit stops based on network centrality parameters and how transit demand of PT stop are vary with network centrality, Ahmedabad city, India. The study was based on the node-axial diagrams derived from road and transit network of the city, in which the axial nodes represent stops and road intersections. Axial lines, which connect two nodes, were weighted based on, travel time. The network centrality of nodes was computed at different radius level (0.6km, 3km, 4km, 5km …, and 10km) using Closeness, Straightness and Betweenness centrality. Transit demand of stops was evaluated in terms of the number of passenger daily boarding at stops. Results indicate that all three parameters revealed a significant correlation with transit demand within the radius of average trip length. Further it indicated that influence of different centrality parameters on transit demand varies by type of PT stops. By considering that, six regression models (more than 85% accuracy) were developed, to explain transit demand of different types of stops based on centrality values. Therefore study suggested that method developed in this study is robust, dynamic planning tool that will offer promise for transport planning applications in Indian context.
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Introduction

"Cities are the major contributors to economic growth, and inter-city and intra-city movement are crucial for improved quality of life" (Singh, 2005). Leda (2010), in his recent publication on 'Sustainable urban transport in Asian context' has mentioned that, "Neither an efficient urban economy nor a convenient urban life could have realized without the development of urban transportation devises". Depending upon the particular circumstance, these benefits are generally believed to lie in the overall transportation efficiency, protection of environment, safety, improved mobility for the disadvantaged section of the society and energy conservation" (Munshi, 2003). Provision of public transport is an essential component in sustainable functioning of urban area.

World Bank and UNDP (2004) have expressed adversities the likely future impact of motorization on middle-sized cities in Asia and Pacific regions. "They claim that, while many mega and primary cities in the fast developing like Indian region have an acknowledged transport crisis that has attracted major planning efforts, and extensive large-scale investment, the middle-sized cities (with only a fraction of the resources available to them) remain neglected and as result will reach their own crisis points unless effective policies are developed and implemented" (Dimitriou, 2006). In India, overall population growth and increasing urbanization have led to the especially rapid growth of middle-sized and large cities, which have been overwhelmed by the sudden jump in travel demand (Pucher et al, 2005). The supply of transport infrastructure and services, by comparison, has lagged far behind demand. Public sector finances, in general, are so limited that funding for transport improvements is woefully inadequate. Most transport facilities are used far beyond their design capacity (Pucher et al, 2005).

Increased concern over declining air quality and other transport related urban and social problems in these regions have influenced the focus of recent policy objectives in India; the National Urban Transport Policy encourages integrated land use and transport development. This is because it is believed that configuration of land use and transport system influence individual travel and therefore shape travel demand in the city. The Government of India also realizes that "it is important for urban transport, planners and development authorities to work in tandem towards property development, which would provide resources for promoting use of public transport, perdestrianisation and non-motorized forms of transport with the objective of reducing congestion, fuel consumption, vehicular pollution, etc" (Ramchandran, 2007). Thus this sets the need to look at how development and design of urban areas influence travel demand, more specifically in the choice of sustainable modes of transport like mass transit modes and non-motorized modes.

Given this background, In Indian, demand aspects of public transit have received very limited attention as compared to the design and engineering aspects in the context of developing countries. "While many previous studies have investigated the improvements at transit stops and stations, past research have in general, lacked causal clarity of how such improvements can increase transit ridership. Most of these studies were conducted from a design perspective, and suggest improvements at transit stops and stations that are often obvious (e.g. providing more seats and shelters, improving lighting, keeping facilities clean)" (Iseki et al., 2007). Besides the limited research interests, transit demand applications in developing countries suffers from inadequate and inappropriate methodological innovations (Gwilliam, 2004).

The difficulty of many of these current methods adopted for demand modeling are either too quantitative or are expensive and data-consuming tasks. TRL report published in Transport Research Laboratory 2004 (cited in Cairns 2011) emphasized that the applications of traditional transport modeling which are commonly use in developing countries is an expensive affair and inefficient method to understand public transport demand (Chiaradia 2006 cited in Paul, 2009). National urban transport policy 2006 noted that, the virtual lack of a database on urban transport statistics has severely constrained the ability to formulate sound urban transport plans and reliably assess the impact of the different initiatives that have been taken (MOUD, 2006). Given the fact that transport studies conducted in India are project based, most transport demand studies are either very aggregate or based on poor data (Munshi, 2009). Thus, there is a need to develop an alternative method to measure transit demand which can efficiently work under above mentioned data and cost constraint situations of dynamic Indian cities. In catering to the above need, this study looked at a set of simple models which can be developed using network centrality measures based indicators.

This study focused on an emerging set of research literature those employed in transit demand applications in PT modes of cities in developed countries. Those researches have based on network centrality parameters which revealed successful results in measuring transit demand. Amongst, Scheurer, J. et al (2007); Kazerani, A. and Stephanr, W. (2009); Porta, S. and Latora, V (2007) works in Australia; Jun, C. et al (2007)'s work in Seoul, Korea; Kishimoto, T. et al (2007)'s work on Japan are some of admirable recent studies which applied centrality parameters in transit networks. Yet, all above studies based on developed countries and there are none or very limited applications with referring to the emerging cities in developing world where such research need the most. Further, many researches those are focused on cities in developed world do not directly applicable to cities in Asian Context (Kishimoto, 2007; Hasuan, 2008; Munshi, 2009). Therefore, there is a need to look at the applicability of these simplistic models in defining PT demand of cities in Indian context.

Given circumstances, this research attempts to answer whether there is relationship between transit demand and network centrality in the context of Indian cities and if so, to what extent? How it can be measured in PT stops? How can it be useful in planning and decision making process in Indian context? Therefore, the main objective of this research is to study the applicability of centrality measures to explain public transit demand for a case city of Ahmedabad, India.

Literate review

Literate review - Centrality measures

Applications of centrality measures was initially a popular concept in the fields of information technology and computer engineering but recently applied in spatial planning; to model, forecast, and explain matters related to accessibility. In mid-eighties, a group of scholars in London led by Bill Hillier (Hillier and Hanson 1984; Hillier 1996) made effort on mapping centrality in cities under the notion of space syntax. Space syntax is a theory about space and human behavior, which, together with tools and methods for analyzing human interaction in the built

environment, examines the impact of accessibility in spatial layouts on behavior, communication and interaction. Centrality was here termed as 'integration' and mapped as a property topology of the system based on an index of closeness or accessibility. Space syntax approach studied the applicability in understanding the evolution of space; identifying highest potential to become centers and now well established in the fields of urban planning and design.
Porta, S. and Latora, V. (2006) have worked out an application; Multiple Centrality Assessment (MCA) considering the topology (how streets are connected each other) goes together with the metric of the system (distance is in fact computed metrically rather than just topologically). They introduced three new different measures as Betweenness, Closeness, and Straightness. The MCA model measures a location "being central" not limited to being close to all others, but also being the intermediary between others, being straight to all others and being critical for the efficiency of the system as a whole (Porta et al 2007). Porta, Crucitti and Latora (2007) argued that, the movement networks can be studied through assessing Multiple Centralities instead of single-best-fit centrality measure. This was a stimulus for a number of recent literatures those attempted to identify the centrality through multiple measures.

There are number of studies attempt to develop applications based on centrality parameters in the sphere of transport planning. Scheurer, J. et al (2007) introduced a GIS-based tool designed to assess centrality and connectivity which tested the applicability in urban public transport networks of Australian cities (Perth, Melbourne). They used Degree Centrality, Closeness Centrality and Betweenness Centrality parameter to identify and visualize strengths and weaknesses of geographical coverage, network connectivity, competitive speed and service levels of public transport networks. Kazerani, A. and Stephanr, W.; (2009) studied dynamics and temporal aspects of people's travel demand studied through applying a modified version of betweenness centrality. Jun, C et al (2007) used weighted syntax-based values by O-D trips to compute centrality values and developed relationship between Depths values in space syntax and the number of transfers in the journey of Rail, Tram, and Bus routes of Seoul city, Korea. Weiland, J (2007) demonstrates the applicability of space-syntax analysis in 19 worldwide metro systems and found correlation between boarding at metro stations and centrality parameters including integration, connectivity and total depth). Kishimoto, T. et al (2007) demonstrates the space syntax based (C_depth) application to identify the optimal location of routes and stops of LRT in Maebashi city, Japan.

Briefly, the emerging literature on applicability of centrality measures as a tool in transits demand emphasizes network centrality measures as versatile enough to explain fundamental qualities related to transit demand as transit ridership, transfer at stops and through-traffic in networks.

Literate review - Factors influence on transit demand at transit stops

Public transportation is defined as transportation by a conveyance that provides continuing general or special transportation to the public. It includes various modes such as buses, subways, rails, trolleys, and ferry boats (Tran and Kleiner 2005 cited in Belwal and Belwal 2010).Further, Public transport is usually regulated as a common carrier and is usually configured to provide scheduled service on fixed routes on a non-reservation basis (UITP, 2011).Being the first points of contact between the passenger and the transit service, access to public transport stops is an important factor affecting overall transit demand and trip travel time (TCRP 1996). Further, recent researches on the transportation have suggested that transit users can be increased through locating transit stops in strategic locations (Johnson, 2003; Holtzclaw 1994 and Murray & Wu 2003 cited in Foda 2010). Therefore, identification of locations, which connect and attract more people to public transport, obtains vital importance in planning process (Rodrigue, 2009).

Most literature agrees that there are many factors affect on transit ridership of transport stops. Amongst, residential density (Pushkarev & Zupan, 1977), employment density (Hendrickson, 1986), connectivity between residential areas and CBD (Hendrickson, 1986), regional development (Liu, 1993; Kain& Liu, 1995), residential density, employment density, land use mix and network connectivity (Cervero, 1993; Kain& Liu, 1995; Nelson &Nygaard, 1995; Gomez-Ibanez, 1996; TCRP, 1996; Spillar & Rutherfod, 1998; Chung, 1997; Carane, 2000), accessibility of the stop to downstream land use and accessibility of upstream land use (Cervero, 1993; Kain& Liu, 1995; TCRP, 1996; Gomez-Ibanez, 1996; Spillar& Rutherford, 1998; Crane, 2000; CUTR, 2004), service quantity factors as service frequency, speed, integration and service coverage (Gomez-Ibanez, 1996; Kohna, 2000), service quality factors as station safety & safety en-route, station information, cleanliness (Cervero, 1990; Abdel-Aty&Jovanis, 1995; Syed & Khan, 2000), walkability to stop (Bernick&Cervero, 1997; Cervero, 1998; Dittmar&Ohland, 2004) legibility of stop (Mees, 2000; Vuchic, 2005) and availability of parking facilities (Cervero, 1993; Abdel-Aty&Jovanis, 1995; TCRP, 1996; Syed & Khan, 2000) are important factors affect on transit ridership.

Study area

Case study conducted at Ahmedabad Municipal Council Area (AMC) which is the commercial capital of Gujarat. Ahmedabad is one of the emerging urban centers and seven largest urban agglomeration in India with population of 5.7 million (2010) within the municipal area (466sqkm). Ahmedabad Municipal Transport System (AMTS) & Janmarg Bus Rapid Transit System (BRTS) are the key agencies providing city public transport service. AMTS is the oldest system and it provides service for entire municipal cooperation area. Network length of AMTS is 549km. Janmarg Bus Rapid Transit System (BRTS) which is recently introduce public transport system in city with the objective of moving people efficiently and presently it operates 25km route length (2010 July). Public transport model share of Ahmedabad (16% in 2008) has improved due to the first phases of BRTS (after 2010) yet Ahmedabad is still far below compare to the public transport model share of other larger cities as Mumbai (45%), Delhi (43%), Kolkata (54%), Chennai (31%), Hyderabad (35%), and Bangalore (32%) (MOUD, 2008). One of the biggest advantages of Ahmedabad is it still has the time and space to avoid the worst experiences of motorization and congestionof the mega cities like Delhi, Mumbai, Kolkata. "Failure to develop an alternative vision to ''trend outcomes'' will leave medium-sized cities destined to similar (or a worse) set of lethal forces that have led to the insatiable demands of motor vehicles in larger Asian cities" (Dimitriou, 2006).

In this background, the early transportation initiatives for Ahmedabad and findings of this study can cater emerging need while leading to a sustainable urban development.

Method

The research methodology employed for the study included five-steps (Figure-4). A special feature of the methodology is that it attempted to developed simple and affordable methodological framework to measure transit demand based on centrality measures and demonstrated the applicability of that in case study area.

Selected centrality parameters to measure transit demand of PT stops

As an initial step, suitable centrality parameters applicable to identify transit demand were identified. This has been done through detailed literature review on network centrality concept, factors affecting transit demand of transit stops, centrality parameters and its relevance to transits demand, case studies and applications of network centrality in relation to transit demand studies. Accordingly, following centrality parameters were selected.

- Local Closeness Centrality (LC); to captures the level of accessibility (based on physical distance) of a stop from neighborhood nodes.
- Local Straightness Centrality (LS); to captures the level of legibility of a stop from neighborhood nodes.
- Global Closeness Centrality (GC); to captures the level of accessibility (based travel time) of a stop at the city scale.
- Global Straightness Centrality (GS); to captures the level of imagebilityof a stop at the city scale.
- Betweenness Centrality (BeA and BeB);to capture the idea that a node is central if it lies on the shortest paths (BeA: based on physical distance or BeB: based on service frequency and speed) that link many other nodes with each other. Alternatively, the extent that node locate intermediary between shortest paths (depend on travel time or distance) which connect other nodes in city.

Measuring of centrality of PT stops

Two types of nodal axial maps were generated in this step to measure the centrality of stops. First type of nodal axial maps (type-A) which represent PT stops and road intersection as node and connection between them as links; and links were weighted by physical distance. This axial map use to capture centrality of stops in terms of physical distance. Other axial map (type-B) is modified version of the first and use to capture centrality of stops in terms of travel time (links were weighted by PT route speed and service frequency)

In this study first, centerlines of city road network (prepared by Munshi, 2010 including Arterial, Collector, Sub-arterial & Local roads) converted into links and nodes. In order to do that, each road centerline was broken at the intersection; place where two or more centerlines meet. Then, PT routes were overlaid and centerlines further broke at stops. Final Axial Map –A indicates road intersections and PT stops as points; and links

Then axial line were weighted based on impediment value (dij), as by dividing the average inter peak travel time in minutes by the average frequency of services per hour as show in following equation. Because this study assume people choose lowest-travel time path on the route network map when travelling from a node to any other node. Thus the lower the score, the greater the ease of movement (by travel time and service frequency) along the associated route.

$\mathbf{d_{ij} = t_{ij}/f_{ij}}$

$\mathbf{d_{ij}}$ = **impediment value** of link segment between nodes i and j (average of both directions)

$\mathbf{t_{ij}}$ = **travel time** between nodes i and j (average of both directions)

$\mathbf{f_{ij}}$ = **service frequency** in departures per hour per direction between nodes i and j

Then, MCA Extension in ArcGIS 9.1 and 'CLI' software (developed by Prof Sergio Porta and National Institute of Nuclear Physics of Catania, Sicily, Italy) were used to compute centrality values of nodal axial maps. Based on computed values, 'Network Centrality Index' was prepared. 'Network Centrality Index' comprised with different centrality values (calculated based on different centrality parameters) of PT stops. Preparation of transit Index Transport studies generally use the number of trips or passengers and passenger kilometers as the indicator to measure transit demand. This study refers public transits demand as user attraction to transit stops (generally called as number of passenger boarding at stop). Data related to transit ridership (number of passengers boarding by stop) on BRTS (year 2010 July) and AMTS (year 2007 Nov.) were collected from secondary sources and stored in ArcGIS database. 'Transit Demand Index' was prepared based on those daily passenger boarding data by stop. Distribution of both AMTS and BRTS transit demand values reveals that few stops have higher demand (less than 10% AMTS & BRTS stops obtained transit demand values more than (Mean+3Std. Dev.)) and act as transit hubs. Whilst, large number of stops with lower transit demand are high in number (about 90% AMTS & B RTS tops obtained transit demand values less than (Mean+3Std. Dev.) act as regular stops. Therefore, this study categorized stops into four categorize based on distribution of transit demand as type A, B, C, D and E. Type 'A' stops have the highest transit demand and consist of less than 1% of total stops. Type 'E' stops have low transit demand compare to all and it accounts 60% of total stops. Distribution of the centrality values shows a correspondent pattern as transit demand.

Relationship analysis between centrality and transit demand values

The 'Transit Demand Index' and 'Network Centrality Index' values for transit stop were compared to identify the relationship. The analysis was carried at three different levels. First, results of two indices were analyzed graphically by using maps and graphs. Then correlation and regression analysis was employed to find out the nature and the strength of relationship between centrality and transit demand of stops. Outcomes of the analysis established the relationship between centrality & transits demand at stops, identified the suitable centrality parameters to measure transit demand of different types of stops and developed regression models based on centrality parameters to explain and predict transit demand of different type of stops. Initial findings of the study were revealed a significant relationship between transit demand values and centrality values of transit stops. Yet, detailed results indicated that global level centrality parameters (GC & GS) were not able to derive strong correlation of coefficient with transit demand. This was considered as possible to be a limitation of the method adopted. In order to verify that, centrality of transit stops were re-calculated at nine different distance levels (from each stop) as 0.6km, 1km, 2km, 3km, 4km, 5km, 6km, 7km and 8km and 10km instead of previous two levels of global (10 km) and local (0.6 km). Centrality values of each stop at all nine distances were respectively co-related with transit demand to identify the influence on transit demand.

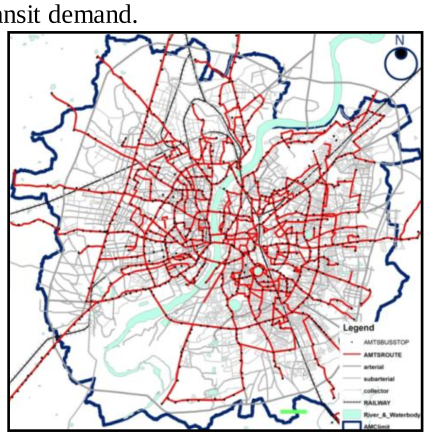

Fig 1. AMTS Network, Based on ITDP study 2009

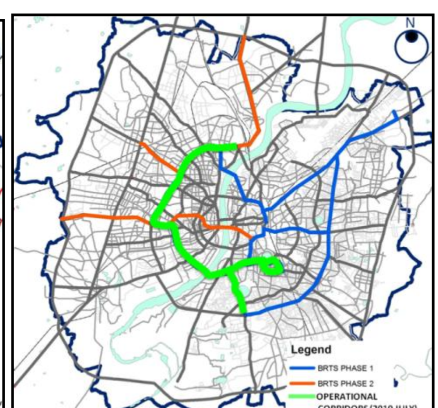

Fig 2. BRTS Network, Based on 8th month report Janmarg BRTS

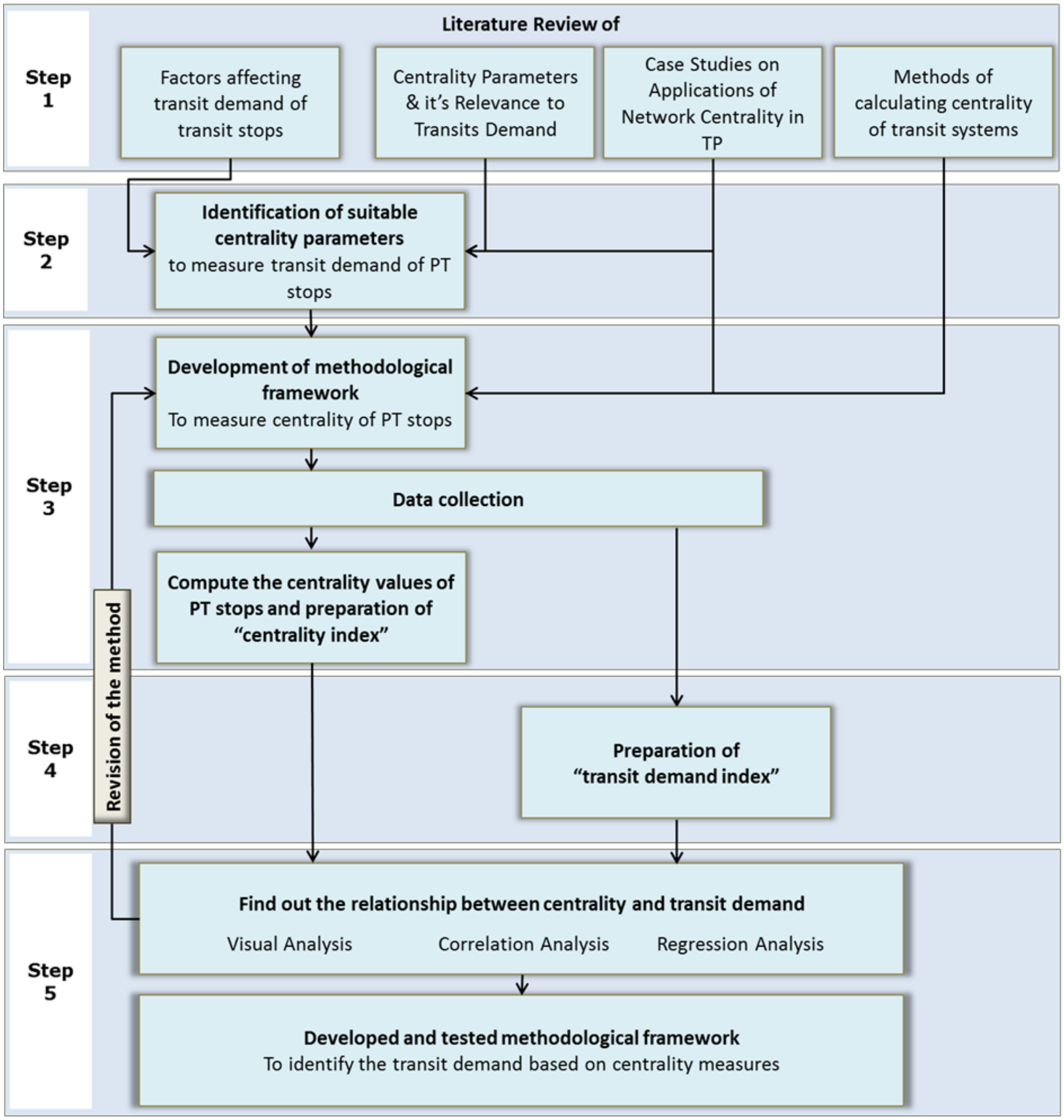

Fig 3. The research methodology

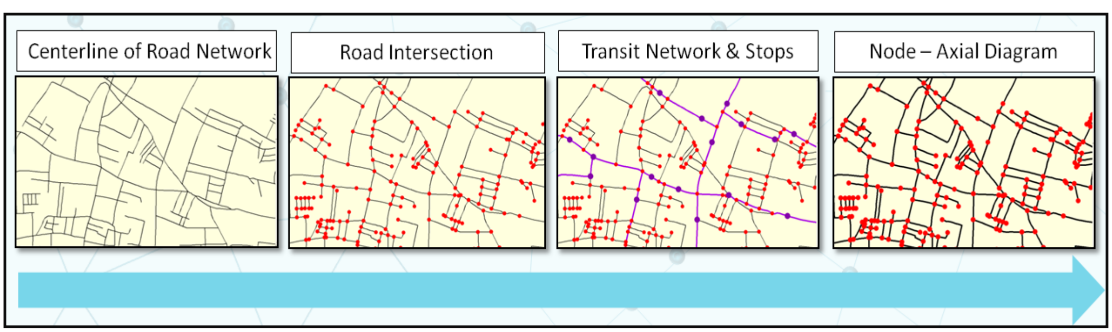

Fig 4. Step of Axial Map preparation

Table 1: Data used for calculation of impediment values

Parameter	AMTs Links	BRTs Links
Average Speed	18.4 km/h (ITDP Survey,2007)	25 km/h (JANMARG: BRTS, 2010 July)
Service Frequency	Based on AMTs route service frequency information 2007 & 2010	Based on BRTs route service frequency information 2010 July

Analysis and results

Visual analysis relationship between Transit Demand and Centrality Values PT Stops

Visual analysis in one of the important qualitative analysis methods used in many of recent network centrality studies to demonstrate the applicability in relation to real world phenomena (Paula 2007). Distribution of centrality values and transit demand values were map based on distribution of value. It should be noted that centrality and transit demand maps are presented by comparable scaled and colour coded symbols. Then visual correspondence between transit demand and centrality map were analyzed. Results indicate that there is a good visual correspondence between transit demand and BeB centrality values of AMTS stops. The nodes belong to first category, which records the highest Betweennes and transit demand values reveals more than 80% similarity. Second category recorded 63% similarity while third category recorded 47% similarity. Last category, which records the lowest BeB and transit demand values, reveals more than 95% similarity. Accordingly, 92% of stops from total AMTS stops recoded very good visual correspondence. More than 76% of BRTS stops from total 39 stops recoded very good visual correspondence including 100% from second category, 50% from third category and 88% from third category. Findings of visual analysis pointed a clear correspondence and it stresses again that network centrality can apply in identifying transit demand at stops. Further, it can use as a understandable method of representation in planning through maps and graphs.

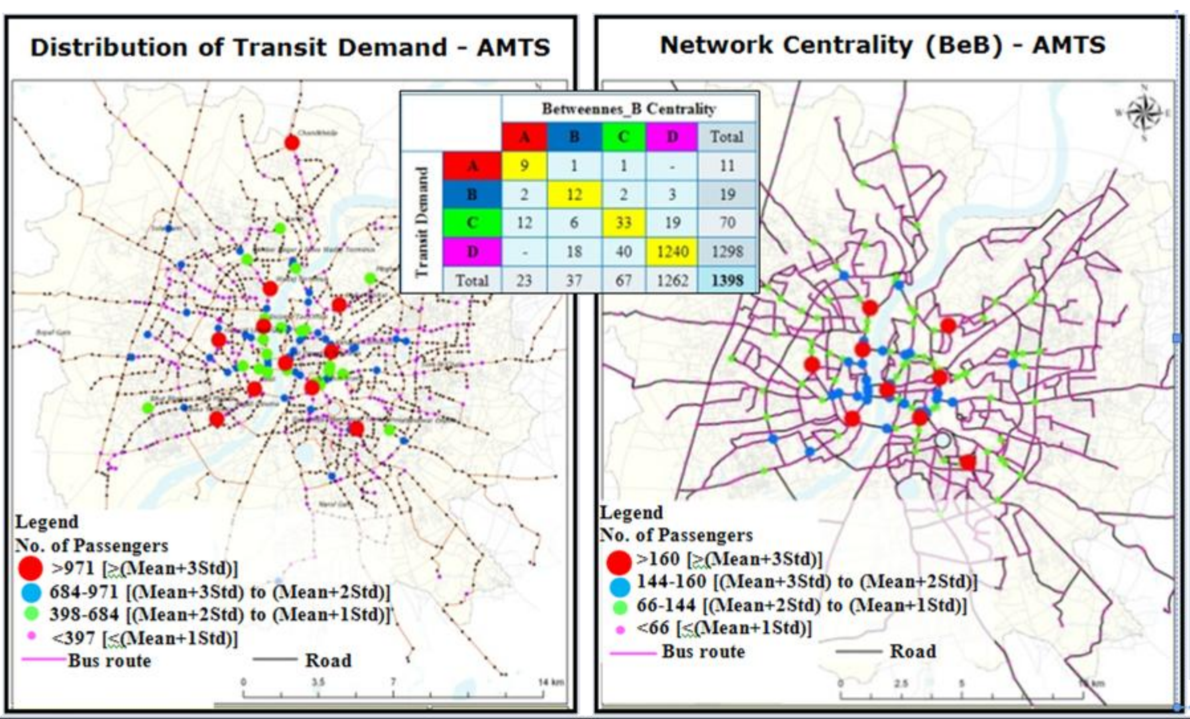

Fig 5.Visual correspondence between transit demand and centrality BeB centrality values of AMTS stop

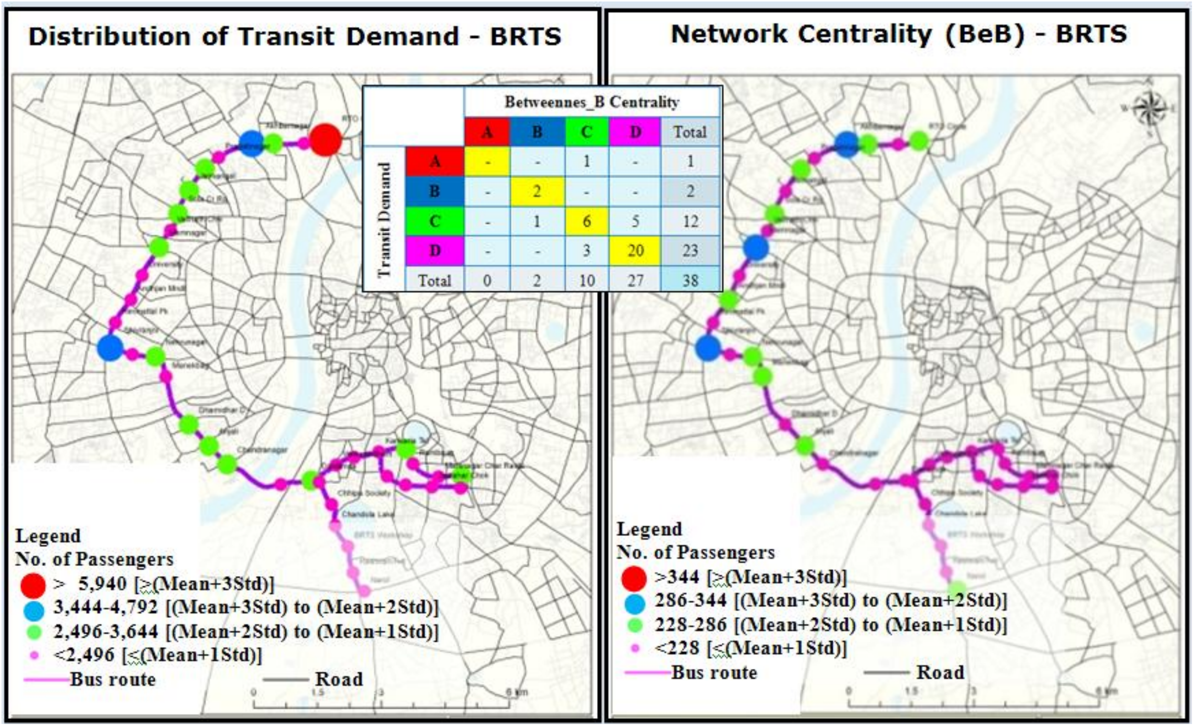

Fig 6.Visual correspondence between transit demand and centrality BeB centrality values of BRTS stop

Correlation between Transit Demand and Centrality Values PT Stops

'Bivariate Pearson correlation coefficient test' in SPSS (Statistical Package for Social Science, 18th version) software was employed to find out the nature and the strength of a relationship between transit demand of stops and each centrality parameter. This analysis was operated in seven levels based on type of stops (i.e. All AMTS stops, All BRTS stops, A, B, C, D and E type of stops). Following table was illustrated summary result correlation analysis.

In this inquiry, significant positive correlation between transit demand values and network centrality values identified. That indicates the capability of centrality measures in explaining transit demand of PT transit stops. However, the level of coefficient of correlation is different by centrality parameters and type of stops. The transit demand of stops obtained a significant coefficient of correlation with all centrality parameters at the radius of 5-7 km. Average trip length of Ahmedabad city (6.2 km, AMC 2007) is exactly within this radius. Accordingly, all three parameters can explain transit demands within the radius of average trip length.

However, BeB does not show any relationship with transit demand at 0.6 km distance (0.6 km is the walking distance which PT users travel from origin to bus stop) but neighborhood level behavior explain by Local Closeness and Local Straightness. Further, 'Type A' recorded highestcorrelation with transit demand and centrality value of all three parameters in influence radius more than 7km. In case of 'Type B 5-7 km radius from stops, C 3-5 km radius from stops and D <3 km radius from stops. It indicates that stops can categorize in hierarchical order by influence area. Accordingly stops which influence on entire city as 1st level , stops which have influence area of more than 7 km as 2nd level, stops which have influence area of 5-7 km as 3rd level, stops which have influence area of 3-5km as 4th level and other as 5th level

Type of Stops	Closeness Centrality at							
	Local	3km	4km	5km	6km	7km	8km	Global
All BRTS	0.51**	0.30*	0.34**	0.71**	0.80**	0.63**	0.20*	-0.09
All AMTS	0.50**	0.54**	0.51**	0.81**	0.82**	0.68**	0.61**	0.35**
A	0.13	0.53**	0.63**	0.65**	0.86**	0.86**	0.88**	0.90**
B	0.16	0.40*	0.61**	0.68**	0.80**	0.74**	0.44**	0.35*
C	-0.02	0.16	0.64**	0.75**	0.61**	0.22*	0.21*	0.15
D	0.28	0.38*	0.46**	0.67**	0.46**	0.04	0.08	0.01
E	0.90**	0.39*	0.38*	0.37*	0.34	0.01	0.03	0.35

Type of Stops	Straightness Centrality at							
	Local	3km	4km	5km	6km	7km	8km	Global
All BRTS	0.53**	0.31*	0.49**	0.78**	0.69**	0.51**	0.31**	0.29**
All AMTS	0.49**	0.45**	0.74**	0.46**	0.62**	0.12	-0.01	-0.08
A	0.20	0.21	0.34*	0.23*	0.28*	-0.17	-0.39	-0.19
B	0.01	-0.19	-0.08	0.32*	0.50**	0.31	-0.16	0.11
C	-0.07	0.17	0.60**	0.70**	0.54**	0.36*	0.19	0.15
D	0.38*	0.06	0.52**	0.68**	0.56**	0.02	0.05	0.02
E	0.85**	0.25	0.09	0.31*	0.19	-0.04	0.00	-0.19

Type of Stops	Betweennes Centrality at							
	Local	3km	4km	5km	6km	7km	8km	Global
All BRTS	-0.07	0.50**	0.63**	0.77**	0.81**	0.80**	0.73**	0.69**
All AMTS	0.03	0.72**	0.65**	0.78**	0.78**	0.78**	0.79**	0.77**
A	0.00	0.51**	0.73**	0.76**	0.74**	0.72**	0.74**	0.77**
B	-0.06	0.56**	0.69**	0.62**	0.62**	0.62**	0.61**	0.58**
C	-0.01	0.33**	0.46**	0.67**	0.69**	0.67**	0.71**	0.66**
D	0.04	0.38*	0.40*	0.65**	0.65**	0.65**	0.58**	0.65**
E	-0.05	0.26*	0.58**	0.67**	0.67**	0.67**	0.62**	0.68**

(Note; Correlation significant at the **0.01 level and * 0.05 level
: R>0.8, : 0.8>R<0.6, : 0.6>R<0.4, : 0.4>R<0.2, : R<0.2)

Fig 7. Summary result correlation analysis

Multiple Regression Analysis

Forward multiple regression analysis was employed to estimate the transit demand using centrality values and to identify comparative impact of different level of centrality on transit demand of different type of stops. In other words, a quasi-hedonic model explaining the transit demand values taking the following form is going to be created, tested, and analyzed. Forward linear regression is performed in this regard.

$$\mathbf{Pax=}\boldsymbol{f}\mathbf{(LC_{0.6},LC_3,LC_4,LC_5,LC_6,LC_7,LC_8,LS_{0.6}LS_3,LS_4,LS_5,LS_6,LS_7,LS_8,BeB_3,BeB_4,BeB_5,BeB_6,BeB_7,BeB_8,BeB_{10},GS,GC)}$$

The response variable is the transit demand denoted by 'Pax'. The predictor variables are LocalCloseness($LC_{0.6,}LC_{3,}LC_4,LC_5,LC_{6,}LC_{7,}LC_8$),LocalStraightness($LS_{0.6,}LS_{3,}LS_{4,}LS_5,LS_{6,}LS_{7,}LS_8$),Betweennes($BeB_{3,}BeB_{4,}BeB_5,BeB_{6,}BeB_{7,}BeB_{8,}BeB_{10}$),GlobalStraightness(GS) and Global Closeness(GC). Figure 8 summarizes the results of linear regression analysis with confidence interval at 55% level.

Type of Stop	Predictors	R	R Square	Un-standardized Coefficients		Standardized Coefficients	t	Sig.
				B	Std. Error	Beta		
All AMTS	(Constant)	0.963	0.927	-12.691	.895		-14.187	.000
	Ln_BeB$_{10}$			0.174	.026	0.314	6.614	.000
	Ln_LC$_6$			0.380	.012	0.204	31.728	.000
	Ln_LS$_5$			0.726	.112	0.194	6.471	.000
	Ln_LC$_{0.6}$			3.607	.089	0.156	22.340	.000
	Ln_LS$_{0.6}$			1.069	.026	0.141	12.054	.000
All BRTS	(Constant)	.887	.853	-13.321	3.056		-4.358	.000
	Ln_BeB$_{10}$			1.218	.205	.560	5.926	.000
	Ln_LS$_6$			2.394	.525	.417	4.560	.000
	Ln_LC$_{0.6}$			1.387	.652	.178	2.129	.041
A	(Constant)	0.931	0.867	-1.333	2.207		-.604	.000
	Ln_BeB$_{10}$			.647	.107	.712	6.061	.000
	Ln_GC			1.191	.451	.310	2.640	.000
B	(Constant)	0.955	0.911	3.595	.377		9.546	.000
	Ln_BeB$_{10}$			.195	.018	.743	10.869	.000
	Ln_LC$_6$			.485	.081	.424	5.997	.000
	Ln_LS$_6$			.017	.007	.174	2.551	.000
C	(Constant)	0.905	0.819	2.624	.473		5.550	.000
	Ln_BeB$_{10}$			.442	.109	.327	4.065	.000
	Ln_LC$_5$			.076	.016	.359	4.712	.000
	Ln_LS$_5$			.278	.052	.458	5.367	.000
D	(Constant)	0.984	.971	4.079	.129		31.079	.000
	Ln_BeB$_{10}$			.232	.032	.276	7.288	.000
	Ln_LC$_{0.6}$			.164	.017	.502	9.727	.000
	Ln_LS$_3$			.054	.011	.246	4.825	.000
E	(Constant)	0.945	0.903	-10.710	1.252		-8.551	.000
	Ln_BeB$_{10}$			.303	.014	.390	22.858	.000
	Ln_LC$_{0.6}$			2.071	.123	.320	16.871	.000
	Ln_LS$_{0.6}$			2.891	.173	.317	16.741	.000
Dependent Variable: Ln_Pax								

Fig8: Regression model summary

Results indicate that transit demand of PT stop can be predicted through the developed regression models, which have more than 85% accuracy. Accordingly, influence of different centrality parameters on transit demand varies by type of PT stops as follows.

- Transit demand of AMTS stops are influenced by
  - the extent that stops locate intermediary (30%) to the shortest paths (depend on travel time; service frequency and speed) connecting other nodes in city
  - the extent that stops near (physical distance-20% or cognitively-20%) to nodes which locate in out 6km/ average trip length of the radius distance from stops.
  - the extent that stops near (physical distance-15% or cognitively-15%) to surrounding nodes which locate in either immediate vicinity (walking distance) of the stops or about 6km/ average trip length of the city radius distance from stops.
- Transit demand of BRTS stops mainly depend on the network configuration at city level than neighborhood level. Accordingly,
  - BRTS stops which are locating intermediary to the shortest paths (depend on travel time; service frequency and speed) connecting other nodes in city(56%), cognitive closeness at 6km (avg. trip length) level (42%)
  - Nearness to neighboring nodes in terms of physical distance are influence on 18% of transit demand of BRTS stops.
- Transit demand of main transit hubs in city are depend on the level of accessibility to stop in terms of travel time (which depend on speed and service frequency) than the travel distance. Accordingly,
  - stops which locate near to all the other nodes in city, along the shortest paths by travel time (58%) and intermediary to shortest paths (depend on travel time; service frequency and speed) which connect other nodes in city (45%) are capability to act as the main hubs in city than other stops
- Transit demand of medium size stops (type C stops) are depend on
  - the extent that stops locate intermediary to shortest paths which connect other nodes locate within the distance of 5km from stop (70%) and nearness to the those stops in terms of travel time (which depend on speed and service frequency) (30%).
- Transit demand of small size stops depends on
  - the nearness (in terms of physical distance) (65%) and legibility (35%) of the stops to nodes locate immediate vicinity (walking distance) of the stops.

Conclusions

The main objective of this research was to study the applicability of centrality measures to explain public transit demand for a case city of Ahmedabad, India. Accordingly, this study concluded that centrality measures are useful to measure transit demand of transit stops of Ahmedabad city with referring to both AMTS and BRTS.

Closeness, Straightness and Betweenness were identified as appropriate centrality parameters that can use to measure street and transit network centrality of transit stops. All three parameters revealed a significant correlation with transit demand within the radius of average trip length. However, BeB does not show any relationship with transit demand at 0.6 km distance but neighborhood level behavior explains by Local Closeness and Local Straightness. Results indicate that influence of different centrality parameters on transit demand varies by type of PT stops. By considering that, six regression models (more than 85% accuracy) were developed, to explain transit demand of different types of stops based on centrality values.

Though this research successfully achieved desired objective yet this can be developed into much advance analysis by doing further studies in relation to network centrality and passenger transfers, temporal change in transit demand and impact of city from on network centrality of PT systems. This research has contributed to with a robust, dynamic planning tool that will offers promise for transport planning applications in Indian context as; to identify the impact from network augmentation to transit demand of existing stops; to identify the impact from proposed land use plans to transit demand of existing stops; and to select location for transit stops or to plan multimodal system. Further, this is a positive contribution of emerging literature in spatial applications of network centrality parameters with a case of emerging Asian city.

References

Belwal, R. and Belwal, S.(2010): Public Transportation Services in Oman: A Study of Public Perceptions. Vol. 13 No. 4 Journal of Public Transportation., 2-3.

Cervero, R.R. and Kockelman. K. (1997): Travel Demand and the 3Ds: Density, Diversity and Design.Transportation Research-Part D 2., 199-219.

Dimitriou, H.I. (2006): Towards a generic sustainable urban transport strategy for middle-sized cities in Asia: Lessons from Ningbo, Kanpur and Solo.Habitat International 30., 1083-1088.

Foda, M.A.(2010): Using GIS for Measuring Transit Stop Accessibility Considering Actual Pedestrian Road Network. Journal of Public Transportation Vol. 13, No. 4., 23-26.

Gwilliam, K. (2004): Public Transport in the Developing World. Quo Vadis?. The World Bank Publication.,1-5.

Hillier, B. (1996): Space is the machine. Cambridge. Cambridge University Press.

Jun,C., Kwon, J.H., Choi, Y. and Lee, I. (2007): An Alternative Measure of Public Transport Accessibility Based on Space Syntax.Springer-Verlag Berlin Heidelberg.,281- 291.

Kazerani, A. and Winter, Y. Modified Betweenness Centrality for Predicting Traffic Flow. Available from: URL:http://www.biodiverse.unsw.edu.au/.../PDF/Kazerani_ and_Winter.pdf

Kishimoto,T.,Kawasaki, S. Nagata, N. and Tanaka, R. (2010): Optimal Location of Route and Stops of Public Transportation, Available from: URL: http://www.spacesyntaxistanbul.itu.edu.tr/papers%5Clongpapers%5C075%20- %20Kishimoto %20Kawasaki%20Nagata%20Tanaka.pdf

Leda, H. (2010): Sustainable urban transport in an Asian context. Tokyo: Spring., 281- 291.

Ministry of Urban Development (MOUD). (2006): National Urban Transport Policy India. Government of India.,1-7.

Ministry of Urban Development (MOUD). (2008): Study on traffic and transportation policies and strategies in urban areas in India. Government of India.1-5

Munshi, T. (2003): Planning Public Transport of Ahmedabad City in India. Enschede: UPLA, ITC.,1-16.

Munshi, T., W. Belal, and M. Dijst (2004): Public transport provision in Ahmedabad, India: accessibility to work place. Publication of: WIT Press.

Munshi, Talat, et al. (2014): Logistic regression and cellular automata-based modelling of retail, commercial and residential development in the city of Ahmedabad, India. Cities., 68-86.

Paul, A.An integrated approach to modeling vehicular movement networks: Trip assignment and space syntax', Available from: URL: http://etd.lib.ttu.edu/theses/available/etd-07052009-141723/unrestricted/Paul_Abhijit_Diss.pdf

Porta, S. and Latora, V. Correlating street centrality with commerce and service location in cities', Available from: URL: http://www. arxiv.org/pdf/physics/0701111

Porta, S., Scheurer, J. and Curtis, C. (2008): Spatial Network Analysis of Public Transport Systems: Developing a Strategic Planning Tool to Assess the Congruence of Movement and Urban Structure in Australian Cities. The University of Melbourne, Victoria., 2-5.

Singh, S.K. (2005): Review of Urban Transportation in India. Journal of Public Transportation Vol. 8, No. 1.,80-85.

Tan, A., Voegtline, M., Bekele, S., Chen, C.S. and Aroian, R.V. (2008): Expression of Cry5B protein from Bacillus thuringiensis in plant roots confers resistance to root-knot nematode. Biol. Control., 47: 97-102.