RELATION BETWEEN URBAN FORM AND BRTS TRANSIT USE

Case of Ahmedabad

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- Introduction
- Objectives, Research Question
- Transit Ridership and Urban Forms
- Current Debates on Transit Oriented Development
- Study Area Stop areas
- Correlations
- Analysis
- Conclusions
• With increasing personal vehicle use, results in air pollution and GHG emissions. An oft-suggested alternative to reduce the negative externalities of the personal vehicle use is the development of an efficient public transportation system. (Chakour & Eluru, 2013)

• Many Indian cities dramatically transformed their mobility through the implementation of many bus transit solutions in the past few years (India, EMBARQ, 2009).

• BRTS has become populous as a means to provide reliable, non-automobile based mobility and alleviate the impacts of rising congestion in the city (India, EMBARQ, 2009).
• Understanding the **factors that affect transit ridership** thus becomes important for the **success** of any given transit system. (Banerjee et.al., 2005)

• Previous studies have ascertained that a relationship exists between ridership and the urban forms. Density and land-use mix have a positive impact on ridership. (Ewing & Cervero, 2010; Banerjee, 2005)

• “Urban form is a broad concept, implies the spatial patterns or arrangements of individual urban elements such as buildings, streets and land use.” (Munshi, 2013)

Urban forms are conventionally represented by six groups of indicators, referred to as the **6 D’s**.

<table>
<thead>
<tr>
<th>Cervero and Kockelman, 1997</th>
<th>Ewing and Cervero, 2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>Destination</td>
</tr>
<tr>
<td>Diversity</td>
<td>Distance</td>
</tr>
<tr>
<td>Design</td>
<td>Accessibility</td>
</tr>
<tr>
<td>Demand</td>
<td>Management</td>
</tr>
</tbody>
</table>

(Cervero, 2014; Cervero & Kockelman, 1996; Munshi, 2013)
AIM
To identify the relationship between Urban Form and BRTS transit ridership, at BRTS stop locations in Ahmedabad.

OBJECTIVES
i. To identify the urban form variables of density and diversity that relate to BRTS transit use.
ii. To analyze the relationship of urban form and ridership use of BRT in the selected station areas.
iii. To analyze the relationship between BRTS riders and their residential building typologies.
Ridership is defined as the number of passengers using a particular form of public transport. The 2 methods to measure ridership are:

i. Average weekday, monthly, or annual boarding

ii. Transit journey-to-work (commute) mode share, and also the percent of work trips made by public transit


Average weekday boardings were used as a data source due to the correlation between boardings and alightings i.e. people start on their return trip the same place they ended - the beginning of the trip.

(Johnson, 2003; Banerjee et. al, 2005 and Estupinan & Rodriguez, 2008)
Density

Density is always measured as the variable of interest per unit of area. The effects of density on travel demand have long been acknowledged. Higher densities are associated with more public transport use, more walking and cycling, and less car use.

Variables:  Population density - Persons per hectare
          Dwelling Unit density– No. of Single family or multiple family units per hectare

(Source: Estupiñán & Rodríguez 2008; Johnson 2003; Banerjee et. al., 2005)

In Ahmedabad’s context

<table>
<thead>
<tr>
<th>Parameters to measure</th>
<th>Ahmedabad context</th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population density</td>
<td>Considering the growth of the city (morphological make-up)</td>
<td>Net densities will be calculated. Literature shows a positive relationship.</td>
</tr>
<tr>
<td>Dwelling Unit</td>
<td>The variable becomes housing typologies; as we do not have single family or multi family units rather apartments, slums etc. would be a more interesting look</td>
<td></td>
</tr>
</tbody>
</table>

(Image Source: Development plan Ahmedabad)
**Diversity**

Diversity measures pertain to the number of different land uses in a given area and the degree to which they are represented in land area, floor area, or employment.

- Land Use Diversity/ Entropy = \[ \sum \frac{P_n \times \ln(P_n)}{\ln(N)} \]

Where, \( N \) = number of different land-uses in the station area or buffer area; and \( P_n \) = proportion of land in units (acre, hectare) of the \( n^{th} \) land-use within the station area or buffer area.

The greater the value of Land Use Diversity greater the mix of land use in the area. The values range from 0 to 1, where 1 denotes maximum possible diversity.

(Banerjee et. al., 2005; Munshi 2014; Kumar & Goliya, 2014)

<table>
<thead>
<tr>
<th>Parameters to measure</th>
<th>Ahmedabad context</th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land-use balance</td>
<td>Mix land-use prevalent in Ahmedabad</td>
<td>Vertical mix also taken into consideration. Mixed land-use leads to higher ridership</td>
</tr>
<tr>
<td>Urban form Characteristics</td>
<td>Indicators</td>
<td>Categories (during surveys) in Ahmedabad's (Indian) context</td>
</tr>
<tr>
<td>----------------------------</td>
<td>---------------------------</td>
<td>----------------------------------------------------------</td>
</tr>
<tr>
<td>Density</td>
<td>Housing typology</td>
<td>1) Bungalows,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) Row Houses,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3) Semidetached,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4) Apartments,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5) Slums,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6) Gamtal and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7) Chawls</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8) Other Buildings</td>
</tr>
<tr>
<td>Diversity</td>
<td>Land-use balance/Entropy</td>
<td>1) Residential,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) Commercial,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3) Mixed,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4) Others</td>
</tr>
</tbody>
</table>

Plotted development
CURRENT DEBATES ON TOD

Transit Oriented development Zone, Ahmedabad
(source development plan, ahmedabad)

- Higher FSI for increasing density, urban form changes drastically.
- High rise, mixed land use promoted so as to maximize access to public transport, and often incorporates features to encourage transit ridership.
CURRENT DEBATES ON TOD

CASE of CURITIBA, BRAZIL

- Low and middle income groups pushed out of this transit zone, thus reducing the transit ridership
- Affordable to higher income groups that do not use public transit occupy
- Higher floor space area units built
- Pressure on the developers to recover these expenses
- Transit oriented zone with higher FSI
- Land Values go up
- Cost of infrastructure go up


(Case study Curitiba Brazil, Dualtre & Ultramari, 2012)
- An average of 1,35,000 passengers ride daily in the BRTS
- Network length of 86 kilometers
- Number of working stations are 120
- Distance between 2 stations 800m
- Bus fleet 160 buses

Average daily passenger trips and revenue collection

(Source: Thennarasam, M & CEPT)
Influence zone Radius

- Proximity or Distance to transit station is an important factor.
- Transit ridership diminishes rapidly as distances from transit stations increases.
- One-quarter mile i.e. 400m is the limit that most people will walk for most trips.

(Banerjee, 2005; Cervero 2014; Janmarg BRTS, 2006; Utermann, 1984)

Stop area Selection criteria's

i. Higher ridership station areas.
ii. Areas that are not transfer station.

Selected Stop areas (Image Source: Janmarg BRTS, 2006; CUE office, A'bad)
### SECONDARY DATA SUMMARY

(Source: Area Planning Studio data, 2014 & 2016; GIS maps)

<table>
<thead>
<tr>
<th></th>
<th>Akhbarnagar</th>
<th>Dharnidhar Derasar</th>
<th>Isanpur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station area (in sq. km)</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Ridership (Average Daily boarders)</td>
<td>3604</td>
<td>1528</td>
<td>1492</td>
</tr>
<tr>
<td>Density (in persons/sq. km)</td>
<td>36448</td>
<td>25649</td>
<td>41779</td>
</tr>
<tr>
<td>Density (in persons/ hectare)</td>
<td>366</td>
<td>257</td>
<td>418</td>
</tr>
<tr>
<td>Building Use (Entropy)</td>
<td>0.004</td>
<td>0.003</td>
<td>0.002</td>
</tr>
<tr>
<td>Plotted development density (units/Ha)</td>
<td>116</td>
<td>191</td>
<td>220</td>
</tr>
<tr>
<td>Apartment density (units/Ha)</td>
<td>37</td>
<td>44</td>
<td>68</td>
</tr>
<tr>
<td>Slum and chawl density (units/Ha)</td>
<td>617</td>
<td>0</td>
<td>226</td>
</tr>
<tr>
<td>FSI (currently consumed Average)</td>
<td>0.8</td>
<td>0.8</td>
<td>0.9</td>
</tr>
</tbody>
</table>
## CORRELATIONS
### Between urban form and BRTS transit use variables

<table>
<thead>
<tr>
<th></th>
<th>B_Type</th>
<th>B_Use</th>
<th>Pop Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Correlation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ridership (average daily boardings)</td>
<td>Pearson Correlation</td>
<td>.357**</td>
<td>.103**</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>2911</td>
<td>2911</td>
</tr>
</tbody>
</table>

- Relationship significant at p<0.05
- Relationship between ridership and population density is insignificant (p=0.125>0.05)
- Small associations exist between building use (entropy) and transit ridership.
- Moderately strong relationship exists between building typologies and BRTS transit ridership.
As Building Typologies is the most associated of the Urban Form variables with ridership, further a survey of boarders at the three delineated stops were carried.

A total survey of 120 BRTS boarders to establish the Transit Ridership profile in three categories:

- Socio-economic profile
- Travel Characteristics profile
- Housing typology profile
<table>
<thead>
<tr>
<th>Income</th>
<th>Count</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 5000</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>5000 – 10000</td>
<td>24</td>
<td>20%</td>
</tr>
<tr>
<td>10001 – 20000</td>
<td>32</td>
<td>27%</td>
</tr>
<tr>
<td>20001 – 30000</td>
<td>11</td>
<td>9%</td>
</tr>
<tr>
<td>30001 – 40000</td>
<td>13</td>
<td>11%</td>
</tr>
<tr>
<td>40001 – 50000</td>
<td>3</td>
<td>3%</td>
</tr>
</tbody>
</table>

47% of the persons belong to the Lower income group.
**Travel Profile**

- **78%** of the BRTS transit riders live within the influence zone of 400m.
- **65%** of the riders walk to the transit stop.

### Distance Travelled by the Riders before Reaching the Stop Vs Number of Riders

![Bar Chart]

- **57%** of riders travel 100-200 meters.
- **38%** travel 200-300 meters.
- **19%** travel 300-400 meters.
- **8%** travel 400-500 meters.
- **13%** travel 500-600 meters.
- **4%** travel 600-700 meters.
- **9%** travel more than 700 meters.

### Purpose of Travel

- **71%** for Education.
- **22%** for Others.
- **6%** for Recreational/Social.
- **1%** for Work.

### Mode Used to Reach the Stop

- **65%** Walk.
- **17%** AMTS.
- **9%** 2 Wheeler.
- **3%** Auto Rickshaw.
- **2%** Cycle.

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**Note:** The above statistics were gathered from the 9th Urban Mobility India Conference & Expo 2016.
As Strong associations were observed previously, residential typology profile of the BRTS riders is analyzed.
Residential typologies

- Slum and Chawls: 25%
- Apartments: 67%
- Plotted development: 8%

% of housing typologies

Income Groups:
- <10000
- 10001 - 20000
- 20001 - 30000
- 30001 - 40000
- 40001 - 50000

% of Housing Tenure

Income Groups:
- Owners
- Renters
Apartment types

- 1 BHK: 23%
- 2 BHK: 38%
- 3 BHK: 3%
- 4 BHK: 8%
- 501-1000 sq. feet
- More than 1,500 sq. feet

Percentage of apartment units

- Slums and Chawls
- Plotted development

Areas (in sq. feet)

- <500
- 501-750
- 751-1000
- 1001-1250
- 1250-1500
- >1500

RESIDENTIAL TYPOLOGY PROFILE
Understanding the Parking provisions in the residential typologies

Hypothesis: Parking management researches prove that ‘If a provision of allotted parking is present in the buildings, then a resident is likely to be a vehicle owner and have low chances of using the public transit.’

(Source: Mohan, 2013)
Depending upon the descriptive analysis of the three locations and overall Ahmedabad the following correlations between variables are conducted to understand which of the variables have strong associations:

- Housing typologies and socioeconomic variables
- Travel characteristics
### Housing Typologies and Socioeconomic Variables

<table>
<thead>
<tr>
<th>Correlations</th>
<th>Pearson’s Correlation value</th>
<th>Significance (p)</th>
<th>Inference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable 1</td>
<td>Variable 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Housing typologies</td>
<td>Area of the residence</td>
<td>0.493</td>
<td>0.000 (p&lt;0.05)</td>
</tr>
<tr>
<td>Housing typologies</td>
<td>Number of rooms (residence)</td>
<td>0.417</td>
<td>0.000 (p&lt;0.05)</td>
</tr>
<tr>
<td>Housing typologies</td>
<td>Tenure</td>
<td>-0.398</td>
<td>0.000 (p&lt;0.01)</td>
</tr>
<tr>
<td>Housing Typologies</td>
<td>Income</td>
<td>0.183</td>
<td>0.045 (p&lt;0.05)</td>
</tr>
<tr>
<td>Housing typologies</td>
<td>Vehicular ownership</td>
<td>0.260</td>
<td>0.004 (p&lt;0.01)</td>
</tr>
<tr>
<td>Vehicular Ownership</td>
<td>Parking provision</td>
<td>-0.343</td>
<td>0.000 (p&lt;0.05)</td>
</tr>
<tr>
<td>Ridership (average daily value)</td>
<td>Income</td>
<td>0.279</td>
<td>0.002 (p&lt;0.05)</td>
</tr>
</tbody>
</table>
## TYPICAL BRTS RIDER’S HOUSING TYPOLOGY

<table>
<thead>
<tr>
<th>Housing typologies</th>
<th>Area of the residence</th>
<th>Number of rooms</th>
<th>Tenure</th>
<th>Income</th>
<th>Vehicular ownership</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Averagely 750-1000 sq. feet</td>
<td>1 BHK- three rooms and 2 BHK – four rooms</td>
<td>Tenure an important consideration</td>
<td>Income groups of Rs. 5,000-20,000</td>
<td>1 owned two-wheeler with no allotted parking provision inside the building compound</td>
</tr>
<tr>
<td>Correlations</td>
<td>Variable 1</td>
<td>Variable 2</td>
<td>Pearson’s Correlation value</td>
<td>Significance (p)</td>
<td>Inference</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>---------------------</td>
<td>---------------------</td>
<td>-----------------------------</td>
<td>------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Distance travelled</td>
<td>Travel time</td>
<td>0.721</td>
<td>0.000 (p&lt;0.01)</td>
<td>Strong associations</td>
<td></td>
</tr>
<tr>
<td>Mode Choice</td>
<td>Distance travelled</td>
<td>0.445</td>
<td>0.029 (p&lt;0.05)</td>
<td>Moderate associations</td>
<td></td>
</tr>
<tr>
<td>Mode Choice</td>
<td>Travel time</td>
<td>0.199</td>
<td>0.000 (p&lt;0.01)</td>
<td>Small associations</td>
<td></td>
</tr>
<tr>
<td>Mode Choice</td>
<td>Age of the user</td>
<td>0.198</td>
<td>0.031 (p&lt;0.05)</td>
<td>Small associations</td>
<td></td>
</tr>
<tr>
<td>Mode Choice</td>
<td>Gender of the user</td>
<td>0.252</td>
<td>0.005 (p&lt;0.01)</td>
<td>Small associations</td>
<td></td>
</tr>
</tbody>
</table>
### TYPICAL BRTS RIDERS TRAVEL CHARACTERISTIC

<table>
<thead>
<tr>
<th>Mode choice</th>
<th>Distance travelled</th>
<th>Time taken</th>
<th>Age &amp; Gender</th>
</tr>
</thead>
</table>

- Walking is preferred when distance lower than 400m
- Walking is preferred when time taken to reach the stop is less than 5 minutes.
- Age and gender also affect mode choice, age group (16-60) and males as well as females prefer walking to the stop.
CONCLUSIONS

- At the station area level, urban form variables of density as well as diversity have an impact on the BRTS transit ridership—positive and strong relations.

- Building typologies are strongly correlated to transit ridership.

- Residents from certain building typologies are the target group, if transit ridership is to be increased then this target group is to be allowed to live near the transit stops.
  - Target group: Residents living in mid-rise, apartment type buildings.

- If this kind of development that allows the typical BRTS rider to accommodate it is promoted then there is more probability of increasing BRTS ridership in Ahmedabad.
1. The following land-use can be promoted in the BRTS influence zone.
   - Can be location specific aspect
   - Promotion of mid-rise apartment buildings
   - Average unit size of 750 sq. feet to 950 sq. feet
   - Low parking requirements.

2. Parking requirements
   - case specific as on-street parking in congested parts of the city should be reduced.
   - Regulations with parking maximums
   - Chargeable parking FSI

3. Plots reserved for rental housing

4. Walk-able stop areas, as walking is the most popular mode choice
THANK YOU