Travel Pattern Variations by Location, Gender, and Income in Bangalore, India

by

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Many developing nations are currently faced with the challenge of designing and implementing transportation infrastructure and systems in the context of rapidly growing urban populations and constrained resources. Inappropriately designed transportation infrastructure has negative implications through increased emissions.\(^1\) Appropriately designed transportation infrastructure must be tailored to the unique demands of a city, and respond appropriately to the differing demands of different kinds of urban form – e.g., monocentric or polycentric, require different transport practices. Energy demands in a monocentric city are larger per capita than those in a polycentric city (Figueroa 2014), adding to increased emissions. As cities in India continue to develop, the facilitation of pedestrian and biking infrastructure may have the largest positive effect on emissions, especially in polycentric cities with several small self-supporting nodes. However, within monocentric cities, commutes are likely to be longer, in both time and distance, with a high percentage of the trips congesting the central area of the city.

With the rapid urbanization of India, there has been increasing consumption of transportation, transportation infrastructure, and natural resources. Some cities in the developing world have confronted this growth in demand through mass transit with high ridership, particularly in South America. As the cities in developing countries continue to grow, it is imperative that future infrastructure practices and policies focus on efficient methods and plans to proactively prevent the continued rise and sustained use of individual motorized vehicles (Chen 2011). The implications of comprehensive transit planning that understand the linkage between land use and transportation, will have significant effects on emissions in cities.

\(^1\) Currently, India’s per person emissions of carbon dioxide are one tenth that of the United States. As such, the potential impact of increased motorization in a growing nation should not be overlooked or underestimated, especially as the cycle of adoption of single-occupancy, motorized transit is self-reinforcing (Dimitriou 2001).
Comparable to other developing countries, traffic congestion is becoming an ever increasing problem in India. Trip times greater than an hour for distances less than five kilometers are commonly reported in commuter reports and assessments. Travel times greater than an hour are an indicator of increasing burdens on transportation networks, which results in decreased accessibility to services by commuters/residents. Problems caused by a lack of functioning and efficient transportation lines are exacerbated by the haphazard application of design and implementation of roadbuilding regulations.

Bangalore has high levels of congestion throughout the day, made up primarily of private motorized transit, auto rickshaws, and buses. Besides inadequate planning and insufficient investment in viable public transit systems, a second reason for this congestion may relate to the misreading of a city’s urban form and the resulting misdiagnosis of its transport options that unknowingly and/or unintentionally result in the problems seen in most cities: increased private vehicle use, increased emissions, and a lower quality of life for the residents. For example, in a monocentric city, spending on pedestrian infrastructure could be the wrong choice if done on the outskirts, where the majority of trips are greater than one-mile. Conversely, in a polycentric city where hypothetical trip distances are less than one mile, spending on a mass transit system to move individuals further distances could also result in low ridership, and thus an increase in the per capita emissions (Tiwari, 2002).

In this paper I focus on Bangalore, India, a rapidly growing city that is a classic case study of escalating congestion, to ask questions about travel patterns, urban form and transit choices. This paper specifically draws on the 2014 Bangalore Household Survey, one of the largest and latest transportation surveys of the city, to develop a current transportation profile for the city of Bangalore. I focus on three questions: 1) What is the relationship between commuting patterns and spatial location within the city, including commuting patterns within Bangalore’s many satellite neighborhoods (e.g. Whitefield, Electronic City), and what do commuting patterns tell us about Bangalore’s evolving urban form? Is it growing into a monocentric city or a polycentric city? Given the emerging urban form is the city making
appropriate transportation choices?; 2) How do travel patterns differ by income. This question is central to understanding issues of access and the distribution of transportation burdens on different population segments; and 3) finally, a related question is about gender justice in transportation. How do Bangalore’s travel patterns differ by gender? This assessment will provide a detailed understanding and insight to develop appropriate transit investments in the future. Greater understanding of the differences across transportation needs and demands by gender and income will allow for better informed transport policy initiatives.

**RELEVANCE TO TRANSPORT POLICY OF URBAN FORM**

To understand the effects of infrastructure on commute patterns across city forms (e.g., monocentric versus polycentric), analysis of urban form is important. Urban form is defined by Warner (2014) as the spaces, places and boundaries that define city life, and is under transition in India. According to some estimates, 70% of the built environment that will exist in 2030 is yet to be built (McKinsey 2010). Urban form and transportation patterns are cyclical (Litman 2015). “Monocentric” urban form cities are typified as having a dominant Central Business District (CBD) (Figure 1). The Central Business District serves as a main location for jobs and commerce that encourages routine commuting from populations living in the surrounding environments. In this case scenario the majority of commuters...
live in zones 3, 4, and 5. In a monocentric city, the transportation network facilitates commuting into the central city for the largest share of employees.

In a “Polycentric” city (Figure 2, Los Angeles), there are multiple nodes (areas) which serve as diverse business districts. Residents may commute to the closest node to their house thereby allowing for and encouraging shorter commuting distances. In a polycentric city, mass transit systems are feasible, however, their primary purpose shifts to serve as a means to connect the business districts to commercial districts, which typically is a larger share of total trips.

When investigating travel differences in Dutch cities, Schwanen (2001) determined that the deconcentration of urban land uses, as seen in a polycentric city, results in an increased amount of non-motorized transit. With income distributions in Indian cities, polycentric form allows individuals to access, via walking, employment which they may otherwise not be able to afford because of transportation costs (Tiwari, 2002). Likewise, White (1988) determined that decentralizing employment reduced overall commute times, with residents tending to seek employment in spatial proximity to their residence.

The prevailing view in existing literature is that access to a CBD is best provided by a mass-transit network for the network to be efficient, likewise, a dominant CBD must exist for a high capacity transit system to be feasible. Therefore, the need for a more complete understanding of Indian cities is critical and immediate. If countries similar to India develop in the same manner as the United States, they would require twenty times more energy than currently consumed (http://www.worldpopulationbalance.org/energy_india).

Thus, the literature studies commute patterns across city forms on the basis of the total time and distance for home-based work trips. In addition, cities in India are denser than their western counterparts, with some wards housing more than 25,000 individuals per square mile. Properly designed and regulated transportation and land use policies in polycentric cities may contribute to less sprawl,
decreased commute times, decreased emissions, and reduced costs, than in comparably sized monocentric cities.

**URBAN FORM IN BANGALORE**

Bangalore has recently seen increased economic growth due to its role as India’s IT hub, resulting in the city’s population almost doubling in the past four decades, rising from less than two million individuals in 1971 to more than ten million today. The adoption of cars, taken from the registration data, suggests that more than one-hundred times more automobiles were registered in Bangalore in each individual year for 2009, 2010, and 2011, when compared to all vehicles registered in the decade from 1986-1996. Individuals living in the region say that this number dwarfs in comparison to the adoption of motorized two-wheelers, a phenomenon common to the developing world. Travel choices are influenced by access to existing infrastructure and availability of access to transport (e.g., moped) (Bopp, 2013). Given the recent trends in increased access to motorized two-wheelers and registered automobiles, coupled with the growth in urbanization, construction, and transportation demands, Bangalore should adapt policies and practices that appropriately address Bangalore’s urban form and proactively address the potential impact from the unintended effects of emissions on quality of life.

Leading transport planners in India (e.g., Dinesh Mohan 2008, Geetam Tiwari) posit that “high ownership of motorcycles, [and the] non-availability of funds to build expensive grade separated metro systems and official plans encouraging multi-nodal business activity in... [cities] have resulted in the absence of dense high population Central Business Districts (CBD).” They argue that this has led to city forms which encourage a particular type of growth, which takes the “…form of relatively dense cities-within cities,” pushing the boundaries of urban agglomerations to swell to unsustainable scales.

The effects of city structure on commuting patterns, and the effect of commuting patterns on city structure (Rodriguez 2004) play an integral role on the development and adoption of commuting
patterns. Land use is not solely a function of transportation; transportation is also a function of land use (Rodriguez 2004). Because transit is a means to an end, a means of reaching a specific amenity or benefit (good or service) and not a good in and of itself, the expansion of transport networks can determine how effectively that amenity/benefit can be reached or whether the result will be costly congestion. A comprehensive understanding of this symbiotic relationship is imperative to determining effective policies to mitigate adverse effects and develop proactive practices to minimize emissions.

From my field observations in Bangalore and conversations with local planners, it is clear that recent transportation decisions, such as the location of the airport, and zoning decisions that created the disconnected satellite cities of Whitefield and Electronic City, have contributed to sprawl. The distribution of economic activity throughout these zones has led to an increasing residential zone beyond the traditional city center. Thus, the construction of gated communities on the urban periphery demonstrate sprawl that is already occurring. Lacking access to viable public transit, coupled with the distances to access amenities, the modal shares generated by the gated communities are dominated by the automobile (EMBARQ India 2014). For example, buses and walking make up only 16% of trips originating in these Gated Communities, compared to 61% of all trips in the city of Bangalore, (Ibid). While the creation of polycentric job centers may reduce mean commute times, the lack of dense attractors, in the form of concentrated employment centers, results in reduced efficiency for high capacity metro transit in the future. The dominance of employment within a single ward over others would indicate that the connectivity to that node could be improved through mass transit. However, if no nodes dominate, the economic centers that do not have mass transit could end up subsidizing the centers that do.

THEORY OF INDUCED DEMAND AND IMPLICATIONS ON TRAVEL PATTERNS

The theory of induced demand states that road improvements lower barriers for private vehicle traffic and result in an increased number of private vehicle trips (Litman 2015). Additionally, they lead to
the need for additional roads and therefore result in a negative feedback cycle in which the pedestrian environment is constantly eroded (Litman 2014). Many times, this leads to leapfrogged development and a lack of funds to pay for road maintenance and repair, a trend which is further worsened by the additional traffic encouraged by the additional paved areas. In the case of India, Badami (2004) points out that the majority of funding goes to building freeways and flyovers that further fragment the urban fabric since they are difficult for foot-traffic to navigate. As mentioned previously, the cost for a single flyover can equal that of an inexpensive bus rapid transit (BRT) line.

Adoption of Personal Vehicles

The current trend in many developing countries is to engage in suburban development that is primarily accessible by personal vehicle (Mohan 2002). Further, this suburban development reinforces the adoption of the personal vehicle, which subsequently results in increased demand for high-speed roadways in the city. Lack of planning in these areas mainly because they fall outside of formal jurisdictions has resulted in completely market based solutions, with huge externalities that cities in the developing world are just beginning to cope with. The impacts of sprawling development on the environment and on quality of life are only beginning to be understood, even in high income countries. Moreover, the capital required for remediating sprawling development is far more intensive than that required for the construction of centralized, compact, mixed-use development in the first place. Countries that have not yet developed their land in a sprawling pattern are potentially the winners if they are able to exit the cycle of ever increasing individual motorized transit. Perhaps the most feasible way to do this is through the Extra-Territorial Jurisdiction practiced by many American cities, in which the zoning of a buffer around the city at the location where the city anticipates one day expanding, is controlled within the city.
The intended and unintended increases in the production of additional personal vehicle trips is of growing concern in many Indian cities, where the largest increase in building activity is occurring on the urban fringe in the form of gated communities (EMBARQ 2014). As Schnore anticipated in 1959, “… downtown congestion would be relieved, [but] the growth in cross-hauling could eventually overwhelm suburbs with traffic.” This congestion is already occurring in many Indian cities, leading to increased time in transit for public transit and individual private transit, as well as increased walk times due to the disruption of a pedestrian network created by flyovers inside the city.

When coupled with the disruption to the pedestrian routes experienced by a grade-separated interchange, as well as the subsequent high-speed pedestrian collisions that frequent these structures, a need for solutions tailored to the Indian context is evident. This is also corroborated by Sabapathy (2012), who states that Bangalore should make “investments for transportation infrastructure and transportation policy… directed towards encouraging public transport, walking and non-motorized transport, rather than the sole development of roadway infrastructure that primarily caters to personalized modes of high-income commuters.” In the context of India, the largest observed need for transportation infrastructure and planning relates to multi-modal connections tailored to the predominate mode – walking (Badami 2004, EMBARQ 2014).

**DATA AND ANALYSIS: THE 2014 BANGALORE HOUSEHOLD SURVEY**

*Inclusion Criteria for Analysis*

In 2014, EMBARQ India carried out a unique travel behavior survey in Bangalore. The Bangalore Household Survey consisted of 9,075 individuals in 2,522 households and explored a variety of travel-related questions, such as commute times, distances, expense, and mode. The survey was conducted in random locations throughout the city and contains information about income, gender, and several other demographic characteristics. The data are geolocated with latitude and longitude, which allows for spatial
comparison with a proposed dominant employment node. I propose two methods for testing the monocentricity of Bangalore, as explained below. However, due to the survey targeting structures, all slums were excluded from analysis. This comprehensive dataset was supplemented further by a 445 household survey done in gated communities throughout the city. The gated community survey gathered many of the same questions as addressed in the Bangalore Household Survey, and are therefore able to be used to draw comparisons between the two. Together these datasets allow us to better understand the current urban form and transportation choices and patterns of Bangalore residents. During 2014, I worked firsthand with the Bangalore Household Team, and was involved in reviewing and analyzing spatial distributions of transportation patterns, as well as differences across gender and income, to understand the contribution of urban form to transit in developing countries.

Scope of Review

Using this dataset I propose to test several relationships between travel patterns, distance of a residence from the city center (i.e., Mahatma Gandhi Road [MG Road]), or other economic nodes in Bangalore, and the resulting urban form. Central to this analysis is the debate regarding Bangalore’s spatial evolution into polycentric or monocentric form, and what transportation and land use policies might be most pertinent for the future. For example, Ewing and Cervero (1998) found that when mixed-use developments (i.e. retail, residential, and commercial on the same site) are located at the periphery of a city, they actually produce a greater number of trips than less intensive land uses located internally to a city. “Almost any development in a central location is likely to generate less automobile travel than the best-designed, compact, mixed-use development in a remote location” (Ewing 1998). On the other hand, Mohan (2008) has been a proponent of India’s evolution of polycentric cities, where all of an individual’s needs, such as healthcare, schooling, food and work are theoretically accessible within a single ward, thereby reducing overall travel distances. From this idea he concludes that, “[current] evidence suggests that metro rail systems, especially the construction of two or three lines at great cost,
do not help in reduction of private vehicle use, congestion or pollution.” However, if a city is monocentric, with the major traffic attractor in a centralized location, the value added by mass transit lines increases. As such, a misdiagnosis of the city structure negatively affects the design and allocation of transportation infrastructure and land use policies. As India continues to grow into the world’s most populous country, this effect has the potential to drastically impact emissions, energy consumption, land use, and transport requirements for the future.

TESTING FOR MONOCENTRICITY

In order to address the issues of urban form in Bangalore, I will apply two different methods to test for monocentricity. Due to data restrictions, I am not able to use methods which include employment, and thus will use McDonald’s 1987 method, as well as Dokmeci’s 1994 method. While the applications of these methods are less than ideal, the model that they present should allow us to accurately define Bangalore as mono- or polycentric.

McDonald’s Method


In figure 4, I have used the ward surrounding MG Road as the center, and created zones outward from there to test for differences in travel patterns. The red dots located on the map are locations where the Bangalore Household Survey was completed, and overlaying this information with the ward shapefile provided by OpenBangalore.org, I was able to determine average commuting category by ring. As shown in figure 3, the variation between travel times was not significant by ring. I was not able to test for employment density as an attractor as a variable because employment data were not available by zone.
Figure 3: Distance from City Center

Figure 4: Average Commute Time by Ward
Travel Pattern Variations by Gender, Income and Location in Bangalore, India

My model (table 1), a linear regression of the average travel time from each ring, explained less than two percent of the variation in travel time (Adj R-squared = 0.0197).

**Table 1: Linear Regression of the Average Travel Time by Ring**

| Ring | coefficient | standard error | t-score | P>|t| |
|------|-------------|----------------|---------|-----|
| 1    | -1.304      | 0.669          | -1.95   | 0.053 |
| 2    | -0.429      | 0.657          | -0.65   | 0.514 |
| 3    | -0.672      | 0.633          | -1.06   | 0.289 |
| 4    | -0.611      | 0.628          | -0.97   | 0.331 |
| 5    | -0.715      | 0.634          | -1.13   | 0.260 |
| 6    | -0.939      | 0.640          | -1.47   | 0.144 |
| 7    | -0.021      | 0.807          | -0.03   | 0.979 |
| constant | 2.250      | 0.611          | 3.69    | 0.000 |

Due to the homogeneity between transport patterns within the wards, as well as the low value of R-squared, this model suggests that the rings themselves, and thus the distance from the geographical city center, does not influence travel times. However, there is some indication that travel times are significant (P > 0.053) in the first ring- namely, the urban core. This may, however, simply be a result of the job/housing balance in the location, rather than a reflection of the form. As such, if employment data by ward are available in the future, a more rigorous application of McDonald’s method is warranted.

As discussed above, the lack of a clear monocentric form reduces the positive effect of a mass-transit system e.g. metro or BRT. Increased coverage of bus transit may provide better accessibility for the residents of the city of Bangalore than comparable spending on other transportation systems, including the construction of additional road surfaces. The additional road surfaces will increase vehicle miles traveled (VMT) (Rodriguez, 2004), but will not result in increased accessibility for low-income households living within the city, particularly if those families are unable to afford a two-wheeler. Additionally, the two-tiered system of busses in the city fragments the mission of moving people around into moving well-off individuals around and moving poorer individuals around. This “separate but equal”
system does not increase accessibility for those who need it most, and should be abandoned in favor of one comprehensive bus network.

Dokmeci’s Method

In 1994, Dokmeci and his team tested for monocentricity in the city of Istanbul. They had hypothesized that the population growth on the peripheral districts led to subsequent employment growth in the same, resulting in a more polycentric city. This was envisaged as a result of Istanbul becoming so large that “due to agglomeration diseconomies, a monocentric urban structure could no longer prevail.” If the same effects are seen in Bangalore, one can presume that the threshold has been exceeded wherein transportation patterns have forced the city to shift to polycentricity. While Dokmeci used a three part method, involving volume of paper mail, employment levels per district, and commute times, I used only the commute times, since the mail volumes and employment levels were not available at the same level of analysis.

Table 2: Average Commute Time by Ring

<table>
<thead>
<tr>
<th>Ring Number</th>
<th>Average Population Density</th>
<th>Average Commute Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>9503</td>
<td>2.25</td>
</tr>
<tr>
<td>1</td>
<td>25202</td>
<td>2.37</td>
</tr>
<tr>
<td>2</td>
<td>26553</td>
<td>2.31</td>
</tr>
<tr>
<td>3</td>
<td>38701</td>
<td>2.18</td>
</tr>
<tr>
<td>4</td>
<td>21919</td>
<td>2.23</td>
</tr>
<tr>
<td>5</td>
<td>11515</td>
<td>2.16</td>
</tr>
<tr>
<td>6</td>
<td>4565</td>
<td>2.19</td>
</tr>
<tr>
<td>7</td>
<td>N/A</td>
<td>2.23</td>
</tr>
</tbody>
</table>

In Table 1, I again found that the average commute time did not differ greatly by distance from the CBD (MG Road). In fact, the second ring appears to have the highest commute time, which would indicate a lack of monocentricity. Additionally, if one examines the average population density of the rings, there is also no correlation between commute times and population density (Adjusted R-Square = -0.106,
The rings used in this analysis were defined above in figure 4. While this method misses where the employment centers are located, the extrapolation of average commute time by ring from the CBD reinforces the earlier findings, suggesting that Bangalore is polycentric. The fact that this is independent of the population densities could be an indicator of a poor alignment between jobs and housing available in the city.

The second range for travel time (table 2) was between 15 and 30 minutes per one-way trip, which indicates that the average commute in the city is potentially short enough to be shifted to a less energy intensive use. Table 3 below shows us that the majority of these trips are being made by walking, BMTC busses, and two-wheelers. While two-wheelers increase accessibility, their inherent danger may not be the best fit for the chaotic road network that exists in Bangalore. As such, an increase in the provision of public transit, and additional provision of safe non-motorized networks could be a good fit for these short-duration trips.

DIFFERENCES IN TRAVEL PATTERNS BY GENDER

The literature indicated that women generally have less time to spend in traveling, due to their need to fulfill familial responsibilities within the household. As such, the accessibility for the same household will generally be higher for males than for females, in the context of Bangalore. This results in a mismatch which planners and policy makers should consider when they are recommending transportation projects, as well as land use scenarios. The largest difference affecting mobility can be displayed by the disparity between ridership of two-wheelers, which men use at more than three times the rate of women (table 3). This divergence affects women’s accessibility above and beyond their already restricted travel time budgets. As such, it is important to investigate how gender plays a role in accessibility.
In the survey, displayed in table 3 below, a Pearson chi-square test indicated that travel mode differs by gender ($\chi^2 = 409.79$, $p<0.001$). The largest differences were in women being less likely to travel via two-wheeler (34% of male trips vs. 10% of female trips), and more likely to walk (24% of male trips vs. 46% of female trips). Time spent traveling also differed by gender ($\chi^2 = 99.47$, $p<0.001$), with females traveling shorter durations than males, particularly in the Less than 15 Minute category, with 29% of men, but 40% of all female trips. Women (39% of trips) are also more likely to ride public transit than men (34% of trips), which results in an uneven negative impact from poor public transit for female commuters.

When investigating Travel Time by gender (figures 5 and 6), males travel at least as long as females do for every ward, with the exceptions being Jakkuru (n=63, female=18), which is located to the north of town and Prakash Nagar (n=38, female=8), near MG Road. This analysis indicates that while travel times differ by gender, it appears that females are traveling for shorter durations than their male counterparts.

In summary, I have determined that travel patterns in aggregate are vastly different for women and men in the city of Bangalore. As mentioned above, this is an important consideration for future transit provision. These effects are not only prevalent across mode, but also across travel time, which when taken together restrict accessibility for women in the developing world more than for their male counterparts.
Table 3: Travel time by Mode and Gender

**Male (P<0.001)**

<table>
<thead>
<tr>
<th>Time Range</th>
<th>Auto</th>
<th>Bicycle</th>
<th>BMTC Bus</th>
<th>Car</th>
<th>Company/School Bus</th>
<th>Other</th>
<th>Taxi</th>
<th>Two-Wheeler</th>
<th>Walking</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 15 Minutes</td>
<td>0.96%</td>
<td>0.29%</td>
<td>2.06%</td>
<td>0.26%</td>
<td>0.91%</td>
<td>0.42%</td>
<td>0.05%</td>
<td>8.07%</td>
<td>15.77%</td>
<td>28.78%</td>
</tr>
<tr>
<td>15-30 Minutes</td>
<td>0.99%</td>
<td>0.73%</td>
<td>8.90%</td>
<td>1.35%</td>
<td>2.58%</td>
<td>0.29%</td>
<td>0.08%</td>
<td>14.60%</td>
<td>7.68%</td>
<td>37.18%</td>
</tr>
<tr>
<td>30-45 Minutes</td>
<td>0.10%</td>
<td>0.21%</td>
<td>8.35%</td>
<td>0.65%</td>
<td>1.01%</td>
<td>0.10%</td>
<td>0.03%</td>
<td>7.47%</td>
<td>0.57%</td>
<td>18.50%</td>
</tr>
<tr>
<td>45-60 Minutes</td>
<td>0.00%</td>
<td>0.03%</td>
<td>4.22%</td>
<td>0.31%</td>
<td>0.78%</td>
<td>0.10%</td>
<td>0.00%</td>
<td>2.76%</td>
<td>0.10%</td>
<td>8.30%</td>
</tr>
<tr>
<td>More than 1 hour</td>
<td>0.60%</td>
<td>0.00%</td>
<td>4.03%</td>
<td>0.13%</td>
<td>0.70%</td>
<td>0.21%</td>
<td>0.03%</td>
<td>1.48%</td>
<td>0.05%</td>
<td>7.23%</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>2.65%</strong></td>
<td><strong>1.25%</strong></td>
<td><strong>27.56%</strong></td>
<td><strong>2.71%</strong></td>
<td><strong>5.98%</strong></td>
<td><strong>1.12%</strong></td>
<td><strong>0.18%</strong></td>
<td><strong>34.37%</strong></td>
<td><strong>24.17%</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Female (P<0.001)**

<table>
<thead>
<tr>
<th>Time Range</th>
<th>Auto</th>
<th>Bicycle</th>
<th>BMTC Bus</th>
<th>Car</th>
<th>Company/School Bus</th>
<th>Other</th>
<th>Taxi</th>
<th>Two-Wheeler</th>
<th>Walking</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 15 Minutes</td>
<td>1.30%</td>
<td>0.14%</td>
<td>1.73%</td>
<td>0.29%</td>
<td>2.02%</td>
<td>0.58%</td>
<td>0.00%</td>
<td>3.47%</td>
<td>30.92%</td>
<td>40.46%</td>
</tr>
<tr>
<td>15-30 Minutes</td>
<td>1.66%</td>
<td>0.22%</td>
<td>11.27%</td>
<td>0.87%</td>
<td>4.91%</td>
<td>0.07%</td>
<td>0.00%</td>
<td>4.55%</td>
<td>13.58%</td>
<td>37.14%</td>
</tr>
<tr>
<td>30-45 Minutes</td>
<td>0.29%</td>
<td>0.07%</td>
<td>8.89%</td>
<td>0.29%</td>
<td>1.45%</td>
<td>0.00%</td>
<td>0.07%</td>
<td>1.23%</td>
<td>0.94%</td>
<td>13.22%</td>
</tr>
<tr>
<td>45-60 Minutes</td>
<td>0.00%</td>
<td>0.00%</td>
<td>5.20%</td>
<td>0.07%</td>
<td>0.87%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.22%</td>
<td>0.14%</td>
<td>6.50%</td>
</tr>
<tr>
<td>More than 1 hour</td>
<td>0.00%</td>
<td>0.00%</td>
<td>1.73%</td>
<td>0.00%</td>
<td>0.51%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.43%</td>
<td>0.00%</td>
<td>2.67%</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>3.25%</strong></td>
<td><strong>0.43%</strong></td>
<td><strong>28.83%</strong></td>
<td><strong>1.52%</strong></td>
<td><strong>9.75%</strong></td>
<td><strong>0.65%</strong></td>
<td><strong>0.07%</strong></td>
<td><strong>9.90%</strong></td>
<td><strong>45.59%</strong></td>
<td></td>
</tr>
</tbody>
</table>
DIFFERENCES IN TRAVEL PATTERNS BY INCOME

As gender was determined to be important above, demonstrated by the divergent travel patterns of females and males, income may also play a role in the accessibility an individual experiences. Thus, an investigation of travel patterns by income levels can contribute to our understanding of deficiencies and unintended consequences of established transportation networks.

A regression of Travel Time on Income using the logarithmic transformation of each of these variables allows for calculation of elasticity and indicates that for each 22% increase in income, there is a corresponding 15-minute increase in travel time. Thus, in the Bangalore Household Survey, as wealth increases, the distance traveled increases ($P<0.001$) (Table 4). However, income explains only 3% of the variation in travel time (adjusted $R$-squared = 0.03), indicating that there are potentially other variables that have much higher predictive value than income. This reinforces the findings previously discussed and highlights how income is linked less with travel patterns in India than in the western context.

Table 4: Commute Time by Income

<table>
<thead>
<tr>
<th>Row Labels</th>
<th>Up to 50 thousand</th>
<th>50 thousand to 2 Lakhs</th>
<th>2 to 5 Lakhs</th>
<th>5 to 7.5 Lakhs</th>
<th>7.5 to 10 Lakhs</th>
<th>More than 10 Lakhs</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 to 30 minutes</td>
<td>29%</td>
<td>41%</td>
<td>35%</td>
<td>47%</td>
<td>32%</td>
<td>80%</td>
</tr>
<tr>
<td>30 to 45 minutes</td>
<td>15%</td>
<td>16%</td>
<td>28%</td>
<td>22%</td>
<td>30%</td>
<td>7%</td>
</tr>
<tr>
<td>45 mins to 1 hour</td>
<td>7%</td>
<td>6%</td>
<td>10%</td>
<td>12%</td>
<td>16%</td>
<td>7%</td>
</tr>
<tr>
<td>Less than 15 minutes</td>
<td>44%</td>
<td>31%</td>
<td>18%</td>
<td>16%</td>
<td>9%</td>
<td>7%</td>
</tr>
<tr>
<td>More than 1 hour</td>
<td>4%</td>
<td>6%</td>
<td>8%</td>
<td>3%</td>
<td>14%</td>
<td>0%</td>
</tr>
<tr>
<td>Grand Total</td>
<td><strong>17%</strong></td>
<td><strong>47%</strong></td>
<td><strong>10%</strong></td>
<td><strong>3%</strong></td>
<td><strong>1%</strong></td>
<td><strong>0%</strong></td>
</tr>
</tbody>
</table>
Figure 7: Travel Time by Income

Figure 8: Commute Mode by Income
When Travel Time is regressed on Income stratified by bracket, however, all $P$ values exceed 5%, indicating that a finer gradation than above or below the median household income is not statistically significant. This may be a result of the lack of predictive power of income on travel time in the Indian context, or a result of the wide variation in size of each income bracket (i.e., only 5% of the surveyed population fell within the highest three income brackets).

**DISCUSSION**

1. **Monocentricity vs Polycentricity in Bangalore**

   Given that both of our methods indicated a lack of monocentricity within the city of Bangalore, I determined that the city is, in fact, polycentric. This results in a mismatch between the ongoing Bangalore Namma Metro project and what current transportation practice suggests fits best with the spatial structure of the city of Bangalore. While metro may be the best solution for cities with dominant central business districts, this is quite unlikely to be the case here. As such, provision to increase the current metro beyond the existing footprint should no longer be investigated.

   Accessibility appears to be high throughout the city, when measured by commute times to employment. The reported values for travel time indicate that most people are seeking employment within a 30-minute radius of their residence. Given the levels of congestion in the city, this may be as short a commute as 3 miles, trips which could be captured by other modes if they are provided and improved. However, there appears to be some mismatch between employment and housing, at least in the central city. This calls for additional analysis of the jobs-housing balance within the city, which if properly balanced, could result in an increase in aggregate accessibility.
2. **Gender and Travel Patterns**

Researchers have found important differences across gender for both travel time and mode. As Anand and Tiwari (2005) wrote, “women spend more time traveling on slower modes of transport.” The quality of life implications for low-income households with both parents working are worthy of consideration for planners in all fields. While in the past, women found ways of accessing work near their homes (Anand 2005), as impoverished Indian households are forced to the edges of cities through programs similar to Urban Renewal in the U.S. (Anand 2005, Doshi 2012), their increasing travel times reduce time for reproductive, productive, and leisure activities. Due to the share of reproductive responsibility placed on women, and the mode shares in which they engage, women “will only find work within 1 hour of commuting time” (Anand 2005). As Anand also addresses, a lack of mobility “causes poverty by affecting [women’s] access to livelihood opportunities.”

The public transport facilities in India have been reported as being “…insufficient and dismal” (Ashalatha 2013). Ashalatha reports that women in Thiruvananthapuram prefer buses even over cars. This disparate impact is especially important in locales where women are increasing their involvement in the professional workplace, and require higher degrees of accessibility in order to meet all of the demands that are placed on their time (Fatima 2014, Hanson 2010). Women have been reported to make shorter work trips, and thus reduce their accessibility to jobs (Gordon, 1989). The issue surrounding this has been attributed to various reasons: income, occupation, marital and family status, and mode. However, Gordon (1989) found that when controlling for all of these effects, the difference in travel patterns were still present in the United States. Gordon did note that as family size increased, the portion of time that is allotted to work-trips decreases. As a result of this, the commuting patterns for women are not the same as men, especially in the Indian context, with larger households and more variation.
between mode shares (Anand 2005). Because of the effect of gender on travel patterns, the need to understand how women are using the transportation network in Bangalore is also important.

3. Income and Travel Patterns

Accessibility to employment has been linked to income levels (Nelson 1992). As such, the transportation infrastructure in a city should be designed in such a way that individuals can access the employment opportunities which match their skill sets. In an autocratic American context, this almost requires every worker to have a personal vehicle, while in the Indian context, it frequently requires the residence be within a walkable distance. Because of this locational requirement that is specific to income levels, further investigation of travel patterns by income is warranted.

Transportation patterns are especially important in lower income cities, where the costs of transport are frequently a higher percentage of personal wealth. In parts of India, up to 50% of the employed population report no commuting expenses, reinforcing the large modal share of walking (Anand 2005). Like this analysis, past studies have been based upon cross-sectional studies, and thus deserve reanalysis in a rapidly urbanizing region, which is currently building transportation networks. As indicated elsewhere in the literature (Chen 2011) perhaps more important than cost is the amount of time that is spent traveling for households with above average incomes. However, some authors report a bias towards a car culture, with the private vehicle being a symbol of privilege (Ashlatha 2013, Kim 2014.)

According to Sabapathy (2012), “[t]here is very little information available on factors affecting travel distance in the context of India.” Sabapathy makes a call for “further studies that include multiple firms randomly selected for each of the [work] sectors… [with] factors that affect travel behavior such as work place distances of workers… households… and schools be considered.” This is particularly true in light of urbanizing populations, coupled with increasing rates of motorization. If we are to properly plan for transportation needs in India’s megacities, we must first understand the travel patterns. Badami (2004)
confirms a premise previously set forth by Tiwari and Singh (1980), finding that bus-riders from the outskirts of Delhi with low monthly incomes spend more than 25% of their income on daily commuting. This quantification of travel time is very important for a city’s future growth and has never been calculated for Bangalore.

CONCLUSIONS

Using a unique travel behavior dataset for Bangalore this paper tested for differences in travel patterns by household location, gender, and income. I found that Bangalore has become a polycentric city, with transportation patterns across the city appearing to be independent of distance from the hypothesized geographical center. As a result of this polycentricity, transportation design, pedestrian network allocation, and potential delegation of the bus network as a feeder to the metro system should be further investigated.

As demonstrated above, women are more likely to have a shorter commute, and less likely to travel by personal motorized vehicle. As such, the transportation demands placed on the network by women are vastly different from those of men. Neglect of the bus network will disproportionately affect women, as will a lack of investment in safe pedestrian paths. Investment in these two areas will not only result in a higher level of accessibility for those who currently use them, but can draw individuals from more resource-intensive modes of transit (Chen 2011).

With the income breakdowns in our sample, where only 5% of reported trips are made by individuals from households making more than 5 Lakhs Indian Rupees (INR) per year, one must be careful drawing conclusions. However, the large sample of the 50 thousand to 2 Lakhs INR portion lends itself to confidence for the portion of the population within that income bracket. Our data show that the majority (69%) of trips are less than 30 minutes in duration, indicating that any increases in accessibility beyond this point are likely to be muted. The two-wheeler currently dominates almost all other modes, with the
notable exception of walking trips for the subjects in the lowest two income brackets, whose trips made up 84% of our sample! As a result, the largest positive effect for low-income populations in Bangalore would be investment in a safer, more highly-connected pedestrian network. However, given that the prevalence of Bangalore Metropolitan Transport Corporation (BMTC) bus trips by both income brackets was significant (28%), increased spending on a bus network would also greatly improve mobility for the urban poor.

For a developing country, where there are still large mode shares in public transit and walking, appropriation of funding for transit that serves the majority of the people rather than the automobile owners would appear to better meet the goals of transit planners in Bangalore. The findings of this report indicate that more consideration should be given to modes of transit other than the automobile, particularly walking. Additionally, spending on the provision of a bus network providing public access has the potential to stave off much of the adoption of motorized two-wheelers (Chen 2011). While this investment is likely to be expensive, the alternatives require greater road networks as well as an increased consumption of fuel by individual motorized transit and potentially a greater consumption of time due to increased rates of congestion.

In his 2008 paper on Metro Rail in India, Mohan states that “There is still no clear vision... about what will make Indian cities better places to live in as far as mobility and access are concerned.” While this paper does not directly address his concerns, I have contributed a deeper understanding of travel patterns in Bangalore, and by extension, cities in the developing world that have grown rapidly in recent decades. Connecting citizens to a CBD through rail is logical in a monocentric city, but provides less value in a polycentric city, unless the nodes themselves are connected. As such, the proper allocation of transportation funds for Bangalore may be to increase the safety and aesthetics of walking infrastructure, and improving the accessibility to bus routes and times for individuals in all income brackets.
If Bangalore continues to evolve many cities within a city, the metro will not be a viable solution, and even BRT will be difficult to properly fit into the urban fabric, being both too expensive to create new lines as well as lacking clear destinations which would result in low ridership. However, the strengthening of the sidewalk network for short trips as well as increased spending on a comprehensive bus network, increasing both frequency and coverage, will allow for the large number of relatively short trips (less than 30 minutes) to be accomplished with the least congestion, emissions, and expense. If Bangalore chooses not to address the transportation needs of the city, it will continue to require additional roadways to keep up with the exponential growth in private motorized transit, particularly motorcycles and motor scooters. In short, the current path leads towards additional emissions per capita, and an urban fabric which requires individual transit to access amenities.

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Works Cited


