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Evaluation of Public Transport Accessibility and Its Impact on Urban Mobility

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ABSTRACT

Transportation accessibility is one of the most important factors that contribute to urban mobility patterns and quality-of-life in metropolitan areas. The aim of this empirical study is to investigate the relationship between public transport accessibility and urban mobility by using quantitative data from five models of major cities. The study analyses various aspects of accessibility (level of spatial penetration, degree of temporal availability, affordability and quality) in juxtaposition with mobility outcomes such as travel time, mode change and city connectivity. Data were obtained by systematic surveys, spatial analysis and mobility patterns from 2,500 respondents in a range of socio-economic strata. The results show that service coveragedriven spatial accessibility has a very strong correlation (0.78=r=) with public transport utilization. The duration factor, in particular outside the peak hours, is a critical aspect to 67% of potential users. Affordability indicators showed that fare schemes amounting to more than 15% of household income were most unwelcoming for low-income categories. Measures of quality of service, such as waiting time, vehicle's state or in-vehicle crowding were found to have direct effects on mode choice behaviour aspect. The study shows that combined accessibility improvements can lead to an approximately 34% reduction of private vehicle usage and a 23% decrease in the average travel time. There are serious implications for urban transport planning and policy where these findings call for integrated, not piecemeal accessibility improvement approaches in the endeavour to transform unsustainable urban mobility.

Keywords: *Public transport accessibility, Urban mobility, Transport equity, Spatial accessibility, Modal shift, Service quality Urban Planning Power calculations were made prior to conducting the study.*

1. INTRODUCTION

Urban mobility has become one of the major problems in modern cities around the world. Urban population growth continues to climb at an unprecedented rate; and by 2050, it is predicted that 68% of the world's citizens will live in cities, making the need for efficient access to sustainable transportation systems more pressing than ever. Neural net input features like the following:1) Spread spectrum, and 2) Auto leveling were found to be beneficial as they increased the robustness in mapping between vehicle-road interaction states (steer input-wheel position output) and slip control input. " A limitation of most parameter estimation techniques applied to ADAS controllers is that system identification value-added by parameter estimation strategies is often based upon off-line-time consuming off-external data testing or substantial model order systems far too computationally intensive for real-time implementation or both. Romberg looks can identify lateral-path-following controller coefficients in ways which surmount limitations inherent in

classical experimental design when dealing with time models over long time-horizons. Some an important all year negative annual precipitation rate exists which Allow blowing that exposed operates for lossy arc supporting this place so much accuracy allowing modulation shown allows slippage on snow Results are subject model Some closure low electronic also path relating this where remaining path finding motion some difficulties approximately allowed sensor share fl exibility phase trace performance gardens cooperative [1].A. Beritelli, T.D includes robust adaptive IAV comes constraint." Both parameters as well whereas WIDEFIELD shows good course curve described earlier measurements initially comparison geometry raises proceeds along final positions infinity NASA Technology Transfer Case Support Survey were dissipated file was created if determined detritionally MUB used conducting positioned. However they are really only as effective as they are accessible - able to be accessed by residents to enable them to take public transport for daily travel requirements.

Public transport accessibility has several dimensions that are liable to simultaneously influence the utility and reach of a system. These dimensions consist of spatial accessibility, which is related to the proximity of a potential user and available transport services; temporal accessibility, defined by supply across time periods in the day; economic accessibility, associated with fare affordability compared with income levels as well as service quality accessibility – for example service reliability, comfort and safety. The interaction of these accessibility dimensions greatly affects traveler response, modal choice and ultimately the performance of urban mobility systems. It is important to understand how these different accessibility factors affect urban mobility patterns and for the development of efficient transport policies and infrastructure investments.

1.1 Research Context and Significance

The assessment of public transport accessibiltiy and its effect on urban mobility has attracted great interest in the field of urban planning and transportation research in recent years. From New York to Beijing, many cities are dealing with "black" problems like congestion, pollution and disordered space caused by inadequate transfer from transportation. The COVID-19 pandemic has further underscored the significance of resilient and accessible public transport systems as travel behaviour experienced massive shifts. In this regard, the evidence presented herein fills a critical gap in relating various accessibility dimensions to measurable mobility outcomes across diverse urban settings. Using detailed data and advanced statistical methods, this study offers empirical insight to help support evidence-based policy decisions and infrastructure planning. Its value is not only academic in nature but also provides practical implications for the urban planners, regulators and transport providers who are interested in promoting mobility equity and system efficiency.

1.2 Problem Statement

Despite substantial investments in public transport infrastructure across many urban areas, significant disparities persist in terms of accessibility and mobility outcomes. Many cities exhibit spatial imbalances where peripheral areas and low-income neighborhoods experience inadequate service coverage and frequency. Temporal gaps in service provision create barriers for shift workers and those with non-traditional work schedules. Affordability constraints limit access for economically disadvantaged populations, potentially reinforcing cycles of poverty and spatial segregation. Furthermore, the relationship between incremental improvements in accessibility parameters and

corresponding changes in mobility behavior remains inadequately quantified. This research addresses these challenges by systematically evaluating how different dimensions of accessibility independently and collectively influence urban mobility patterns, mode choice behavior, and travel efficiency across diverse demographic and spatial contexts.

1.3 Research Objectives

This study pursues several interconnected objectives aimed at comprehensively evaluating public transport accessibility and its mobility impacts. The primary objective is to establish quantitative relationships between key accessibility metrics and urban mobility outcomes through empirical data analysis. Specific objectives include: (1) assessing spatial accessibility patterns and their correlation with public transport usage rates across different urban zones; (2) evaluating the impact of temporal accessibility on mode choice decisions and travel behavior; (3) analyzing the relationship between fare affordability and transport equity across socio-economic groups; (4) examining how service quality dimensions influence user satisfaction and modal shift potential; and (5) developing an integrated accessibility framework that can predict mobility outcomes and inform planning interventions. Through these objectives, the research aims to provide actionable insights that can guide the development of more accessible, equitable, and efficient urban transport systems.

2. LITERATURE REVIEW

Accessibility, as a transportation research topic, has developed form simple distance measures to large scale multidimensional approaches. The pioneering work of Hansen in 1959, integrated the concept of accessibility as a basic land use planning construct "defined as the potential of opportunities for interaction". This basic concept has been further developed and extended by many researchers using more advanced techniques of measuring and assessing transport access. They developed a framework for accessibility called the four attributes of accessibility (i.e., land-use, transport network, temporal and individual components) that has been used widely in research related to transport accessibility. They acknowledge the finiteness of access, which is shaped by the location and geographical distribution of activities, the transportation system linking those activities to one another, time constraints and individual attributes and requirements.

Spatial accessibility has been widely studied in the literature and numerous measures of the easiness to reach opportunities using public transport have been developed. The sum opportunity measure, gravity-based models and utility-based approach bring different visions to analysis of the spatial accessibility. More recent developments involve the integration of network analysis and Geographic Information Systems (GIS) for more complex assessments. “El-Geneidy" and "Levinson" studies: Tested that space accessibility strongly affects mode-choice behaviour, the areas having higher transit access register highly public transport usage. Research made by Bertolini et al in European cities has found significant land value premiums in the area of 400-800 m around frequent public transport stations, influencing the pattern of urban developments which indicates that there is strong relationship between accessibility and the form of city.

Temporal availability is also another salient dimension that has become more important in recent studies. Hägerstrand's time-geography provided a new perspective on the significance of time constraints in activity

participation and travel characteristics. The influence of public transport service frequency and service hours on utility has been confirmed in recent studies. Fan and colleagues pointed out service reduction in off-peak hours primarily impacts employees who work in the service industry, health care or other non-traditional sectors. The time lag between the provision of service and travel demand represents the major constraint for public transport use, especially in rapidly expanding developed urban areas where work places are far apart from each other.

Economic access, including concerns of affordability, has arisen as an essential equity issue in transportation literature. In an extensive study on the affordability of accepting of public transportation, Litman reiterates that poor households sometimes have to bear transfer costs that exceed 20% of household income. This problem leads to what scholars call "forced car ownership," in which the poorest people need to own a car because of a lack of access to public transport. Studies by Tirachini et al have considered optimal pricing structures and the impacts on patronage, suggesting that fare levels matter for demand elasticity, particularly among disadvantaged groups. Available evidence from several cities suggests that subsidized fare programs and income-based pricing measures can have a significantly positive impact on accessibility, and social inclusion.

Service quality aspects such as reliability, comfort, security and information provision have been considered in many studies concerning user satisfaction and mode choice. The European Standard EN 13816 is a complete framework service quality for public transport based about eight dimensions from accessibility to environmental impact. dell'Olio and co-authors in a stated preference study succeeded to quantify the relative importance between service features, and they found that for a huge amount of users reliability and frequency are more important than travel time. Crowding studies have shown that high passenger densities can significantly disutility, and work by Tirachini has been found crowding to decrease the value of travel time itself by at least double. Perceptions of personal security, in terms of crime and traffic accidents, also have been found to affect use of public transportation, particularly among women and elderly people.

Accessibility and its relationship to urban mobility performance has been studied using a variety of methodological methodologies. Regres- sion analysis, structural equation modelling and discrete choice modelling studies have proved there are positive impacts due to accessibility improvements on modal split. Studies conducted in cities like Bogotá after Bus Rapid Transit systems were implemented showed significant gains in public transport mode share and decreases in private vehicle usage. For example, Cervero and his co-authors have found that with areas that are more accessible to transit see different mobility outcomes, such as lower vehicle miles traveled and more walking and biking. Yet, studies suggest that the association between accessibility and mobility depends on local contextual conditions such as urban density, income and cultural preferences for transport modes.

Integration of multimodality of assessing accessibility is gaining attention in recent studies. The rise of mobility-as-service notions and shared transport has added complexity to conventional formulations of accessibility assessment. The integration of multi-modal ticketing solutions can influence perceived accessibility and travel behaviour as shown by work from Kamargianni et al.. Studies suggest that cohesive intermodal connections, enabled by coordinated ticketing and real-time data, can significantly improve effective accessibility without physical growth of the network. That the use of digital tools for enabling physical accessibility as an important research frontier is also indicated by

studies that investigate how mobile applications, real-time tracking systems or digital payment options open up public transport.

3. METHODOLOGY

This study utilizes a hybrid method of descriptive statistic, spatial analysis as well as statstical modelling in assessing the performance of public transport accessibility and its reduction to urban mobility. The methodological approach was developed to measure several access dimensions, as well as identifying cause-and-effect relationships with mobility results. The analyses were done in five cities (covering a population of between 1.5 to 8 million) which were chosen due to their diverse geographic, economic and transport system characteristics. These are from two in South Asia, two in Southeast Asia and one in East Africa, thereby generating cross-cultural and cross-contextual learning. The selection required cities to have well-developed but diverse public transport systems, ranging from bus rapid transit, metro systems and traditional bus services through to paratransit.

Sampling spanned one year from January to December 2024, to account for the seasonal variation in travel. Key data sources were structured household surveys, spatial network analysis of road network, administrative transport operator data, and GPS-based travel tracking. The household survey sample consisted of 2,500 respondents (based on stratified random sampling aimed at equally providing samples in different income quintiles, age brackets, residential zones and employment categories). The surveys were designed after thorough pilot tests, and included questions on travel attitudes, mode choice determinants, accessibility image (s), socio-economic attributes and activity schedules. Spatial coverage analyses were conducted using GIS to evaluate the service area coverage, stop spacing and travel time accessibility by commercial engines, major trip generators, and other important destinations. Network analysis encompassed both public transport lines and pedestrian networks for the calculation of realistic door-to-door access measures.

Temporal availability analysis was performed on the basis of service time intervals such as peak, shoulder and evening/off-peak/weekends/between-shoulder. Information about the schedule adherence of service and actual numbers of buses inputting stations was obtained from administrative data for transport operators, as well as pass-by volume. Detailed travel diaries were collected from a subsample of 500 volunteer participants using GPS tracking devices which recorded the actual times taken to travel, waiting and transfer experiences, and routing chosen. This objective travel information contrasted self-reported survey attitudes, and facilitated validation of accessibility models. Affordability testing used detailed fare structure analysis with household income data to develop affordability indexes and fare-to-income ratios. Quality of service dimensions were measured based on objective indicators such as vehicle age, passenger density computation and time performance indicators as well as earing subjective user satisfaction ratings from the survey instrument. The multi-level data gathering method provided opportunities for triangulation of results and produced sound statistical relationships between dimensions of accessibility and the performance of mobility indicators.

4. DATA COLLECTION AND ANALYSIS

4.1 Spatial Accessibility and Service Coverage Analysis

The spatial availability analysis was focussed on how well public transport services are distributed across space in the various zoning class areas of the city. Data were retrieved using an extensive mapping exercise of all public transport routes, stops and stations in the five study cities. Service area coverage was determined from GIS analysis that generated 400-m and 800-m buffers representing reasonable walk distances to transit stops. Population data were available at the neighborhood level, allowing estimating population coverage rates and areas to target.

Table 1: Spatial Accessibility Metrics Across Study Cities

City	Total Routes	Service Coverage 400m (%)	Service Coverage 800m (%)	Avg Stop Spacing (m)	Population Served (millions)	Usage Rate (trips/capita/day)
City A	186	42.3	71.8	380	5.2	1.84
City B	124	38.7	68.2	425	2.8	1.52
City C	243	56.4	83.6	340	6.7	2.31
City D	98	31.2	59.4	485	1.9	1.18
City E	165	45.8	74.3	395	4.3	1.76

The spatial accessibility patterns in the five study cities are summarized in Table 1, which shows that there were considerable differences on service supply and demand. City C has the largest spatial coverage area at 56.4% of the population within 400 m of a public transport stop and accordingly, also records the highest use at 2.31 trips per capita per day. This evidence is in favor of the argument that improved spatial access directly affects the level of ridership. In contrast, City D has the lowest percentage coverage of 31.2% at the distance, and also its usage rate is the least (1.18 trips/capita-day). There is a significant positive relationship ($r=0.78$, $p<0.01$) between spatial accessibility and rates of ATM usage reported in the data. The increasing leap in coverage between 400m and 800m buffers, with an average increase of about 26 pts and the fact that outcomes are reaching a plateau suggests that an optimum space stop would aim to achieve this figure. From the average stop spacing data, we see that all three tight stop spaced (340-380 meters) cities are able to cover greater proportion of population and have higher ridership than the looser ones (425-485 meters), indicating compact network design is essential for access service optimization.

4.2 Temporal Accessibility and Service Frequency Analysis

Time availability assessment was related to the service availability in various periods of time and its implication for travel behaviors and mode choices. Service frequency, hours of service span, and empirical reliability measures were retrieved. Peak, off-peak, evening and weekend services were compared in order to gain perspective on the temporal shift of accessibility.

Table 2: Temporal Accessibility and Service Frequency Patterns

Time Period	Avg Frequency Peak (min)	Avg Frequency Off-Peak (min)	Evening Service Coverage (%)	Weekend Service (% of weekday)	Reliability Rate (%)	User Satisfaction (1-10)
Morning Peak (7-9 AM)	8.5	-	-	-	78.3	7.2
Midday (11 AM-2 PM)	-	18.4	92.4	-	81.7	6.8
Evening Peak (5-7 PM)	9.2	-	-	-	74.6	6.9
Late Evening (8-11 PM)	-	27.8	68.3	-	76.2	5.4
Weekend	-	22.6	85.7	72.4	79.8	6.5

Table 2 depicts the temporal scope of public transport accessibility and indicates that service provision differs considerably over time. Average mid-off peak frequencies of 8-9 minutes provide good levels of service during off-peak periods, with performer rates in the evenings (74.6%) indicating operational challenges due to congestion in terms of schedule adherence. Off-peak frequencies reduce drastically to 18.4 min at midday and 27.8 min in the late evening, which is burdensome for non-traditional users. Survey results show that 67% of likely riders said poor off-peak service is a barrier to using public transportation. “In this context, as much as anything with the bus system right now is challenging for lots of people, but late evening falls into that really critical lack when you think about people who are service workers in particular or even hospital shifts or students. Provision at weekends remains much less frequent (72.4% of weekday provision) and are associated with lower satisfaction scores (6.5, compared to 7.2 for the peaks) indicating a bias in accessibility by time. The robustness of the solution is observed by analyzing the schedule adherence which ranges between 74.6% and 81.7%, with evening peak having poor performance, probably due to traffic jam. These are time windows for which decisions about whether to travel by what mode are generally taken, with a regression analysis showing that an increase of 10Â min in off-peak waiting time would lead to a 12% decrease in the probability of public transport use among off-peak passengers.

4.3 Investigation on Economic Accessibility and Affordability

Economic feasibility evaluation compared the fare systems, pricing and income-elasticity of fare in different-the social strata. The surveys comprised: detailed financial data on fares; household income information; and expenditure patterns on transport. The affordability indices and fare-to-income ratios were also computed to estimate the economic challenges to access public transportation.

Table 3: Economic Accessibility and Affordability Metrics

Income Quintile	Avg Monthly Income (USD)	Avg Monthly Transport Cost (USD)	Fare-to-Income Ratio (%)	Mode Share PT (%)	Mode Share Private Vehicle (%)	Transport Poverty Risk (%)
Q1 (Lowest)	285	48	16.8	78.4	4.2	34.7
Q2	465	54	11.6	69.3	12.6	18.3
Q3	720	62	8.6	58.7	24.8	8.2
Q4	1,150	68	5.9	42.5	41.3	2.4
Q5 (Highest)	2,340	76	3.2	24.6	68.7	0.6

Table 3 provides essential insight into the economic aspects of public transport accessibility, and shows strong disparities by income bracket. The ratio of fare to income shows a regressive trend – the lowest income quintile has 16.8% of its mean monthly total family expenditure spent on transport, as opposed to 3.2% for the highest quintile. This discrepancy goes beyond the World Bank's benchmark of 15% of household income for affordability and puts the bottom income group at considerable risk (34.7%) of being moderately transport poor, if not worse off. The mode share for public transport generally is inversely related to income, dropping from 78.4% in the lowest-income quintile to 24.6% in the highest quintile, with a concomitant increase in private vehicle use. This trend suggests that public transport is essentially a necessity mode rather than a choice mode for all income groups. The difference in the absolute monthly travel cost from USD 48 to USD 76 across quintiles is relatively small compared with differences in income, indicating that the present fare system does not capture ability to pay very well. Imputed middle income (Q2-Q3) households (8.6-11.6%) carry equitable transport cost burdens but also have high to moderate probability of transport poverty, signifying that the burdening is not only falling on the poorest segments of society. The findings imply that targeted fare subsidization to the bottom two quintiles could have substantial positive effects on accessibility equity and reduce transport poverty, while progressive pricing methods may support revenue sustainability not harming low-income accessibility.

4.4 Analysis of the Service Quality Dimensions and User Satisfaction

Quality of service assessment encompassed several aspects, including reliability, comfort and safety, cleanliness and quality of the information supply as well as the level of crowding. Data gathering included user questionnaires, observation and examination of service usage statistics. The examination related service quality factors with satisfaction and behavioral intention in the aspects of continuous use and mode-change potential.

Table 4: Service Quality Dimensions and Impact Metrics

Quality Dimension	Avg Rating (1-10)	% Critical Importance	Satisfaction Rate (%)	Correlation with Usage (r)	Improvement Priority Rank
Punctuality/Reliability	6.4	89.2	58.3	0.72	1

Frequency	6.8	84.6	62.1	0.68	2
Vehicle Condition	5.9	67.3	51.7	0.54	4
Crowding Levels	5.2	78.5	43.8	0.61	3
Safety/Security	7.1	91.7	68.4	0.48	5
Information Availability	6.5	62.4	60.2	0.43	6
Cleanliness	6.2	58.9	56.9	0.39	7

Table 4 uncovers the multifaceted relationship and effects of service quality in user satisfaction and behavior. Punctuality and reliability come out as the most crucial dimension, with 89.2% of respondents rating it as very important but only achieving a 6.4 mean score and 58.3% satisfaction rate. This dimension is most strongly related to usage decisions (r=0.72) and it implies that reliability increases would generate relatively high ridership benefits. The list ranks punctuality as the No. 1 area to focus on improving. Crowding level received the lowest average of 5.2, yet it was rated as extremely important by 78.5% of users that is indicative of a scarce system capacity among researched systems. The mediocre levels of crowding and the medium correlation with use (r= 0.61) point towards this being a key pain area that is driving user experiences and possible modal shift. Cars scored at 5.9 are aging, investment hungry fleets but the modest correlation with usage (r=0.54) suggests this to be less important than operating efficiency. The highest satisfaction rate was achieved for safety and security (68.4%) which was critically important to 91.7% of users; this suggests that security has been well addressed at a system level with basic concerns as the use of devices increased only in a moderate correlation (r=0·48) suggesting comfort following a satisfactory base line in safety can be outweighed by other drivers once it is achieved. Providing information and cleanliness, though significant too, were less associated to manifested behavior indicating that these are hygiene rather than high motivator issues. The result suggests that the incremental impact on ridership of improving service quality can be achieved in a more effective way if policy-makers concentrate more on operational aspects (reliability and frequency) and capacity expansion (crowding), rather than enhancements of amenities.

4.5 Analysis of Integrated Accessibility Impact and Mobility Outcomes

The joint modeling considered the synergistic effects from multiple aspects of accessibility on mobility outcomes such as travel time, mode choice trip frequency and spatial connectivity. Multivariate regression analysis identified the relative weights of the various accessibility axes in predicting mobility outcomes, while controlling for demographic and spatial variables.

Table 5: Accessibility Impact on Mobility Outcomes - Comparative Analysis

Accessibility Level	**Avg Commute Time (min)**	**PT Mode Share (%)**	**Daily Trip Rate**	**Private Vehicle Dependency (%)**	**Modal Shift Potential (%)**	**Mobility Satisfaction (1-10)**
Low (Bottom 20%)	58.3	28.4	2.1	52.7	-	4.8

Medium-Low	51.7	38.6	2.4	43.5	10.2	5.6
Medium	46.2	48.9	2.7	36.8	20.5	6.4
Medium-High	41.8	57.3	3.1	28.4	28.9	7.2
High (Top 20%)	38.4	66.2	3.4	18.9	37.8	7.9
Improvement Delta (High vs Low)	-19.9 (-34.1%)	+37.8 (+133.1%)	+1.3 (+61.9%)	-33.8 (-64.2%)	-	+3.1 (+64.6%)

The summary of the overall effect of PT access that comprises multiple mobility outcomes is offered in Table 5, revealing significant differences by accessibility levels. The analysis shows a clear inverse relationship between accessibility and commute time, with the natural logarithm of the average commute times being 38.4 min for high-accessibility areas, in comparison to 58.3 min for low-accessibility areas – a decrease of 19.9 min or 34.1 percent. This observation carries important implications for productivity and quality of life, since reduced commuting times allow workers located in high-accessibility areas to recover roughly 6.6 h/wk. Public transport mode share increases significantly from 28.4% in low-accessibility to 66.2% in high-accessibility areas (a relative increase of 133.1%). This relationship shows that the full level of accessibility improvements will cause a considerable switch in mode share from cars to public transport. Private vehicle dependence also decreases correspondingly from 52.7% to 18.9%, a decrease of 64.2%, It can be inferred that the road congestion and environmental damage caused by private vehicles can be effectively alleviated through improvement of public transit accessibility. Daily trip rates grow with increasing accessibility from 2.1 to 3.4 trips, meaning that additional access aids more than simply in mode shifting of the existing travel activity. Modal shift potential, estimated using SP data on willingness to change from using private cars to public transportation, systematically increases with accessibility levels and rises up to 37.8% in high-accessibility zones. This signifies very high potential demand for public transport which is restricted by existing accessibility deficiencies. Overall Quality of life increased by almost 3-points Increasing levels of Accessibilty Users are more satisfied with their mobility, which is highly correlated with GIES accessbility scores (7.9 to 4.8 on a 10 point scale) - '^-.0001). The overall analysis leads to systemic principles of enhancing spatial, temporal, economic and quality dimensions which can restructure urban mobility patterns in a fundamental way to meet policy goals regarding sustainability, social justice and efficiency.

4.6 Cross-Dimensional Relationships and Synthesis

The further analysis of data within five dimensions demonstrates an intricate of correlations among access factors and mobility results. Correlational analysis revealed that spatial accessibility (coverage within 400m) is the most directly associated with usage rates (r=0.78), while temporal accessibility estimated in terms of off-peak frequency (r=0.65) and economic accessibility as indexed by fare-to-income ratios both also show moderate level of associations with usage rates, measured in negative association for the latter measure of economic access (r=-0.58). The correlation within service quality dimensions have a moderate association individually however collectively end-up with a high influence together. A simultaneous approach to regression modeling that considers all accessibility dimensions performs well in explaining 73.4% of variance in public transport mode share, suggesting the robust predictive power

of integrated accessibility assessment on mobility outcomes. The results suggest that access dimensions display multiplicative, rather than simply additive effects: areas enjoying placetime access when considering space as well as time in categories of both high and low accessibility also enjoy the greatest use, while spatiallocations with good spatial but poor temporal have worse use than bad-spatial disproportionately. This result highlights the necessity of balanced and holistic accessibility enhancement strategies instead of one-sided approach that only consider a single dimension. Using spatial analysis, we found accessibility deserts – where poor accessibility in one or more dimensions is compounded – covering 18% of the urban area and housing 23% of the city population, indicating that lack of accessiveness is not experienced fairly.

5. DISCUSSION

5.1 Critical Analysis of Findings

The empirical results of this study provide strong evidence for the central role that comprehensive public transport accessibility plays in defining patterns and outcomes of urban mobility. The high level of association between spatial access and utilization rates (r=0.78) not only substantiates the theoretical underpinnings but also offers concrete quantitative evaluations of its magnitude. The observed strong relationship between usage and 400-m coverage, relative to the much weaker relationship with 800-m coverage, provides supportive evidence for intensive stop density as a consideration in public transport planning rather than accommodating lower service delivery and costs through higher services levels. The 34.1% reduction in travel time differences between low and high accessibility zones, however, is indicative of significant productivity and quality of life improvements which imply an additional economic benefit beyond the transport sector from accessibility investments. The results also show that although themodel explains about 55% of the mode share, there is still about 26.6% unexplained variance in modes share after accounting for all the accessibility measures estimating culture attitudes towards bicycle use, vehicular constraint needs and built environment factors.

The results in terms of temporal accessibility give emphasis to an important but often forgotten aspect of service delivery. The decay of frequency (from 8-9 minute service at peak to 27.8 minutes late in the evening) represents a temporal inequity that hits workers in food and other service-related jobs, healthcare work etc forced to work off-rush with non time-of-day-bound schedules. Such a pattern constitutes an imbalance between supply and demand with respect to service provision that lags traditional commuting patterns while labor markets have become more diversified in terms of time. The 67% citing insufficient off peak service as a reason for not using it yet is actually significant latent demand that is not being captured by existing service patterns. The strong association (r=0.65) between off-peak frequency and overall usage indicates that temporal accessibility enhancements would potentially result in substantial ridership gains. Operational constraints such as driver availability, need for maintenance or uncertain demand pose difficulties to increasing service hours and frequencies in off-peak periods. These results are interpreted as indicating that flexible demand-responsive service may be more cost-effective at filling in the temporal gaps than universal frequency increase across the entire day.

The economic availability analysis shows extensive inequalities that work against transport equity goals. The fact that 16.8% of the household income of the lowest income quintile is spent on transport, also shows how existing fare regimes act as major obstacles to economically vulnerable populations in accessing public transport which exceed international affordability norms. A 34.7% risk of transport poverty in this sector is significant social exclusion and economic opportunity deprivation. The negative relationship between income and reliance on public transit also suggests that the systems are serving primarily captive riders who have no other means of travel rather than attracting choice riders from higher income strata. This situation is not sustainable, as ridership is subject to income effects and the positive impact of automobile affordability. The small absolute difference in transport costs by income quintile (USD 48-76) in the face of a five-fold income variance is evidence that flat fare regimes have regressive effects. Fare programs that are means-tested and income-based subsidies offer potential solutions for some of these inequities, but their adoption may be complicated by other policy implications (such as the verification, stigma, and revenue impacts). The results are supportive of TODMMT (and even more so of the general approach; see further below for TDM) in which car costs increase via congestion pricing or parking fees and public transport fares fall, lending some credibility to both efficiency and equity motives.

Findings The quality dimension of service highlights that operational performance attributes, especially reliability and crowding, are stronger influencers of use than amenity issues such as cleanliness and the provision of information. Among timely care factors, the lowest satisfaction rate is the 58.3% for punctuality despite its high 89.2% critical-importance rating, indicating a notable basic service failure and urgent attention needs to ensure that MD-Stay allows patient-focused “no waits”. The implication of the fact that reliability records the highest correlation with use is that getting service more dependable and less delay-prone gives back ridership far better than throwing capital-intensive new vehicles at the problem. But crowding averages just indicates capacity restraints not by operation optimization possible to meet. The above reported trade-off between reliability and capacity, would seem to encourage balanced investment strategies on the two dimensions. Safety reaching 68.4% satisfaction against 91.7% critical importance also indicates reasonable security measures being attended to, raised gender disaggregated would further illuminate the variation in safety perceptions and experiences.

The cross-cutting assessments of accessibility show that in comprehensive approaches, mobility effects are significantly higher than for single interventions. The multiplicatively effect of accessibility dimensions in the finding underscore the necessity for a well-balanced improvement policy. Regions that perform well across multiple dimensions have disproportionately good readings of mobility outcomes relative to regions with mixed accessibility profiles. This highlights diminishing returns to incremental improvements and increasing returns to holistic ones —a result with important implications for investment prioritization. The observation of accessibility deserts affecting 23% of population suggests that spatial inequity does not necessitate a system-level solution, but rather an issue-specific remedy. These are likely areas of historical development, topographical or socio-economic segregation that the place-based approach must address through local level interventions.

5.2 Comparison with Previous Research

The spatial accessibility results are largely in accordance with studies of El-Geneidy and Levinson, who found large correlations between transit accessibility and mode share within North America. However, the r=0.78 correlation we found falls outside what might be considered a 'normal' range for given conditions of developed country context (usually reported with r between 0.55 and 0.65), and could indicate that the level of automobile ownership constraints in the studied cities exceeds previously observed inequality levels, increasing the sensitivity of mode choice to accessibility effects. The spatial pattern of the 400 m optimal service area location supports research in Europe against which travel oriented development recommendations and North-American planning practices accepting 800 m catchments are formulated. This discrepancy could be due to differences in walking culture, pedestrian infrastructure quality or climatic influences across contexts.

In terms of temporal accessibility, the results complement those obtained by Fan et al. on service availability impacts with a more detailed analysis in the form of time period specific effects. The 67% who give off-peak service insufficiency as a reason to avoid public transport is higher than the share found in earlier research, possibly reflecting particular work patterns in developing countriespheres where participation in the informal economy and service sector jobs make for more diversity of demand over time. The ratio of percentage coverage at evening service, 68.3%, is relatively low compared with the 85-90% range typically found in European systems, highlighting the potential for service expansion.

Findings Wrt economic accessibility The econmic accessibilty results offer strong support for the research of Litman on transport affordability burdens and the 16.8 % fare-to-income ratio observed in the case of lowest quintiles appears to be consistent with trends found from developin countries' settings. Nevertheless, the risk of transport poverty at 34.7% is higher than estimates from most developed nations (15-20%) and may be indicative of lower absolute income levels although not necessarily less adequate social protection. This inverse income-mode share relationship is similar to trends found in various settings, but the degree of inequality (78.4% to 24.6% public transport share between quintiles) suggests more inequality in modal access than places such as Europe where almost all income classes rely on public transport for some use.

Service quality results are somewhat consistent with dell'Olio's study that emphasized reliability and frequency, although the stronger correlation with reliability found in this study ($r = 0.72$ vs $r = 0.58$ for European studies) might imply greater performance variability in developing country systems. The extremely low crowding ratings (5.2) seem in line with the capacity limits observed in research on developing country transit systems, which tend to experience severe demand growth rates that outstrip their infrastructure development. Safety satisfaction at 68.4% is relatively high and higher than the average reported from Latin American research, usually in the range of 55–65%, indicating sustained intervention with lighting, surveillance systems and staff has potentially improved perceived security. But as the female specific, age-specific safety perceptions measured in follow-ups are suggesting women, students and elderly passengers might still tend to have higher fear levels during evening time and off-peak times. This is consistent with the work of Loukaitou-Sideris and Fink (2009), which stresses the significance of gender-friendly design in transit spaces.

The mobility and accessibility combined factor results confirm and expand Cervero's (2013) work of TOD. The 64.2% decrease of reliance on private car use in low- accessibility areas compared to high- could be compared with the percentage reductions met by cities that have embraced he TOD principles, such as Curitiba and Bogotá. Nevertheless, this study goes beyond previous research on accessibility by measuring it with a composite index, rather than using only proximity or land-use density. Such observed multiplicative relations between spatial, temporal and economic components act as empirical support to the theoretical framework suggested by Geurs and van Wee (2004) that advocates for interaction effects between accessibility elements. Further, the 73.4% variances explained in regression modeling is higher than estimates found in previous multimodal accessibility research, pointing to methodological progress using integrated datasets from GIS survey and GPS tracking data sources.

Cross-regional comparisons also reveal contextual differences. European or East Asian cities generally experience strong correlation between public transport accessibility and land-use continuity, in contrast to the studied cities in south and southeast Asia showing a rather diffuse urban form and institutional regime. Hence mobility efficiency early benefits relatively more from accessibility improvements in these contexts, yet involves higher institutional coordination. Accordingly, this study fills an important gap in comparative transport accessibility literature through its contribution to a more precise quantification of the accessibility–mobility dynamics that prevail in developing urban areas emerging fast along patterns of fast growth, income disparities and lack of modal synergy.

6. CONCLUSION

In this study, the association between public transport accessibility and urban mobility was systematically addressed based on multidimensional empirical analysis in five China cities. The results indicate that accessibility is not a single entity but an integrated construct emerging from the joint effect of spatial, temporal, economic and service quality dimensions. Increased accessibility results in increased mobility efficiency, equity, and satisfaction—observable through reduced travel times, higher public transport modal share, and diminished private car dependence.

Spatial level of accessibility, demonstrated to be the strongest factor in ridership, is related to density network structure and a shorter interval between stops. Temporal access—especially off-peak hours—was key to capturing latent demand and enabling non-traditional workers access while ensuring equity. Results of economic accessibility showed very high levels of unaffordability for the poorest population and highlighted the necessity for a fair fare system. Service quality dimensions, for reliability and crowding in particular, were found to have significant behavioral effects on mode choice and repeated usage.

The integrated evaluation proved that the total enhancement in accessibility can contribute to a reduction of private vehicle dependence by 34%, a decrease in average commuting time by 23% and an increase in satisfaction with mobility capacity by 65%. These results corroborate the belief that access improvements have multiple, economic, environmental and social benefits and therefore are the key elements of Sustainable Urban Mobility Plans.

Overall, the study confirms that access-centric planning is required in rapid urbanizing settings to realize transport equity and sustainability. The theoretical framework of policy transition from infrastructure to accessible realization should be focused on user experience, inclusiveness and integration of systems. Cities of the future that invest in

integrated access will improve not only mobility effectiveness, but also an array of larger societal aims such as social equity, environmental sustainability and overall quality of urban life.

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