Trade-Offs Between Time, Cost, and Uncertainty by Commuters in Hyderabad, India

Stated Preference Survey Assessment

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In developing countries, air quality assessments that include the transportation sector have tended to focus predominantly on assessing technological solutions to problems associated with vehicle pollutant emissions, energy consumption, and greenhouse gases. This focus can be justified on the basis of the favorable cost-effectiveness, political acceptance, and ease of quantifying technological measures—at least in the short term—but unfortunately it often leads to the exclusion of demand-oriented measures. Further, air quality and pollution policy analysts often use assumptions of exogenously determined travel demand patterns, implicitly excluding many opportunities to look at policies oriented toward travel demand as an air pollution control strategy. The air quality impacts of policy measures to influence vehicle kilometers traveled and mode shares, such as bus rapid transit, are investigated. The approach involves developing coefficients with a stated preference (SP) survey that could be used to test policies with a conventional four-step urban transportation model. The main purpose of the SP survey in this study was to examine traveler trade-offs among time, cost, and reliability (measured as uncertainty in vehicle departure time). Some different methods of measuring reliability were tested during the pilot phase of the survey, as were the actual range of parameter values to be tested. Models were estimated using traveler cohorts based on levels of vehicle ownership. In comparing vehicle owners (cars and two-wheelers) with nonowners, owners were found to be substantially more sensitive to time and reliability while nonowners were more sensitive to price. All groups showed notable sensitivity to reliability. Policy implications of these results are discussed, with a notable conclusion being that demand-oriented measures appear to be a fruitful area for further investigation as air pollution control strategies, even when technological measures show strong effectiveness.

In developing countries, air quality assessments that include the transportation sector have tended to have a bias toward assessing technological solutions to problems associated with vehicle pollutant emissions, energy consumption, and greenhouse gases. For example, a series of studies produced by the World Bank as part of its urban air quality management strategy in Asia program (URBAIR) in the late 1990s assessed a number of "abatement" measures for the transport sector, including using unleaded gasoline, improving diesel, introducing low-smoke lubricating oil for two-stroke engines, implementing inspection and maintenance programs, targeting gross emitters, switching fuel, and adopting clean vehicle emission standards. For each city in the program, detailed assessment of costs and benefits were made for these measures. The URBAIR reports also mentioned "improving traffic management" and "construction and improvement of mass-transit systems," although in no case were the costs or benefits of these planning measures quantified. They remained relegated to qualitative afterthoughts (*1*). A similar orientation to technology can be seen in the U.S. Environmental Protection Agency's (EPA) integrated environmental strategies (IES) program (formerly the international co-control assessment program) and in other practical efforts on the issue (*2–4*); planning measures may be mentioned, but are rarely rigorously assessed.

The reasons for this bias are complex: in general, assessments are carried out by air quality experts or experts in automotive engineering and policy, and the role of transportation planners per se has tended to be minimal. The tools and techniques of transportation planning assessment—specifically, travel behavior and demand analysis—have by and large been inaccessible to air quality planners and analysts. This situation has been exacerbated by the poor availability and quality of detailed travel demand surveys, land use information and forecasts, and comprehensive transport network data. It has also been greatly hindered by air quality policy analysts' relative unfamiliarity with these tools and by the often poorly developed state of practice of travel demand forecasting in many developing-country contexts.

As a consequence, air quality and pollution policy analysts working in developing countries often find themselves using assumptions of exogenously determined levels of travel demand, measured as vehicle miles or vehicle kilometers traveled (VKT), as well as of motorization rates, mode shares, and other travel behavior patterns. The policy measures they analyze can change the emissions factors of the vehicles on the road—for example, through new technologies, changes in maintenance and training practices, or policy measures to influence the composition of the vehicle fleet—but they generally must accept VKT as a given. Policies that influence the amount of overall transportation demanded or the modes that travelers choose to take, therefore, tend to be discounted as viable air pollution control strategies.

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Some policy discussions have recently begun to acknowledge and understand the importance of transportation planning, policy, and management as well as technology on pollution and greenhouse gas emissions (*5–7*). However, this increased recognition of the role of transportation planning, policy, and management has been largely descriptive and qualitative; to the authors' knowledge, there has been no concerted effort to try to quantify the effects of transportation planning, policy, and management on future levels of pollution and greenhouse gas emissions in developing countries.

As part of its IES program, EPA has undertaken a study in Hyderabad, India, in cooperation with the Agency for International Development, that attempts to investigate and quantify the air quality impacts of policy measures that try to influence VKT and mode shares, such as bus rapid transit (BRT). The approach involves using a four-step travel demand model in an economic evaluation framework. The core of the modeling framework is the utilization of coefficients developed from a stated preference (SP) survey that was designed to gauge potential traveler response to changes in public transport travel times, reliability, and out-of-pocket costs—the very characteristics that systems such as BRT might introduce. This paper describes the development of the SP instrument, surveying methodology, and some preliminary results.

CHARACTERISTICS OF HYDERABAD

Hyderabad is the capital and largest city in the Indian state of Andhra Pradesh. The city, including the surrounding metropolitan area, has a population of just under 7 million and is one of the fastest growing cities in India, with an economy driven by a strong and vibrant high-technology sector. Population is projected to double in the next 20 years.

Public transport use in Hyderabad has historically been strong, but public transport's predominance has been slipping in recent years. There are about 1.2 million registered vehicles (public and private) in the Hyderabad urban development area (HUDA), with about 75% of those being (predominantly two-stroke) two-wheelers. Table 1 shows aggregated trips and trip mode shares for all purposes in the HUDA.

The relatively low mode share of three-seater and seven-seater auto-rickshaws masks larger impacts on the urban system. Auto-rickshaws in Hyderabad, like two-wheelers, are overwhelmingly powered by two-stroke engines, and therefore are very high emitters of hydrocarbons and particulate matter. Moreover, their size and number and the aggressive driving style of auto-rickshaw operators exacerbate congestion and hinder the speed and reliability of other modes, particularly buses. If the pattern observed in cities in other developing countries in South and East Asia is to be believed, Hyderabad may face a vicious cycle of decline in bus services during the next several years: poor reliability and decreasing speeds lead to decreased ridership as travelers switch to two-wheelers and auto-rickshaws; reductions in revenues and operating budgets for the bus operator; scaled-back maintenance and bus-replacement programs; greater incidence of bus breakdown; worsening reliability; and so forth (*8*).

TABLE 1 Trips by Mode in HUDA

Mode	No. of Trips (millions)	Percentage
Walk	2.47	30.2
Cycle	0.24	2.9
2-wheeler	2.54	31.0
Car	0.18	2.1
3-seater auto rickshaw	0.41	5.0
7-seater auto rickshaw	0.06	0.7
Bus	2.26	27.6
Rail	0.02	0.2
Cycle rickshaw	0.01	0.2
Total	**8.19**	**100.0**

SOURCE: RITES Consulting, LTD, preliminary results of activity-based survey of Hyderabad, administered March 2003 (unpublished data).

Recent indicators from the Andhra Pradesh State Road Transport Corporation, the entity that operates most bus services in the HUDA, suggest that this cycle of decline may come sooner rather than later. In the 6 years between 1996–1997 and 2001–2002, load factors have declined from 75% to 59%. Losses per revenue kilometer increased from 0.64 rupees to 2.17 rupees, an average of 20% per year. While overall service coverage has declined only slightly (3% reduction in passengers carried between 1996 and 2001), the bus fleet has expanded by 23%, meaning it is taking many more buses to carry the same number of passengers, and they are being carried at a decreased level of service. Meanwhile, maintenance will become an increasingly difficult problem. Bus age has hovered just under 7 years old for the past 3 years (only 3 years of data could be obtained), but the rapid acquisition of new buses in recent years has helped keep this down; many of the buses in the fleet are substantially older and will need to be replaced.

How to reverse such trends is a critical policy question. The historic response by policy makers—in Andhra Pradesh and elsewhere—has been to hold down fare levels, often well below actual operating costs (*9*, p. 25). The presumption behind such a policy is that riders are more price-sensitive than time- or reliability-sensitive. The cycle-of-decline analysis above suggests that if this presumption is wrong—and there is anecdotal behavioral evidence to suggest that it may be—the policy may have the reverse effect. A primary purpose of this research, therefore, was to examine empirically how travelers trade off among the attributes of price, time, and reliability.

METHODOLOGY

An SP survey was designed and administered in the HUDA. The purpose of the survey was to try to isolate the effects of time, cost, and reliability on traveler behavior. In addition, researchers hoped to gauge the "inherent" preference for different modes by travelers—that is, composite attributes that capture difficult-to-measure characteristics such as perceptions of safety and comfort. The SP design tests for and isolates these effects by presenting a series of paired travel choices to travelers that manipulate and vary those attributes independently of each other, and then recording which choice travelers indicate they would make, if those choices were available for an actual trip undertaken recently. For simplicity in implementation and analysis, the SP for this project was carried out only for journey-to-work or journey-to-school trips.

Early in the design process, researchers determined that, ideally, the SP design should test for three attribute levels for the three ratio-scale characteristics of price, time, and reliability. Because there is only a finite number of variations in price, time, and reliability that can be feasibly observed and tested in SP (unlike an infinite number of variations in revealed preference methodologies), three is the most manageable number of attributes that can be collected while still revealing some information about the shape of the underlying preference curves, allowing analysts the ability to estimate nonlinear utility functions if need be. To test for the inherent preference for different modes, mode was included as a binary variable (bus or seven-seater auto-rickshaw) that also varied independently of the other variables. Respondents, however, were always given the option of selecting "other" and specifying the mode; thus, the SP design actually tested between three to five modes, depending on the respondent's indicated household vehicle availability.

The resulting full-factorial orthogonal design (54 choice games) was quite large, even after removing clearly dominant choice games. (Some dominant choices were left in the SP during the pilot-testing phase, as a test for rational behavior.) Hensher has suggested that SP respondents begin to fatigue after 10 choice sets, and pilot testing confirmed that threshold (*10*). It was decided, therefore, to use 10 SP games per respondent, one-fourth of the full set of cards with dominant cases removed.

Levels for the various attributes tested, as well as the methodology to derive them, were determined through pilot tests to remain consistent with well-understood best practices in SP; the attribute levels that were presented to respondents were based on the characteristics of the journey-to-work they told us about (*10*). Consequently, interviews began with a conventional travel diary for the previous day (collected for only one working or independent school-age household member, selected at random). Final attribute levels used for cost were 1 rupee less than respondent paid, same as respondent paid, and 2 rupees more than respondent paid. Final attribute levels used for time were 10 min less than respondent's reported travel time, same as respondent's reported travel time, and 15 min more than respondent's reported travel time. Two-person interview teams collected the information; while the first interviewer collected the entire travel diary information from the respondent, the second person calculated the actual values to be presented to respondents. Therefore, respondents were presented with actual values for time and cost, rather than differences from their reported time and cost.

Although the wording of the questions for the price and time attributes was straightforward, the question on reliability proved to be somewhat difficult. Presenting the idea of reliability in a manner that most people understood, yet not confusing it with the concept of waiting time, proved to be tricky. During the pilot phase, a number of potential wording structures were experimented with. The initial wording tested varied the frequency in a week that a certain amount of wait could be expected (i.e., "X times per week, you need to wait 10 min or longer for the bus or auto-rickshaw"). However, the pilot tests revealed that the use of two numerical indicators created a great deal of confusion for respondents.

To overcome that problem, the decision was made to set up the SP game choices with a script that established a posted timetable. All respondents were read the following statement before they began to make their SP choices:

> For the buses that ply the streets of Hyderabad, suppose we were able to post schedules of all the bus routes at the stop you most normally use for the trip you just told us about. . . . For autos, suppose that we were able to organize the services sufficiently such that auto-rickshaw drivers were assigned specific routes and times, and that those times were also posted at the location where you most normally would catch an auto-rickshaw for the trip you just told us about.

The reliability questions themselves were then posed as follows: "Vehicle never leaves more than X minutes after the posted schedule time." In this respect, the reliability questions tested for response to level of uncertainty (in minutes) in departure time. Pilot testing of this wording showed that it was easily understood by respondents. A concern that some respondents would not accept the established premise as plausible did not materialize. No reports of reluctance to accept the premise were received. The set of attribute levels that were used is shown in Table 2. A sample SP game card, showing the format as actually presented to respondents, is presented in Figure 1.

Because the data results are intended to be used as coefficients in the regional network model, the sampling methodology was based on a stratified random sample, with the traffic analysis zone (129) as the stratifying parameter. Data were analyzed by using multinomial logit estimation with the MDC procedure of the SAS package. Separate models were estimated from the SP results depending on access to household vehicles. One model was estimated for households with no vehicles, one for households with access to two-wheelers only, and one for households with access to cars. The structure of this analysis is shown in Figure 2.

RESULTS

Preliminary results based on 2,700 household interviews are reported here. In all, a total of 27,000 choice set data points were collected. Average cost values of the commute turned out to be 7.9 rupees for nonvehicle owners, 11.2 rupees for two-wheeler owners, and 23.9 rupees for car owners. Average travel time values were found to be 36.6 min for nonvehicle owners, 30.9 min for two-wheeler owners, and 35.5 min for car owners. (These are not necessarily the time and cost of particular modes; rather, they are the time and costs reported by individuals with those ownership characteristics.) Separate models were run for respondents who indicated that they had no access to any individual vehicle, those who indicated that they had access to two-wheelers, and those who indicated that they had access to cars. Mode choice elasticities were calculated on the basis of the average time and cost values, midpoint of the reliability range asked about (10 min of uncertainty), and the output model coefficients. The value of time and reliability were also calculated. All these results are shown in Table 3.

Some coefficients for the car-owning model were insignificant at the 95% confidence level (but not at the 90% confidence level), reflecting the fact that the sampling methodology slightly undersampled this group.

TABLE 2 Attributes and Levels Used in SP

How Presented	Time: Relative to yesterday's commute time	Cost: Relative to yesterday's commute cost	Uncertainty: Vehicle never leaves more than this many minutes after scheduled time
Level 1	- 10 minutes	-1 rupees	1 minute
Level 2	0 minutes	0 rupees	10 minutes
Level 3	+15 minutes	+2 rupees	20 minutes

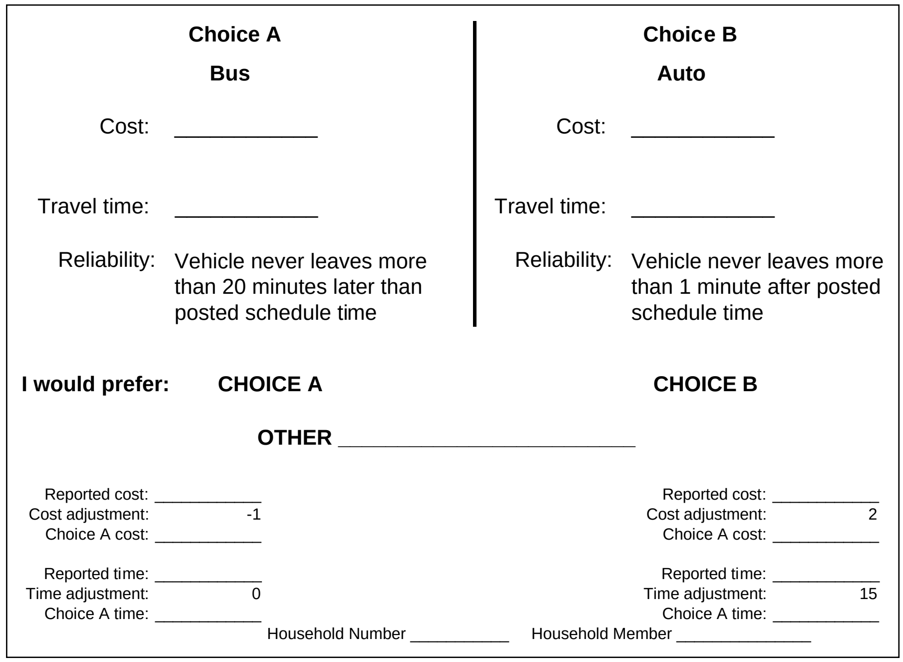

FIGURE 1 **Sample SP game card shown to respondents before customization by interviewer.**

These preliminary results show that time, cost, and reliability are important for households with access to no vehicles or access to two-wheelers. Results are less straightforward for households with cars, in which the coefficients for cost and time, although in the proper direction, are not significant. That the cost coefficient for these households is minuscule (if insignificant) is as expected: in India, households with cars tend to be fairly wealthy and therefore price-insensitive to alternate transport modes. Of more interest is the relationship between the time and the reliability coefficient for car-owning households. The time coefficient is insignificant at the 95% confidence level, but significant at the 90% level. One would expect time to be as important as reliability. Results indicate, however, that car-owning respondents appear to place a premium on reliability.

In fact, both of the other groups also value reliability improvements relatively more than time improvements, as shown by the coefficient values. This means that respondents in all groups would be more tolerant of a modest deterioration in door-to-door travel time than they would be in a modest deterioration of reliability. Respondents with no access to a vehicle remain predominantly responsive to price. The relative price responsiveness of non-vehicle-owning individuals

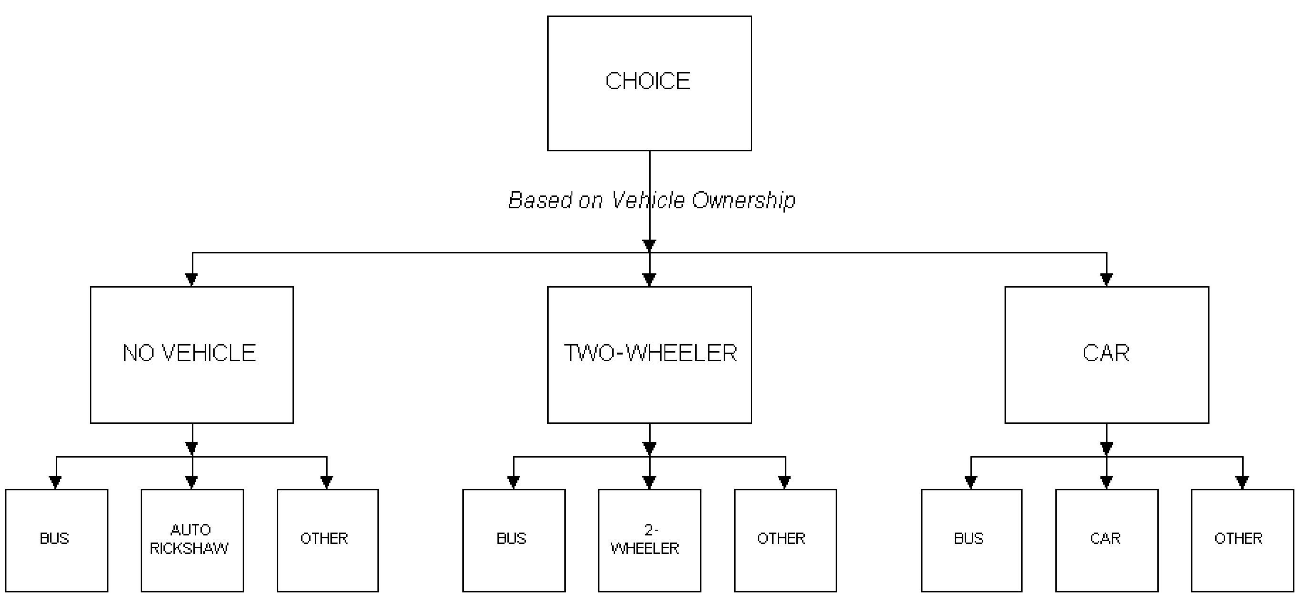

FIGURE 2 **Structure of multinomial logit models assessed.**

TABLE 3 Summary of MNL Results for Three Types of Households

	Conditional Logit Models		
Sample Average Values	**No Vehicle**	**2-Wheeler**	**Car**
Travel Cost (Rs)	7.9	11.2	23.9
Travel Time (Minutes)	36.6	30.9	35.5
Parameter Estimates			
Travel Cost	-0.11 *	-0.02 *	-0.01
Travel Time	-0.02 *	-0.03 *	-0.01
Reliability	-0.04 *	-0.06 *	-0.05 *
Constant - 7-Seater	-0.31 *	-0.59 *	-1.09 *
Constant - Bus	-0.18 *	-0.31 *	-0.69 *
Model Summary			
Observations	12,106	13,451	1,068
Number of Cases	36,318	40,353	3,204
Goodness of Fit			
Likelihood Ratio	1,097	5,138	518
Aldrich-Nelson	0.08	0.28	0.33
Adjusted Estrella	0.09	0.34	0.42
McFadden's LRI	0.04	0.17	0.22
Veall-Zimmermann	0.12	0.40	0.48
Value of Attributes			
Value of Time (Rs/hour)	11 *	91 *	63
Value of Reliability (Rs/minute of uncertainty reduced)	0.38 *	2.88 *	5.18
Marginal Effects (Elasticities) †			
Travel Cost	-0.78 *	-0.19 *	-0.18
Travel Time	-0.62 *	-0.92 *	-0.29
Reliability	-0.36 *	-0.53 *	-0.42 *

NOTE: Rs = rupees, LRI = likelihood-ratio indicator.
* Denotes significance at 95% confidence interval
† at sampled average for time/cost and 10 minutes unreliability

compared with vehicle owners probably reflects, in part, the characteristic that those with no access to a vehicle tend to have lower incomes. Data on income are not sufficiently robust to test that hypothesis. But this difference in responsiveness also reflects difference in perceptions of costs as fixed (or sunk) and variable. Travelers who perceive costs as fixed tend to relate their own prices to average costs—the more I travel, the cheaper it is for each individual kilometer. Those who perceive costs as variable, on the other hand, engage in marginal cost thinking—each individual kilometer I travel simply adds to my cost. As a result, vehicle-owning respondents may have given little credence to any change in prices presented to them.

In the preparation of this study, the authors heard anecdotal stories that some two-wheeler drivers would actually prefer buses if they were reliable and convenient because of concern about safety and bodily injury on the road. These anecdotal preferences were not borne out by the results. The mode-specific constant of two-wheeler owners for buses was –.32, and was significant at the 95% confidence level, meaning that the perception of buses was negative relative to that of two-wheelers, even controlling for differences in time, cost, and reliability. It is not possible based on the information in this study to determine what underlies that negative perception. Nevertheless, it should be noted that the ratio of the travel time coefficient and bus-mode-specific constant for two-wheeler owners suggests that a 10-min time advantage for the bus would effectively eliminate the "inherent" preference for two-wheelers for owners of these vehicles, all else being equal.

IMPLICATIONS

Results of the SP survey have three noteworthy characteristics that may be important lessons for policy making. First, all else being equal, as levels of vehicle ownership rise, households will become relatively more sensitive to time and reliability, and less sensitive to cost. This can be thought of largely as an income effect because vehicle ownership is correlated to income. Second, for all groups, reliability appears to be a relatively more important criterion than time. This means that, as both deteriorate, the propensity to switch modes to gain certainty grows faster than the propensity to switch modes to save time, all else being equal.

Third, among all three groups, buses suffer from an image problem in Hyderabad (although apparently the image of seven-seaters is even worse). Even controlling for the effects of time, cost, and reliability, vehicle owners showed an inherent preference for their own vehicles over buses, and nonvehicle owners showed an inherent preference for walking. Nevertheless, as noted above, small improvements in time and reliability can help neutralize the inherent preferences. In addition, improvements in bus operations might also help change the perceptions underlying those preferences.

These three characteristics suggest that concerted policies focusing on improving bus operations might be an effective means overall of managing future levels of travel demand and might be particularly effective in heading off growth in the use of two-stroke engine vehicles, such as two-wheelers and auto-rickshaws. Policies that effectively give public transport a time and reliability advantage over private transport, therefore, should be viewed not only as transport policy, but also as air quality and climate policy as well.

Of course, there are a range of potential interventions that might increase time and reliability of buses, including provision of dedicated facilities, passage and effective enforcement of bus priority traffic laws, and operational improvements such as platform loading or shifting to proof-of-payment systems that allow multiple doors to be used for access and egress. These various improvements are often packaged together in transport policy discussions under the BRT concept, a term used to invoke the idea that bus systems should be treated as primary systems, like metros, rather than as secondary or fallback means of transport (*11*).

A second phase of this project is to use the coefficients on time, cost, and reliability developed in this project in a travel-demand forecasting model for Hyderabad. This model would be used to estimate how a BRT system, defined for our purposes according to headways and operating speed characteristics, would affect overall travel demand in a horizon year. This assessment depends on the development of a believable business-as-usual scenario that mimics conditions of the cycle of decline discussed in the beginning of this paper. Results of this simulation exercise will quantify more precisely how much of an effect a BRT policy in Hyderabad might have on air quality.

CONCLUSION

For policy makers, it is critical that the results from vehicle-owning groups not be taken simply at face value as reflecting how groups today behave. Rather, these responses should be seen as glimpses into the future—they represent a likely picture of the way tastes and preferences may change as vehicle ownership increases. It is particularly critical to understand these preferences better, and they should be the focus for more research. For example, the preference among vehicle owners (two-wheelers and cars) for their own vehicles, even accounting for time and reliability differences, may in fact be a manifestation of the fixed-cost perception (e.g., the vehicle I own does not cost me anything additional, but the bus does), or it may reflect other aspects of the experience of taking the bus that could not be measured here, such as perceptions of personal safety or comfort. Which of those factors is more important would shape the appropriate policy response.

Perceptions notwithstanding, this research has suggested that sensitivity to time and reliability are important and growing determinants of traveler behavior. BRT as a policy response is well targeted to addressing these determinants as a means of providing accessibility to Hyderabad residents and maintaining bus transport within commuters' expectations without attendant increases in pollution, congestion, and greenhouse gas emissions.

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