Highlights

- The pair-wise weighing method has been used to priorities the choices of commuters to the shift to public transport system
- The primary survey was conducted to collect the data under four parent criteria: reliability, comfort, safety and cost
- Safety was found to be the most important criteria and then reliability, cost and comfort.
- 96% of the commuters are willing to shift to public transport if better services would be provided for public transport system

Citation details:

Jain, S., Aggarwal, P., Kumar, P., Singhal, S., Sharma, S., 2014. Identifying public preferences using multi-criteria decision making for assessing the shift of urban commuters from private to public transport: A case study of Delhi. Transportation Research Part F: Traffic Psychology and Behaviour 24, 60-70. Online link: <http://dx.doi.org/10.1016/j.trf.2014.03.007>

Citation details: Jain, S., Aggarwal, P., Kumar, P., Singhal, S., Sharma, S., 2014. Identifying public preferences using multi-criteria decision making for assessing the shift of urban commuters from private to public transport: A case study of Delhi. *Transportation Research Part F: Traffic Psychology and Behaviour* 24, 60-70. Online link: <http://dx.doi.org/10.1016/j.trf.2014.03.007>

Identifying public preferences using multi-criteria decision making for assessing the shift of urban commuters from private to public transport: A case study of Delhi

Suresh Jain^{a,1}, Preeti Aggarwal^a, Prashant Kumar^{b,c}, Shaleen Singhal^d, Prateek Sharma^a

^a*Department of Natural Resources, TERI University, 10, Institutional Area, Vasant Kunj, New Delhi-110070, India*

^b*Department of Civil and Environmental Engineering, Faculty of Engineering and Physical Sciences (FEPS), University of Surrey, Guildford GU2 7XH, United Kingdom*

^c*Environmental Flow (EnFlo) Research Centre, FEPS, University of Surrey, Guildford GU2 7XH, United Kingdom*

^d*Department of Policy Studies, TERI University, 10, Institutional Area, Vasant Kunj, New Delhi-110070, India*

ABSTRACT

Shifting urban commuters to public transport can be an effective strategy to deal with the energy and environmental problems associated with the transport sector. In order to enhance public transport the mode of choice for urban commuters, public expectations and requirements should be at the centre of the policy-making process. This study uses pair-wise weighing method (i.e. analytical hierarchy process) to derive priorities for different criteria for shifting urban commuters to the public transport system based on their opinion. The primary survey has been conducted to collect the data for identifying public preferences for public transport characteristics under four parent criteria: reliability, comfort, safety and cost, identified based on literature review and expert opinion. This information was collected using questionnaire based surveys between January 2013 and July 2013 from nearly 50 locations using a stratified random sampling technique from nine districts of Delhi. Our results suggest safety as the most important criteria (36% of total) for encouraging the urban commuters to shift from private vehicles to public transport and then reliability (27%), cost (21%) and comfort (16%). Based on above four criteria, commuters were found to be happy with Delhi metro services compared to buses and other mode of public transport due to more frequency, adherence to schedule, less travel time, comfort and safety. Commuters were willing to pay

¹ Corresponding author - Department of Natural Resources, TERI University, 10, Institutional Area, Vasant Kunj, New Delhi-110070, India; Tel: +91-11-2612 2222; Fax: +91-11-2612 2874; Email: sureshjain_in@yahoo.com; sureshj@teri.res.in

more for better public transport service since the travel cost was not considered to be one of the important criteria. The results also showed that 96% commuters are willing to shift to public transport if above criteria or services are considered for providing an efficient public transport system. These results can assist transport planners to integrate public preferences with the available technical alternatives for the wise allocation of the available resources.

Keywords: *Analytical Hierarchy Process, Modal shift, Public transport, Commuter perceptions*

1.0 Introduction

Urban centres all over the world are plagued with unsustainable trends in the transport sector due to increased energy use, air pollution, traffic accidents, congestion and noise pollution (Jain and Khare, 2010). Mitigating transport externalities is a major challenge faced by the governments all over the world. These problems are even more pronounced for developing cities where the rate of vehicle growth is far greater than the rate of growth of transport infrastructure (Santos, Behrndt, Maconi, Shirvani, & Teytelboym, 2010). Like many other urban regions in Asia, Delhi is experiencing considerable growth due to migration and growth in population. Due to strategic location in context to political, economic and commercial centre, Delhi attracts an enormous influx of people, promoting faster growth, resulting in massive demand for passenger transport (Ahmad, Balaban, Doll, & Dreyfus, 2013; Khanna, Jain, Sharma, & Mishra, 2011). It is expected that the distance travelled by people within and outside the city is expected to increase further in Delhi due to demographic marginalization and urban sprawl, resulting in higher reliance on personal vehicles (Economic Survey of Delhi, 2013).

The vehicle fleet of Delhi has increased from 3.16 million in 1999-2000 (4.72% growth rate) to ~7.69 million by the year 2011-12 (7.27% growth rate), with nearly 299 two-wheeler and 162 cars for every 1,000 people (MoRTH, 2011). The increasing shift in motorised mode of transport in megacities of the developing countries is contributing to

increased levels of air pollutants, attributed to vehicular sources (Kumar et al., 2013; Jain & Khare, 2008). This tremendous rise in the number of vehicles is due to the poor quality of public transport system provided in the city. Under the current democratic setup, policy makers and transport managers are faced with pressures of keeping the fares at the existing levels. Such a measure is also desirable to ensure social equity. Since the revenue collected by fares is inadequate, public transport authorities are often unable to recover their operational costs, let alone the investments to improve its services (Singh, 2005). Consequently the poor quality services encourage users to steer away from the public transport.

Whilst the share of public transport in Delhi was 60% in 2001, this decreased to less than 45% in 2008 (Sahai & Bishop, 2009). In fact, buses found to constitute less than 1% of the vehicle fleet in Delhi, but meet almost half of the travel demand leading to overcrowding and poor quality of transport services (Asian Development Bank, 2008). Personal vehicles such as two wheelers and cars or jeeps constitute more than 90% of Delhi's vehicles. This category of personal vehicles is also responsible for deteriorating the air quality in Delhi (Jain & Khare, 2010; Kumar, Gurjar, Nagpure, & Harrison, 2011). The vehicular stock has consequently grown beyond the carrying capacity of roads. This has led to congestion and a decrease in average travel speed leading to further problems related to energy use and emissions (RITES, 2010). Due to the lower average speeds and increasing sprawl, average travel time has therefore increased to 2 or 3 hours per day for their work trip (Pucher, Korattyswaropama, Mittal, & Ittyerah, 2005).

Delhi Government has taken many policy initiatives to curb vehicular pollution since 1998, as shown in Table 1. Major policy interventions in Delhi included ordinary technological interventions that did not return the desired results, calling for a need to promote a shift of Delhi commuters from private to public transport. New policies should

consider encouragement and strengthening of public transport system. Recognising this need, the Government of Delhi has proposed introduction of an Integrated Mass Rapid Transit System (IMRTS), which would cater 70 to 80% of the total travel demand of the city by 2021. The proposed system has corridors for Bus Rapid Transits (BRT), Light Rail Transits (LRT), Delhi Metro and Monorail. The Delhi Metro started operation in 2002 and now has completed Phase-I and II as on January 2013 covering distance of ~190 km. In order to make bus transit more reliable and faster, the Delhi Government has proposed BRT as a part of IMRTS. The pilot BRT corridor in Delhi stretches from Dr Ambedkar Nagar to Moolchand, and is under trial run since 20 April 2008. The pilot project saw some resentment among private vehicle users due to priority given to buses at traffic signals, leading to longer stoppage time for non-bus users.

According to a survey by RITES (2010), Delhi Metro has been successfully able to make commuter shift from privatized modes. About ~46% of metro users were private vehicle users. This success can be attributed to the high quality service provided as compared to the existing bus system in Delhi. On the other hand, BRT has not been able to replicate Delhi Metro's success in terms of public acceptance. Other cities in the world have also shown a similar trend where even after the introduction of IMRTS, the share of private motorised transport has not decreased. For example, the study conducted by Poudenx (2008) in twelve major cities from Singapore, Hong Kong, Europe showed that IMRTS was only successful in drawing the users of non-motorised transport. A study conducted by Wener, Evans, Phillips, & Nadler (2003) on public transport system in New York suggests that the major reason for not shifting private vehicle users to public transport is the quality of service and the stress associated with frequent transfers among different modes. The local commuters could be satisfied with public transport system if their expectations are met by them. These aspects like service quality and stress associated with frequency transfers among different

modes have not been comprehensively dealt with in transport research (Felleson & Friman, 2008) and, research is conquered by choice modeling and stated preference approaches (Cantwell, Caulfield, & O'Mahony, 2009). However, satisfaction is an important aspect which may attract more commuters to shift from private vehicle to public transport. Hence it is very important to understand the commuter perceptions and their behavior about public transport characteristics.

The relevant past studies showed that travel time, cost, frequency of service, seat availability, staff behavior, reliability, availability of information about transport services, comfort, safety, and cleanliness are factors that constitute perceived service quality in public transport services (Redman, Friman, Gärlingb, & Hartig, 2013; Sherestha 2013; Gatersleben & Uzzell, 2007; Nolan 2007; Bhat & Sardesai, 2006; Hensher et al., 2003; Friman, Edvardsson, & Gärling, 2001; Friman & Gärling, 2001; Rietveld, Bruinsma, & Vuuren, 2001). Another study conducted by Felleson & Friman (2008) for nine European cities confirmed these results by highlighting the impact of safety, security, frequency, service reliability, comfort, and the quality of staff behavior on the level of satisfaction with public transport. Poudenx (2008) suggests that the quality and service of transit modes will have to be raised to encourage a shift from private vehicles to public transport. This is because people would only be willing to shift to modes with greater comfort and reliability irrespective of energy use and the related environmental issues. Since public support is seen as a major factor in determining the success of a policy, Goyal & Sidhartha (2003) pointed out that securing public confidence before the implementation of a policy would be a good strategy.

The overall aim of this study is to identify the priorities of commuters for the various public transport characteristics and choices. The multi-criteria analysis has been used to estimate the weightage assign to the criterion given by commuters to shift from private to public transport system. An extensive field surveys in Delhi was conducted to build a novel

data base, so that commuter priorities and perceptions for choice of public transport mode can be assessed.

2.0 Methodology

2.1 Description of the study area

The study was carried in the national capital territory of the Delhi (NCTD) region, as seen in Figure 1. Delhi ($28^{\circ}36'50''\text{N}$, $77^{\circ}12'32''\text{E}$) is the capital of India and is one of the major developing megacities in the world (Kumar et al., 2014). Due to rapid urbanization, the city saw a large-scale migration over the last decade. There has been an increase of ~21% in population between 2001 and 2011 census from 13.9 to 16.75 million. The rapid growth rate of both population and economy is putting enormous pressure on the city's existing transport infrastructure. Delhi shares the pride of having the largest road network (~31,183 km road length) among other cities in India (RITES, 2010). Approximately 46, 27, 8 and 2% of Delhi's road length has the right-of-way between 10 and 20 m, 20 and 30 m, 40 and 60 m, and over 60 m, respectively. Traffic congestion still occurs frequently due to the large volume of traffic on city roads.

2.2 Data collection

The data related to public preferences has been collected in the context to their choice of public transport such as Delhi metro, bus, three wheeler, local train and rickshaw for commuting. The factors effecting commuters choice for public transport has been considered based on existing literature as presented in Table 2. These choices (sub-criteria or sub-factors) has been categorised in to four parent criteria i.e. reliability, comfort, safety and cost, based on experts opinion. The Delphi method has been used to assign various sub-criteria's under the parent criteria based on experts judgements (Jain and Khare, 2010). The questionnaire has been sent to 10 experts in the NCTD. The final category assigned by experts to sub-criterion is presented in Table 2. The data related to above criterion and sub-

criterion has been collected by pair-wise priorities using the cross-sectional sample surveys. The primary survey was conducted in order to get generalized information about the public perception in the study region. Delhi is divided into nine districts, which have people from diverse background and economic profiles. Therefore stratified random sampling technique was adopted to collect samples by considering nine districts (central, north, south, east, northeast, south-west, north-west, west, and New Delhi) in Delhi lying in its three statutory towns (Municipal Corporation of Delhi, New Delhi Municipal Council, Delhi Cantonment Board). The data was collected from commuters using questionnaire based surveys between January 2013 and June 2013 from nearly 50 locations, which are distributed in nine districts as shown in Figure 1. These locations included fuel pumps, parking lots, bus terminals, bus depots, taxi stands, auto stands, shopping complexes and commercial areas in various districts. Surveys were conducted on both weekdays and weekends and were spread equally throughout the sampling duration. In the study, population size (16.75 million) has been taken from 2011 census data. The sample size for data collection during these surveys was estimated using methodology proposed by National Statistical Service (NSS, 2013). In this survey, 5% margin of error has been considered, with 95% confidence while estimating representative sample size. The estimated sample size required for the survey was 385. However, we have collected a total of ~500 samples to avoid any incomplete information while analysing the information.

2.3 Assigning relative weights to criterion and sub-criterion using multi-criteria analysis

Multi-criteria decision making is an important tool which helps in making decisions with several decision criteria and multiple objectives. Analytical Hierarchy Process (AHP), developed by Saaty (1980), is one such ‘multi attribute decision making’ method which provides an overall ordering of options, from the most preferred to the least preferred options.

Pohekar & Ramachandran (2004) in their review of multi-criteria decision making tools found AHP to be the most popular technique for solving problems having multiple objectives. The technique answers questions relating to what to do rather than how to do (Tzenga, Lina, & Opricovic, 2005). The AHP also prioritizes alternatives based on a common set of criteria into quantitative and qualitative terms (Yedla & Shreshta, 2007). In AHP, the problem under study is decomposed into different levels, the top most level is the ultimate goal followed by the criteria and sub-criteria in the second level. The various alternatives form the lower most level (Berrittella, Certa, Enea, & Zito, 2008). The elements at each level are compared pair-wise due assign the relative importance of one criteria or sub-criteria over the other. Therefore, the AHP has been used in this study since the aim is to assign relative weigh to different criterion and sub-criterion of public transport system as explained in the hierarchical scheme (Figure 2 and Table 2).

A public perception survey was carried out to find the relative weights of the various factors. A questionnaire based on pair-wise comparison method of assigning weights was designed. For each response, a comparison matrix was prepared and normalized using the standard normalization procedure to obtain the relative weights/priority vector. This procedure derives priorities by taking the proportion of the row/column factors divided the row/column sum. The individual responses were checked for their consistency using consistency ratio. Inconsistent responses were filtered out and consistent ones were averaged to derive the final weights of the desirable public transport characteristics. Weights for the various sibling sub-criteria were calculated using the same procedure. The global priorities of the sub-criteria were obtained by multiplying the local priorities of the siblings with the priority value of the parent.

3.0 Results and discussions

3.1 Analysis of field survey

The results obtained from field surveys conducted in NCTD is summarised in Table 3. The survey results represented 45, 31, 20 and 4% commuters in the four different age groups that were 15-25, 26-40, 41-60 and >60 years, respectively; out of which 58% were male and 42% were female commuters as shown in Figure 3(a-c). It has been observed that 54% commuters preferred public transport for different purposes such as for work (61%) and others (39%). The most preferred mode of public transport was Buses (52%) compared to Delhi Metro (25%), Auto (16%), Rickshaw (4%) and local train (3%) as presented in Figure 3(d). However, waiting time for buses and three-wheelers were more varied from 5 to 30 minutes depending on their availability in different areas in the NCTD. These commuters travel different distance that ranged from <250 m to >1 km to reach or catch the public transport; out of which 71% uses three-wheelers, 24% travel by foot and 5% by rickshaw from their nearby areas such as residence or work/business place to their destination. Our results also suggested that 94% of commuters showed their willingness to shift to public transport as shown in Figure 3(h). This shift is possible to achieve if consideration of this factor is taken into account in decision making in order to improve the present system more efficient. A similar result has been reported by Foote (2004). This work was carried out for Chicago in order to assess customer-derived performance measures for bus operations. He explained that high-quality service such as safe, clean, on-time and friendly public transport mode has resulted in customer satisfaction and increased ridership. Furthermore, Stradling, Anable, & Carreno (2007) have also reported in their literature based study that it is very important to consider the current and future levels of service required by commuters to assess their satisfaction level for various travel modes.

3.2 Commuters choice for parent criterion used for public transport

The criteria for commuter's choice aimed at public transport included in the survey were safety, reliability, low cost and comfort as shown in Table 4. Safety was found to be

almost ~1.4 and ~1.8 times more important than reliability and low cost travel, respectively. However, Goodwin (1992) in his study identified transport pricing as one of the critical factors determining the successful implementation of a transport policy. Furthermore, reliability was ~1.8 times as important as comfort, which was rated as least important. Similarly, Bhat & Sardesai (2006) have found in their study for Austin, capital city of Texas, that reliability and travel time were most important factors which influence the decisions of commuters. Likewise, Sherestha (2013) has also reported in her Kathmandu (Nepal) based study that comfort, travel time and cost are important aspects in decreasing order that have motivated the commuters to shift to public transport. This work also stated that comfort and travel time was more important over travel cost. This may be due to the reason that the author has not considered criteria like reliability and commuter safety, which made comfort and travel time more important criteria over others.

3.3 Commuters choice for sub-criterion used public transport

The analysis of survey results for various sub-criteria is presented in Table 5. The result shows that personal safety is the most important factor (0.42), followed by reduced number of accidents (0.33) and staff behaviour and their attitude (0.25) as shown in Figure 4(a). Personal safety was ~1.3 and ~1.7 times more importance than the reduced numbers of accidents and staff behaviour and their attitude, respectively. For a more reliable public transport system, good frequency (0.61) has been given priority over adherence to schedule (0.39) as shown in Figure 4(b). In the present context, commuter wants good frequency for public transport system because of higher weightage given by them to this sub-criterion over adherence to schedule. Similarly, Nolan (2007) has found that reliability in the context of arrival and departure times or adherence to travel schedule was one of the key factors discouraging people from using public transport. Further, Rietveld, Bruinsma, & Vuuren (2001) established that most passengers preferred reliability and adherence to schedule over

shorter travel time. In our study, accessibility was the most important sub-criteria preferred by commuters under parent criteria i.e. comfort. Less travel time was given the second highest priority in this group, followed by less crowded public transport, seating availability, cleanliness, low floor, and air conditioning. Similar results have been reported by Gatersleben & Uzzell (2007) for the United Kingdom. They have found that public transport is stressful due to unpredictability and longer travel times. It was also interesting to observe that low floor buses and air conditioning was given the least priority by people, which shows that commuters prefer more reliable public transport in context to accessibility, less travel time, less crowded and cleanliness. Accessibility and efficiency have been identified as the two key factors to increase the patronage of public transport (Murray, 2001; Murray, Davis, Stimson, & Ferreira, 1998). In order to provide better connectivity, feeder buses may encourage a mass shift towards public transport modes. According to the proposed integrated mass rapid transit system (IMRTS) which includes Delhi metro, Bus Rapid Transit (BRT) and Light Rail Transit (LRT) by Government of NCTD, the government aims to provide access to transfer stations within 500 meters to most of the commuters (RITES, 2010).

3.4 Commuters experience and expectations

In the questionnaire, one question was open ended where commuters have responded about facilities or services provided by any of the existing public transport mode. Commuters feel that Delhi metro is a successful example in terms of offering a comfortable, reliable and safe mode of public transport. Commuters mentioned that Delhi metro is more reliable and comfortable due to its frequency and adherence to schedule, less travel time with air-conditioning facility at most of the metro stations and metro coaches. Commuters also stated that Delhi metro is sensitive towards the need of the elderly and the handicapped apart from providing feeder buses to carry passengers to and forth the boarding stations. Parking facility is also made available at all metro stations to make the modal switch convenient for the

commuters as per their requirement. Presence of security personnel and CCTV cameras at the metro station ensures personal safety of the passengers. Despite the fact that buses would serve more to Delhi commuters, it was clear from our survey that people are unsatisfied with the bus service only because of factors such as their reliability, comfort and travel time. It was also observed that average waiting time for buses were more compared to Delhi metro and other modes of transport.

3.5 Potential technical measures for improving public transport services

Murray, Davis, Stimson, & Ferreira (1998) recommended that apart from proximity and reliability, socioeconomic factors must be incorporated in the policies to provide greater access to public transport. High capacity buses, more frequent services and chartered bus systems where commuters pay higher fare for a guaranteed seat can also make public transit travel more comfortable (Tirachini, 2013). The proposed IMRTS in NCTD can be made more reliable by displaying information related to arrival and departure schedule at all boarding stations, internet, travel booklets and helpline phone numbers. Facilities like first and last mile transport connectivity or feeder transit generally increase the opportunities of access to number of places of interest to an increased number of commuters (Chandra et al., 2013). Providing Right of Ways (ROWs) for different public transport modes avoids delay due to congestion and makes public transport more reliable. Intelligent traffic management system, good driving behaviour (by stricter rules and higher penalties), and ROWs can avoid accidents. To ensure personal safety of passengers, the stations can be kept under vigilance by Close Circuit Camera Television (CCTVs) like they have provided in case of Delhi metro, and providing efficient women and senior citizen help lines. Higher quality of services in terms of safe, clean, on-time and friendly public transport modes can promote a shift towards public transport (Foote, 2004; Poudenx, 2008). Differential tariff system based on the quality of service should be implemented. This would provide the user with a choice of availing

higher quality service at an extra cost. Abrate, Piacenza, & Vannoni (2009) have conducted similar study on Integrated Tariff System (ITS) by collecting information from twelve-year panel of 69 Italian public transit providers. They reported that services like validity over an extended network, the availability of a single ticket option, and the application of zonal pricing schemes are effective in raising the number of public transport users. Similarly, Sampaio, Neto, & Sampaio (2008) have reported that tariff structure in public transport systems by providing several ticket types and by giving benefits to card-holder for longer periods at lower costs results in the benefit of both users and transport companies and agencies. Educating the public about the environmental and socio-economic benefits of using public transport can also promote a shift from privatized modes as also suggested by previous studies (Grant-Muller & Usher, 2014; Doll & Balaban, 2013).

4.0 Summary and conclusions

The aim of this study was to identify the commuter's preference for public transport characteristics through multi-criteria decision making approach. The pair-wise weighing method AHP has been used to analyse the data collected from primary field surveys. The commuters of NCTD gave highest priority to safety as compared to other public transport characteristics such as reliability, comfort and cost. The survey results suggest that despite a slightly higher fare in Delhi metro than public buses, the former has been able to earn patronage of a considerable number of former private vehicle users. The present public transport services, apart from private vehicles, Delhi metro is the only safe, reliable and comfortable transport mode as per the commuters perception gathered while collecting information from the commuters, as explained in Section 3.4. The current bus-dominated public transport system is unreliable, overcrowded, and unsafe and poorly maintained as observed during primary survey. Since buses are the life-line of public transport in NCTD,

catering to more than one-third of the travel demand, there is a need to revive the existing bus system to make it competent with private vehicles.

References

- Abou-Zeid, M., Witter, R., Bierlaire, M., Kaufmann, V., & Ben-Akiva, M. (2012). Happiness and travel mode switching: Findings from a Swiss public transportation experiment. *Transport Policy*, 19(1), 93–104.
- Abrate, G., Piacenza, M., & Vannoni, D. (2009). The impact of Integrated Tariff Systems on public transport demand: Evidence from Italy. *Regional Science and Urban Economics*, 39, 120–127.
- Ahmad, S., Balaban, O., Doll, C. N. H., & Dreyfus, M. (2013). Delhi revisited. *Cities*, 31, 641–653.
- Asian Development Bank (2008) Breaking the Trend: Visioning and Backcasting for Transport in India and Delhi. [Online]. Available at <http://www.adb.org/Documents/Produced-Under-TA/39578/39578-REG-DPTA.pdf>. [Accessed 15 December, 2013].
- Bhat, C.R., & Sardesai, R., 2006. The impact of stop-making and travel time reliability on commute mode choice. *Transportation Research Part B*, 40, 709–730.
- Berritella, M., Certa, A., Enea, M., & Zito, P. (2008) Transport policy and climate change: How to decide when experts disagree. *Environmental Science & Policy*, 11, 307–314.
- Cantwell, M., Caulfield, B., & O'Mahony, M. (2009). Examining the Factors that Impact Public Transport Commuting Satisfaction. *Journal of Public Transportation*, 12(2), 1–21.
- Chandra, S., Bari, M.E., Devarasetty, P.C., & Vadali, S. (2013). Accessibility evaluations of feeder transit services. *Transportation Research Part A*, 52, 47–63.
- Doll, C.N.H., & Balaban, O. (2013). A methodology for evaluating environmental co-benefits in the transport sector: application to the Delhi metro. *Journal of Cleaner Production*, 58, 61–73.
- Eboli, L. & Mazzulla, G. (2007). Service quality attributes affecting Customer Satisfaction for Bus Transit. *Journal of public Transport*, 10 (3), 21-34.
- Economic Survey of Delhi (2013). Economic Survey of Delhi 2012-13, Govt. of NCT of Delhi [Online]. Available at http://delhi.gov.in/wps/wcm/connect/DoIT_Planning/planning/misc/economic+survey+of+delhi+2012-13 [accessed 12 December 2013].
- Fellessen, M., & Friman, M. (2008). Perceived satisfaction with public transport services in nine European cities. *Journal of Transportation Research Forum*, 47(3), 93 – 103.

366 Foote, P.J. (2004). Making Buses Better in Chicago: Strategic Implementation of Customer-
367 Derived Performance Measures from 1995 to 2001. *Transportation Research Record:
368 Journal of the Transportation Research Board*, 1884, 18–26.

369 Friman, M., Edvardsson, B., & Gärling, T. (2001). Frequency of Negative Critical Incidents
370 and Satisfaction with Public Transport Services. *Journal of Retailing and Consumer
371 Services*, 8, 95-104.

372 Friman, M., & Gärling, T. (2001). Frequency of Negative Critical Incidents and Satisfaction
373 with Public Transport Services. II. *Journal of Retailing and Consumer Services*, 8, 105-
374 114.

375 Gatersleben, B., & Uzzel, D. (2007). Affective Appraisals of the daily commute: comparing
376 perception of the drivers, cyclist, walkers, and users of public transport. *Environment and
377 Behavior*, 3, 416-431.

378 Goodwin, P. B. (1992) A Review of New Demand Elasticities with Special Reference to
379 Short and Long Run Effects of Price Changes. *Journal of Transport Economics and
380 Policy*, 26 (2), 155-169.

381 Goyal, P. & Sidhartha. (2003) Present scenario of air quality in Delhi: a case study of CNG
382 implementation. *Atmospheric Environment*, 37, 5423–5431.

383 Grant-Muller, S., & Usher, M. (2014). Intelligent Transport Systems: The propensity for
384 environmental and economic benefits. *Technological Forecasting and Social Change*, 82,
385 149–166.

386 Hensher, D. A., Stopher, P., & Bullock, P. (2003). Service quality – developing a service
387 quality index in the provision of commercial bus contracts. *Transportation Research Part
388 A*, 37, 499-517.

389 Jain, S., & Khare, M. (2010). Adaptive Neuro-Fuzzy Modelling for Prediction of Ambient
390 CO Concentration at Urban Intersections and Roadways. *Air Quality, Atmosphere and
391 Health*, 3, 203-212.

392 Jain, S., & Khare, M. (2008) Urban Air Quality in Mega Cities: A Case Study of Delhi City
393 using Vulnerability Analysis. *Environmental Monitoring and Assessment*, 136 (1-3), 257-
394 265.

395 Kathuria, V. (2002) Vehicular pollution control in Delhi. *Transportation Research Part D*, 7,
396 373–387.

397 Kathuria, V. (2004) Impact of CNG on vehicular pollution in Delhi: a note. *Transportation
398 Research Part D: Transport and Environment*, 9, 409–417.

- Khanna, P., Jain, S., Sharma, P., & Mishra, S. (2011). Impact of increasing mass transit share on energy use and emissions from transport sector for national capital territory of Delhi. *Transport Research Part D*, 16, 65–72.
- Kumar, P., Gurjar, B.R., Nagpure, A., & Harrison, R.M., 2011. Preliminary estimates of particle number emissions from road vehicles in megacity Delhi and associated health impacts. *Environmental Science & Technology*, 45, 5514-5521.
- Kumar, P., Jain, S., Gurjar, B.R., Sharma, P., Khare, M., Morawska, L., & Britter, R. (2013). New directions: Can “Blue Sky” Return Over in Indian Megacities? *Atmospheric Environment*, 71, 198-201.
- Kumar, P., Morawska, L., Birmili, W., Paasonen, P., Hu, M., Kulmala, M., Harrison, R.M., Norford, L., & Britter, R., 2014. Ultrafine particles in cities. *Environment International*, 66, 1-10. <http://dx.doi.org/10.1016/j.envint.2014.01.013>
- MoRTH, 2011. Road Transport Year Book (2007 - 2009) (Volume- I). Ministry of Road Transport and Highway, Government of India.
- Murray, A. T. (2001) Strategic analysis of public transport coverage. *Socio-Economic Planning Sciences*, 35 (3), 175-188.
- Murray, A. T., Davis, R., Stimson, R. J., & Ferreira, L. (1998) Public Transportation Access. *Transportation Research Part D: Transport and Environment*, 3 (5), 319-328.
- Nolan, G. 2007. Evaluation of public opinion of existing public transport services in Dublin. Final Year Dissertation, Department of Civil, Structural and Environmental Engineering, Trinity College, Dublin.
- NSS (2013). Sample Size Calculator, National Statistical Service [Online]. Available at <http://www.nss.gov.au/nss/home.nsf/pages/Sample+size+calculator> [accessed 5 January 2013].
- Pohekar, S. D., & Ramchandran, M. (2004) Application of multi-criteria decision making to sustainable energy planning—a review. *Renewable and Sustainable Energy Reviews*, 8, 365–381.
- Poudenx, P. (2008). The effect of transportation policies on energy consumption and greenhouse gas emission from urban passenger transportation. *Transportation Research Part A*, 42, 901–909.
- Pucher, J., Korattyswaropama, N., Mittal, N. & Ittyerah, N. (2005). Urban transport crisis in India. *Transport Policy*, 12, 185–198.

- Redman, L., Friman, M., Gärlingb, T., & Hartig, T. (2013). Quality attributes of public transport that attract car users: A research review. *Transport Policy*, 25, 119–127.
- Rietveld, P., Bruinsma, F. R., & Vuuren, D. J. V. (2001) Coping with unreliability in public transport chains: A case study for Netherlands. *Transportation Research Part A*, 35 (6), 539-559.
- RTES (2010). Transport Demand Forecast Study in Development of an Integrated Road Cum Multi-modal Transport Network for NCT of Delhi. Traffic Survey Results Report Volume III: Main Report. Final report.
- Saaty, T.L. (1980). The Analytic Hierarchy Process. McGraw-Hill, New York.
- Sahai, S. N., & Bishop, S. (2009) Bus system reform in Delhi [Online]. Available at http://www.dimts.in/pdf/Bus_System_Reform_in_Delhi.pdf [accessed 12 April 2009].
- Sampaio, B.R., Neto, O.L., & Sampaio, Y. (2008). Efficiency analysis of public transport systems: Lessons for institutional planning. *Transportation Research Part A*, 42, 445–454.
- Santos, G., Behrndt, H., Maconi, L., Shirvani, T., & Teytelboym, A. (2010) Part I: Externalities and economic policies in road transport. *Research in Transport Economics*, 28, 2-45.
- Sherestha, R. (2013). Low carbon development in transport: Users' preferences for proposed suitable public transport option in Kathmandu metropolitan city, Nepal. Master's thesis submitted at the Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Enschede, Netherland. Available at http://www.itc.nl/library/papers_2013/msc/upm/shrestha.pdf [accessed 01 February 2014].
- Singh, K. S. (2005) Review of urban transportation in India. *Journal of Public Transportation*, 8 (1), 79-98.
- Stradling, S.G., Anable, J., & Carreno, M. (2007). Performance, importance and user disgruntlement: A six-step method for measuring satisfaction with travel modes. *Transportation Research Part A*, 41, 98–106.
- Tirachini, A. (2013). Estimation of travel time and the benefits of upgrading the fare payment technology in urban bus services. *Transportation Research Part C*, 30, 239–256.
- Tirachini, A., & Hensher, D. A. (2011). Bus congestion, optimal infrastructure investment and the choice of a fare collection system in dedicated bus corridors. *Transportation Research Part B: Methodological*, 45(5), 828–844.

- 464 Tzenga, G. H., Lina, C. W., & Opricovic, S. (2005) Multi-criteria analysis of alternative-fuel
465 buses for public transportation. *Energy Policy*, 33, 1373–1383.
- 466 Wener, R., Evans, G., Phillips, D., & Nadler, N. (2003) Running for the 7:45: the effects of
467 public transit improvements on commuter stress. *Transportation*, 30 (2), 203–220.
- 468 Yedla, S., & Shrestha, R.M. (2003) Multi criteria approach for selection of alternative options
469 for environmentally sustainable transport system in Delhi. *Transportation Research Part*
470 *A*, 37, 717-729.

Table 1: A review of key actions undertaken in transport sector for improving air quality in Delhi since 1998 and their implications.

Year	Key Action (s)/ Policy	Implications/ Reactions
1994-95	<ul style="list-style-type: none"> Catalytic converters introduced Unleaded petrol introduced 	This lead to evident reduction of Lead emissions and improved vehicle quality
1996	<ul style="list-style-type: none"> 0.5% Sulphur Diesel introduced Unsuccessful introduction of CNG vehicles for government 	Low sulphur based emissions assessed, but as the number of vehicles increased, so did the amount of SO ₂ emissions
1998	<ul style="list-style-type: none"> Commercial/ transport vehicles older than 15 years phased out 	Faced resentment from consumers, but improved the road vehicle conditions, led to increase in sales of vehicles
1999	<ul style="list-style-type: none"> 0.25% sulphur diesel introduced Taxis older than 12 years phased out India Stage I (Euro I) norms mandated for all vehicle categories Registration of only Bharat Stage II (Euro II) three-wheelers and diesel taxis allowed Restriction on plying of good vehicles during the day Complete removal of leaded petrol 	This lead to significant reduction on Lead in Delhi, removal of Lead as a criteria pollutant.
2000	<ul style="list-style-type: none"> Bharat Stage II (Euro II) emission norms for all private vehicles Buses older than 8 years phased out or made to run on CNG Pre-1990 three wheelers and taxis replaced with new ones using CNG Petrol with 1% benzene mandated 	Cranking reduced in vehicles and VOC emissions were targeted. CNG started to come into use
2001	<ul style="list-style-type: none"> 0.05% sulphur diesel made mandatory Number of CNG vehicles was 26350 Bharat Stage II (Euro II) norms for all commercial vehicles 	
2002	<ul style="list-style-type: none"> All diesel buses phased out or converted to CNG 57240 CNG vehicles in total 	Increased the ambient air quality, NO _x levels seemed to be controlled to a limit
2005	<ul style="list-style-type: none"> Bharat Stage II (Euro II) norms for two wheelers and three wheelers Bharat Stage III norms for four wheelers in 11 cities 	
2006	<ul style="list-style-type: none"> DIMRTS for Delhi (Introduced Delhi Metro & BRT corridors) 	Increased public means, but public resentment for high priority for buses than cars
2010	<ul style="list-style-type: none"> Expected Bharat Stage III (Euro III) norms across country Expected Bharat Stage IV (Euro IV) norms in 11 major cities Delhi Metro Phase I, II complete 	

(Source: Adopted from Kathuria, 2002; Yedla and Shrestha, 2003)

Table 2: Factors effecting choice of commuters for public transport modes.

Factors effecting public transport system	Sub-factors	References
Comfort	Cleanliness	Sherestha 2013; Redman, Friman, Gärlingb, & Hartig, 2013; Tirachini & Hensher, 2011; Felleson & Friman, 2008; Eboli & Mazzulla, 2007; Gatersleben & Uzzell, 2007; Bhat & Sardesai, 2006; Hensher et al., 2003; Friman & Gärling, 2001
	Air Conditioning	
	Seating Availability	
	Low Floor	
	Not Crowded	
	Accessibility	
Safety	Less Travel Time	Felleson & Friman, 2008; Nolan 2007; Eboli & Mazzulla, 2007; Hensher et al., 2003; Friman, Edvardsson, & Gärling, 2001
	Lesser Accident	
	Personal Safety	
	Staff behavior & attitude	
Reliability	Good Frequency	Redman, Friman, Gärlingb, & Hartig, 2013; Tirachini & Hensher, 2011; Felleson & Friman, 2008; Eboli & Mazzulla, 2007; Gatersleben & Uzzell, 2007; Bhat & Sardesai, 2006; Hensher et al., 2003; Rietveld, Bruinsma, & Vuuren, 2001; Friman, Edvardsson, & Gärling, 2001
	Adherence to Schedule	
Cost	Cost of travel	Sherestha 2013; Eboli & Mazzulla, 2007; Friman & Gärling, 2001

Table 3: Statistics summary of survey results.

Survey data	Respondents (in %)
Age group (years)	
15-25	45
26-40	31
41-60	20
>61	04
Gender	
Male	58
Female	42
Preferred mode of transport	
Public	54
Private	46
Public transport used - categories	
Metro	25
Bus	52
Three wheeler	16
Rickshaw	04
Local Train	03
Use of public transport	
For work	61
Others	39
Distance to reach Public Transport	
250 m or less	24
250 m – 500 m	20
500 m – 1 km	29
More than 1 km	26
Mode used to cover above distance	
Foot	32
Three wheeler	57
Rickshaw	08
Feeder Bus	03
Willingness to shift to public transport	
Yes	94
No	06

Table 4: Weights for different criteria of an efficient public transport system

Criteria	Average weights	CI+	CI-
Comfort	0.16	0.18	0.15
Reliability	0.27	0.28	0.25
Safety	0.36	0.38	0.32
Low Cost	0.21	0.22	0.19

Table 5: Weights for different sub-criteria for efficient public transport system

Sub-criteria	Local priority weights	Global priority weights
Comfort		
Cleanliness	0.12	0.02
Air Conditioning	0.05	0.01
Seating Availability	0.12	0.02
Low Floor	0.08	0.01
Not Crowded	0.16	0.03
Accessibility	0.25	0.04
Less Travel Time	0.22	0.04
Reliability		
Good Frequency	0.61	0.16
Adherence to Schedule	0.39	0.11
Safety		
Lesser Accident	0.33	0.12
Personal Safety	0.42	0.15
Staff behavior & attitude	0.25	0.09

Figure

Adminstrative Divisions

Figure 1: Survey locations in Delhi city

Figure 2: AHP hierarchy for an efficient public transport system

Figure 3: Survey results showing commuter preferences and willingness to pay for public transport

(a) Sub-criteria under safety

(b) Sub-criteria under reliability

(c) Sub-criteria under comfort

Figure 4: Commuters choice for public transport system – Sub-criteria