COMPREHENSIVE ASSESSMENT OF SUSTAINABILITY INDICATORS FOR PUBLIC TRANSPORTATION SYSTEM INCLUDING PEDESTRIANS AND FEEDER SERVICES – A CASE STUDY OF DELHI

AMIT DAHIYA

Civil Engineering Department, India

Civil Engineering Department,
National Institute of Technology Patna,
Ashok Rajpath, Patna, Bihar 800005, India
E-mail: amit.dahiya05@gmail.com

RAVINDRA KUMAR*
AND
ERRAMPALLI MADHU

CSIR-Central Road Research Institute (CRRI), India

Principal Scientist, Transportation Planning Division,
CSIR-Central Road Research Institute (CRRI),
New Delhi 110025, India,
E-mail: ravindra261274@gmail.com
E-mail: ravinder.crri@nic.in

SANJEEV SINHA

National Institute of Technology Patna, India

Head of Civil Engineering, Transportation Engineering Section,
National Institute of Technology Patna,
Ashok Rajpath, Patna, Bihar 800005, India

*Corresponding author

ABSTRACT

Purpose: The purpose of this paper is to estimate comprehensive sustainability indicator for Public Transportation System Including Pedestrians and Feeder Services.

Design/methodology/approach: Sustainable transportation related indicators were initially selected for public transportation system (namely for metro, bus and feeder bus) and pedestrians based on past researches. Subsequently, other important indicators have been added to achieve significant sustainability score and a total of 17 indicators were selected for assessment of comprehensive sustainability (seven indicators under Economic, six under Social and four under Environmental categories).

Findings: A hybrid approach based on the Analytical Hierarchy Process (AHP) is considered for assessment of the Sustainability of Public Transportation System including pedestrians and feeder services, For which, specific user interview surveys are performed in South Delhi region and accordingly operational characteristics of the public transport system were also collected.

Originality/value: AHP method is applied for rating the criteria and setting out the priority of designed sustainable indicators. Subsequently sustainable mitigation measures and scenarios for the study area can be evaluated utilising developed comprehensive sustainability indicator for Public Transportation System Including Pedestrian and Feeder Services.

Keywords: sustainable public transportation system; Analytical Hierarchy Process; AHP; sustainability indicators, etc.

INTRODUCTION

Today in the operating environment urban transport systems are facing a radical change due to rapid growth of traffic and population in developing countries. Major cities of many developing countries are facing problems due to rapid increase in vehicle ownership while the road network density and the road-widths still remain the same. As the ownership increasing the level of utilisation of public transport systems is reducing specially in Delhi and getting low in most developing countries.

Therefore a need of common sustainability transportation indicators are required to understand the severity of congestion, transportation demand and supply, and the impact of transport projects on the social, economic and environmental spheres of the society. In this paper, transportation related sustainable indicators were selected for public transportation system (metro, bus and feeder) and pedestrian by reviewing past researches. Some more sustainability related parameters were added to achieve more significant score regarding sustainability by assessment of the selected indicators (no. of indicators: Economic-7, Social-6, Environmental-4). A hybrid approach based on the Analytical Hierarchy Process (AHP) is considered for assessment of the Sustainability of Public Transportation System including pedestrian and feeder services in South Delhi region. AHP is used for rating the criteria and setting out the priority of designed sustainable indicators. Later on, sustainability score is achieved after assessment for the selected routes.

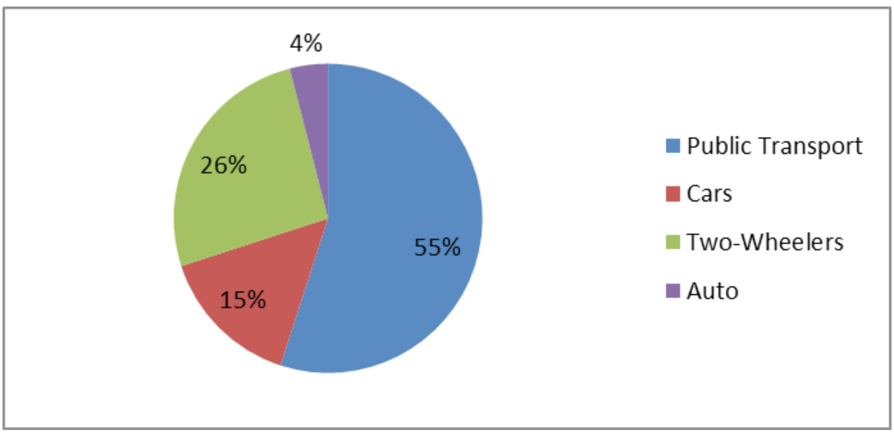
LITERATURE REVIEW AND EXISTING CONDITION

Sustainable Transportation and Sustainability Indicators of Public transportation System are ways of quantifying objectives or sub-objectives. For example, casualty numbers would measure the overall safety objective; locations exceeding a pollution threshold a part of the environmental objective. However, output and intermediate outcome indicators may be helpful in understanding how a change in performance has been obtained. To be effective, outcome indicators must be exhaustive, in that they cover the whole range of objectives, provide sufficient information to decision-makers, and be sensitive to changes in the strategies that are tested (Source: http://www.konsult.leeds.ac.uk/dmg/07/).

Hernandez-Moreno and De Hoyos-Martines (2010) defined the concept of sustainability as a need of the current society to be satisfied without compromising the needs of future generations. While, urban sustainability has been defined as a concept that emphasises on the interrelationship between transport networks, urban structure and urban life (Newman and Kenworthy, 1999). To achieve sustainability in any field a single indicator is not enough and Litman also concluded this in his research also. Litman (2010) concluded that a single indicator is not adequate to encompass sustainability but a set of indicators, which should reflect various goals, objectives and impacts should be used. Sinha (2003) identified various causes for which the sustainability is less in the developing countries. Increasing of urbanisation in an unparalleled way, increase of motorisation and decreasing use of public transport. Their study concluded that sustainability, transit, land use and technology are intrinsically related. Sustainability indicators varies from country to country because of different approaches and priorities (Zavadskas et al., 2005). Indicators are best way to move human activities towards the direction of sustainability (Jemelin and Jolliet, 2003). Sustainability indicators tend to be quantitative and explicit but in practice more qualitative and implicit is used (Bell and Morse, 2001). Kennedy (2005) proposes four pillars for sustainable transportation namely: effective governance of land use and transportation; fair, efficient, stable funding; strategic infrastructure investment and attention to neighbourhood design. Black (1997) investigates sustainable transportation in North America. Anderson et al. (2005) present means and measures through which freight transport can be made more sustainable.

Urban Transport Problem Scenario in New Delhi: Delhi has an extensive road network. The road network of 14,316 km lane that existed in 1981 was expanded to 28,508 km lane in 2001 and 31,373 km lane in 2009. The total number of vehicles registered too demonstrated a significant increase from 562,000 in 1981 to 3,457,000 in March 2001 and 6,933,000 in March 2011 (Website: Delhi Government_1). Figure 1 shows modal shares of daily trips in Delhi.

According to the (GOI, 2012) number of registered motor vehicles in Delhi exceeded the combined vehicle population of four cities (Chennai, Kolkata, Lucknow and Mumbai). Number of passengers cars in Delhi has been calculated as 18,81,135 (171 cars per 1000 people), as opposed to 5,11,457 (109 cars per 1000 people) in Chennai, 1,42,861 (51 cars per 1000 people) in Lucknow and 5,09,246 (41 cars per 1000 people) in Mumbai. Table 1 shows projected modal splits of traffic. Table 2 shows recommended Sustainability Indicator Set by PROPOLIS. Table 3 shows recommended Sustainability Indicator Set by KONSULT.



Source: Delhi Govt. website.

Figure 1 Modal shares of daily trips in Delhi 2007

Table 1 Projected modal splits

S.No.	Mode	Daily Trips-2021 (Intra City)	Modal Share (%)	Daily Trips-2007	Modal share (%)
1	Car	2,983,510	17.1	1,806,380	15.5
2	Two Wheeler	3,490,954	20.0	2,976,832	25.5
3	Auto	549,351	3.2	518,329	4.4
4	Public Transport	10,409,024	59.7	6,369,088	54.6
	Total	17,432,839	100	11,670,629	100

Source: Delhi Govt. website.

Table 2 Recommended sustainability indicator set by PROPOLIS

Sustainability Dimension	PROPOLIS	
	Indicators	Parameters
Environmental Indicators	Global climate change	Greenhouse gases from transport.
	Air pollution	Acidifying gases from transport.
		Volatile organic compounds from transport.
	Consumption of natural resources	Consumption of mineral oil products, transport.
		Land coverage.
		Need for additional new construction.
	Environmental quality	Fragmentation of open space.
		Quality of open space.
Social indicators	Health	Exposure to PM from transport in the living environment.
		Exposure to NO_2 from transport in the living environment.
		Exposure to traffic noise.
		Traffic deaths.
		Traffic injuries.
	Equity	Justice of distribution of economic benefits.
		Justice of exposure to PM.
		Justice of exposure to NO_2.
		Justice of exposure to noise.
		Segregation.
	Opportunities	Housing standard.
		Vitality of city centre.
		Vitality of surrounding region.
		Productivity gain from land use.
	Accessibility and traffic	Total time spent in traffic.
		Level of service of public transport and slow modes.
		Accessibility to city centre.
		Accessibility to services.
		Accessibility to open space.
Economic indicators	Total net benefit from transport	Transport investment costs.
		Transport user benefits.
		Transport operator benefits.
		Government benefits from transport.
		Transport external accident costs.
		Transport external emissions costs.
		Transport external greenhouse gases costs.
		Transport external noise costs.

Table 3 Recommended Sustainability Indicator Set by KONSULT

Sustainability Dimension	*KONSULT*	
	Indicators	*Parameters*
Environmental Indicators	Environmental Protection	Vibration
		Level of different air quality (local) pollutants
		Visual intrusion
		Townscape quality (subjective)
		Fear and Intimidation
		Severance (subjective)
		CO_2 emissions of the area as a whole
		Fuel Consumption for the area as a whole
	Sustainability	
Social indicators	Safety and Security	Personal injury, accidents by user type per unit exposure (for links, intersections and networks)
		Insecurity (subjective)
	Accessibility	Activities (by type) within a given time and money cost for a specified origin and mode
		Weighted average time and money cost to all activities of a given type from a specified origin by a specified mode
		Indicators as above, considered separately for different impact groups
	Equity	
Economic indicators		Delays for vehicles (by type) at intersections
		Delays for pedestrians at road crossings
	Economic Efficiency	Time and money costs of journeys actually undertaken
		Variability in journey time (by type of journey)
		Costs of operating different transport services
	Economic regeneration	Environmental and accessibility indicators as above, by area and economic sector
		Operating costs and revenues for different modes
		Cost and revenues for parking and other facilities
	Finance	Tax revenue from vehicle use

Many application has been used to understand transportation sustainability indicators in which Multiple Criteria Decision Making (MCDM) Approaches for Evaluation MCDM methods are widely diverse. Chen and Hwang (1991) classified a group of MCDM methods according to the type of information and the salient features of information received from the decision maker. MCDM is one of the established branch of decision. Most commonly used MCDM methods:

- The Weighted Sum Model (WSM)
- The Weighted Product Model (WPM)
- The AHP.

METHODOLOGY

The level of utilisation of public transport systems remains pathetically low in most developing countries. Though, various studies were carried out by researcher's in the field of sustainability of public transportation system. The use of indicators in the field of urban transport can help identify critical areas that need to be improved to popularise the use of public transport. Figure 2 shows the details on the methodology adopted in the present study.

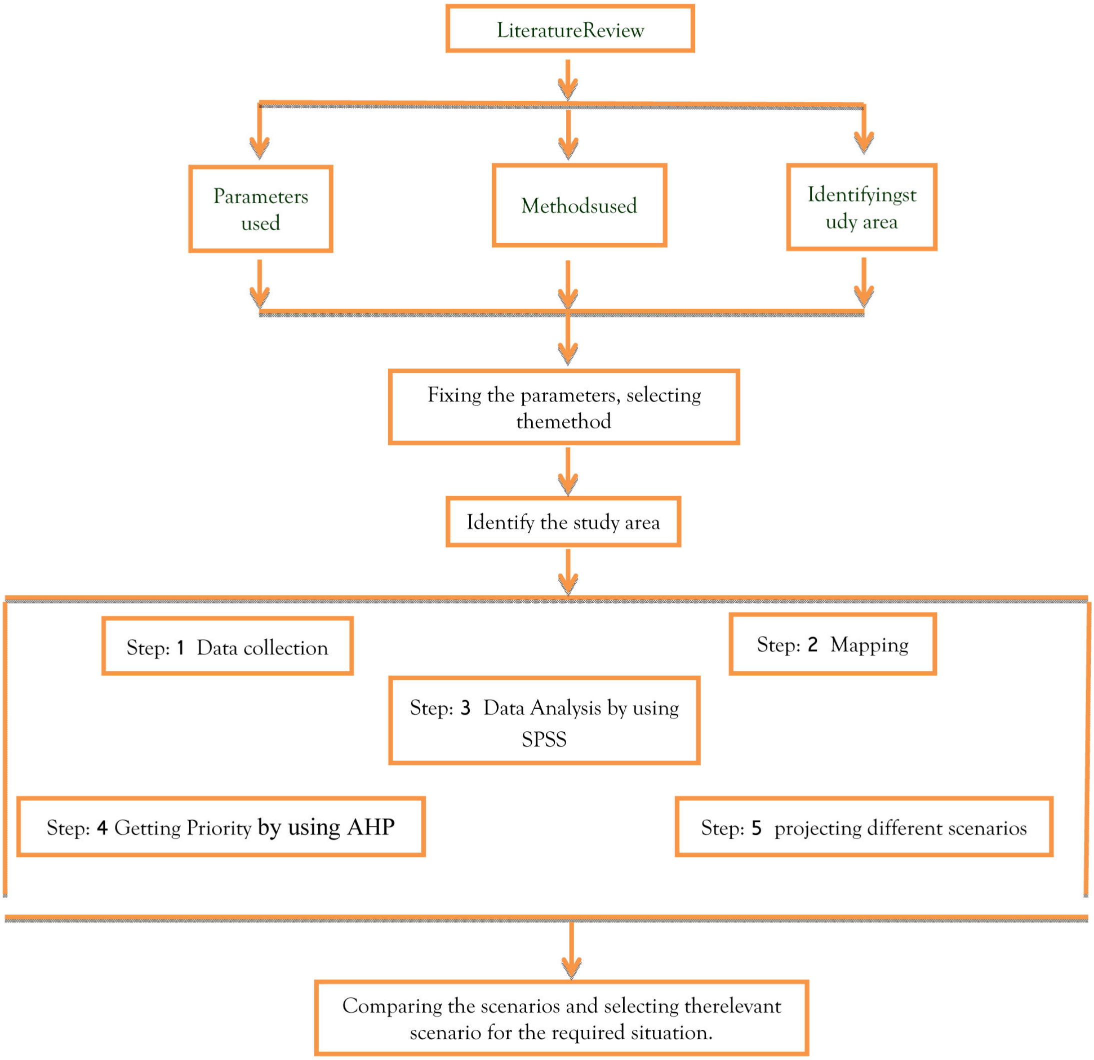


Figure 2 Flow chart of the Methodology

ASSESSMENT APPROACH

Approach taken up for the assessment of indicators of sustainability for public transportation involves technique namely AHP. AHP is used to allocate weights or rate to the selected criteria for assessment of public transportation.

Saaty (1990) proposed AHP and it is a multi-criteria decision-making technique. AHP consist of various steps which are as follows.

- Defining the problem and determining its goal.
- Structuring the hierarchy from the top (the objectives) through the intermediate levels (criteria) to the lowest level (alternatives).

- Constructing a set of pair-wise comparison matrices (size $n \times n$) for each of the lower levels with one matrix for each element in the level immediately above by using the relative scale measurement shown in Table 4.
- The pair-wise comparisons are done in terms of preference of one element over the other. There are $n(n - 1)/2$ judgments required per matrix to develop the set of matrices in step 3. Reciprocals are automatically assigned in each pair-wise comparison. Having made all the pair-wise comparisons, the consistency is determined by using the eigenvalue λmax to calculate the consistency index CI where CI = $(\lambda max - n)/(n - 1)$ where n is the matrix size. Judgment consistency can be checked by seeing the value of consistency ratio CR for the appropriate matrix value in Table 5.
- If CR $\leq$ 0.1, the judgment matrix is acceptable otherwise it is considered inconsistent. To obtain a consistent matrix, judgments should be reviewed and improved. Hierarchical synthesis is now used to weight the normalised eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.

The strength of AHP is that it allows the verification of transitivity property in criteria weights, that is if criteria a has higher weight than criteria b which has higher weight than criteria c, then criteria a will always have higher weight than criteria c. This is the reason why it is chosen over other simple weight allocation techniques.

Table 4 Pair-wise comparison scale for AHP preferences

Numerical Rating	Verbal judgment of preferences
1	Equally preferred
3	Moderately preferred
5	Strongly preferred
7	Very strongly preferred
9	Extremely preferred
2, 4, 6, 8	Intermediate values between the two adjacent judgments
Reciprocals	When activity *i* compared to *j* is assigned one of the above numbers, then activity *j* compared to *i* is assigned its reciprocal

Find the Eigen Vector of the matrix:

Matrix N for n (=3) criteria; [for $n = n^2 - n/2$)]

$$N = \begin{bmatrix} 1 & a_{12} & a_{13} \\ a_{12^{-1}} & 1 & a_{23} \\ a_{13^{-1}} & a_{23^{-1}} & 1 \end{bmatrix}$$

Sum of columns $= Sc_1\ Sc_2\ Sc_3$

Normalise and calculate first normalised principle Eigen vector x_1:

$$|N| = \begin{bmatrix} \frac{1}{Sc_1} & \frac{a_{12}}{Sc_2} & \frac{a_{13}}{Sc_3} \\ \frac{a_{12^{-1}}}{Sc_1} & \frac{1}{Sc_2} & \frac{a_{23}}{Sc_3} \\ \frac{a_{13^{-1}}}{Sc_1} & \frac{a_{23^{-1}}}{Sc_2} & \frac{1}{Sc_3} \end{bmatrix}$$

Eigen Vector X_1

$$X_1 = \begin{bmatrix} \sum \frac{row_1}{n} \\ \sum \frac{row_2}{n} \\ \sum \frac{row_3}{n} \end{bmatrix}$$

Square normalised matrix $|N|$ and calculate next iteration of Eigen Vector until difference $X_{k+1} - x_k$ is neglect able $X_2 |N|^2$.

Find the Eigen vector of the matrix

Calculate largest Eigen value λ:

$$\lambda = Sc_1x_1 + Sc_2x_2 + Sc_3x_3$$

Calculate Consistency Index:

$$CI = \frac{\lambda - n}{n-1}$$

Verify Consistency Ration <10%: CR = CI/RI

Average random consistency (RI) (Table 4):

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0.5	0.8	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Estimation of transportation sustainability: The global utilities are used to determine the city sustainability at any given time t using a Transport Sustainability Index (TSI). Let us denote the global utilities for the criteria $C_1, C_2, \ldots, C_N$ at time t_n by $u_1(t_n), u_2(t_n), u_3(t_n), \ldots, u_N(t_n)$.

Then, the TSI at time t_n is given by:

$$TSI(t_n) = u_1(t_n) \times w_1 + u_2(t_n) \times w_2 + u_3(t_n) \times w_3 + \ldots + u_n(t_n) \times w_N$$

Where $w_1, w_2, \ldots, w_N$ represent the weights of criteria $C_1, C_2, \ldots, C_N$ obtained from AHP.

Table 5 Set of Indicator prepared for this study

Global Objective	*Sub-Objectives*	*Criteria*
	Environmental Effects	Noise Pollution
		Energy Consumption
		Land Consumption
		Air Pollution
Sustainability	Social Effects	Public Health
		User Rating
		Affordability
		Accessibility
		Safety and Security
		Additional facilities provided
	Economic Effects	Household expenditure allocated to transport
		Transport Emission Cost
		Productivity
		Transfer time
		Transport costs and prices
		Additional Employment
		Economic efficiency

RESULT AND DISCUSSION

AHP has been designed in this case as two level of hierarchy as shown in Table 6. The result obtained shows different weights as compared to three main parameters defining sustainability is shown in Table 7.

Table 6 AHP designed for transport sustainability indicators

Decision Hierarchy

Level 0	*Level 1*	*Level 2*	*Global priorities*
Transportation Sustainability	Environment 0.3333	Noise pollution 0.1343	4.5%
		Air pollution 0.5907	19.7%
		Energy consumption 0.213	7.1%
		Land consumption 0.062	2.1%
	Social 0.3333	Public health 0.428	14.3%
		User rating 0.1256	4.2%
		Affordability 0.0935	3.1%
		Accessibility 0.1082	3.6%
		Safety and Security 0.2166	7.2%
		Additional facilities provided 0.0282	0.9%
	Economic 0.3333	Household 0.2625	8.8%
		Transport emission cost 0.057	1.9%
		Productivity 0.282	9.4%
		Travel time ratio 0.1741	5.8%
		Transport costs and prices 0.0692	2.3%
		Additional Employment 0.0751	2.5%
		Economic efficiency 0.0802	2.7%
			1.0

Consolidated Global Priorities

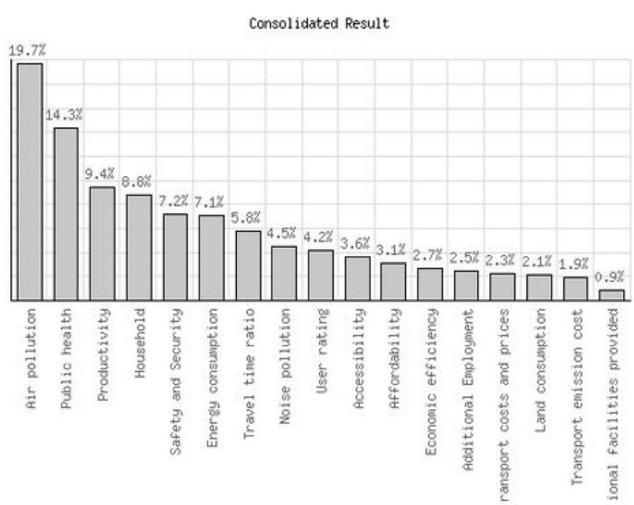


Table 7 Results from AHP process

	Global priorities value	Homogenised utility value	
Environmental Effects			
Noise Pollution	4.5	0.5956	2.6802
Energy Consumption	7.1	0.6206	4.4063
Land Consumption	2.1	0.5286	1.1101
Air Pollution	19.7	0.6047	11.913
	33.4		*20.1096*
Social Effects			
Public Health	14.3	0.6087	8.7044
User Rating	4.2	0.6068	2.5485
Affordability	3.1	0.6559	2.332
Accessibility	3.5	0.3253	1.1385
Safety and Security	7.2	0.4297	3.0938
Additional facilities provided	0.9	0.2039	0.1835
	33.2		*18.0007*
Economic Effects			
Household expenditure allocated to transport	8.8	0.5532	4.8681
Transport Emission Cost	1.9	0.4407	0.8373
Productivity	9.4	0.3704	3.4817
Transfer time	5.8	0.6834	3.9637
Transport costs and prices	2.3	0.5512	1.2677
Additional Employment	2.5	0	0
Economic efficiency	2.7	0.6038	1.6302
	33.4		*16.0487*
Total	*100*		*54.159*

In these preliminary result an online AHP software is used which is based a dummy data which shows the approach of the present study in the selected area in the field of sustainability. The weightage used for the parameter is according to global priority which is attained by the online AHP software (*source*: http://bpmsg.com/academic/ahp.php) by itself. In actual the priority (weightage) of the individual parameter with each other is being carried out by a survey which is done through the expert opinion in which importance will give to the parameter over another on the scale of 1 to 9 and then the weightage in term of priority of the individual parameter over another can be found out and then multiplying the homogenised utility value with the weightage of the parameter and sum of all of them give the value of sustainability index. The result shown in this paper is basic only on the basis of public transportation system data assumed for the outer ring road (South Delhi Region). The further investigation is being carried out which will comprise of all the data together for the parameter set prepared for this study for the assessment of sustainability indicators for public transportation system including pedestrian and feeder services.

CONCLUSION

This paper provide an approach for determination of sustainability of public transportation system including Pedestrian and feeder services in the South Delhi region. Priority indicator are the indicator which affect the sustainability by getting weightage. We can concentrate on the indicator after getting priority which affect sustainability to achieve maximum sustainability in the field of transportation. In this paper an integrated decision-making approach based on AHP for assessment of transport measures on city sustainability is presented. The approach comprises of selecting evaluation criteria, data collection and evaluation of city sustainability using a TSI and impact assessment of the existing public transportation. The current work will comprises of the selected indicators of sustainability which are less in number due to time limit. Future work will involve assessment of public transportation sustainability by making an indicator set of more parameters in number and with that more accurate sustainability will be achieved.

ACKNOWLEDGEMENT

We would like to thank the Director CRRI and to specially thank the experts who kindly participated in our study and our colleagues, for their contribution to the field measurements campaign.

REFERENCES

Anderson, S., Allen, J. and Browne, M. (2005) 'Urban logistics e how can it meet policy makers' sustainability objectives?' *Journal of Transport Geography*, Vol. 13, No. 1, pp.71–81.

Bell, S. and Morse, S. (2001) *Sustainability Indicators: Measuring the Immensurable*, London: Earthscan Publishing.

Black, W.R. (1997) 'North American transportation: perspectives on research needs and sustainable transportation', *Journal of Transport Geography*, Vol. 5, No. 1, pp.12–19.

Chen, S.J. and Hwang, C.L. (1991) 'Fuzzy multiple attribute decision making: methods and applications', *Lecture Notes in Economics and Mathematical Systems*, No. 375, Berlin, Germany: Springer-Verilag.

Corbiere-Nicollier, T., Ferrari, Y., Jemelin, C. and Jolliet, O. (2003) 'Assessing sustainability an assessment framework to evaluate Agenda 21 actions at the local level', *International Journal of Sustainable Development and World Ecology*, Vol. 10, pp.225–237, Available at: http://dx.doi.org/10.1080/13504500309469801.

Government of India (GoI) (2012) *Road Transport Year Book 2009-10 & 2010-11*, Transport Research Wing, Ministry of Road Transport, New Delhi.

Hernandez-Moreno, S. and De Hoyos-Martinez, J. (2010) 'Indicators of urban sustainability in Mexico', *Theoretical and Empirical Researches in Urban Management*, Vol. 7, No. 16, pp.46–60.

Kennedy, C. (2005) 'The four pillars of sustainable urban transportation', *Transport Reviews*, Vol. 25, No. 4, pp.393–414.

Litman, T. (2010) 'Sustainability and livability: summary of definitions, goals, objectives and performance indicators, VTPI', Available at: www.vtpi.org; www.vtpi.org/sus_liv.pdf.

Newman, P. and Kenworthy, J. (1999) *Sustainability and Cities*, Washington, DC: Island Press.

Saaty, T.L. (1990) 'How to make a decision: the analytic hierarchy process', *European Journal of Operational Research*, North-Holland, Vol. 48, pp.9–26.

Sinha, K.C. (2003) 'Sustainability and urban public transportation', *Journal of Transportation Engineering*, Vol. 129, No. 4, pp.331–341.

Zavadskas, E.K., Kaklauskas, A. and Saparauskas, J. (2005) 'Sustainable urban development and web-based multiple criteria analysis', *Foundations of Civil and Environmental Engineering*, Vol. 6, pp.217–226.

WEBSITE

DelhiGovernment_1: Transport, Govt. of NCT, Delhi, Available at http://delhi.gov.in/wps/wcm/connect/f469b2804c2c2c5a81d85999 1226613/11+-+22+Transportpdf?MOD=AJPERES&lmod=-358026974&CACHEID=f469b2804c2c2c5a8 1 9d85999 1226613.

Business Performance Management: Concepts, Methods and Tools to manage Business Performance, Available at: http://bpmsg.com/academic/ahp-hierarchy.php.

BIOGRAPHICAL NOTES

Ravindra Kumar earned his PhD (Engineering) at Edinburgh Napier University (UK) and a Master's Degree (Engineering) at the University of Roorkee (now the Indian Institute of Technology). He has worked for the premiere Central Road Research Institute India for the last 16 years and is a Principal Scientist in the Transport Planning Department, also working as Research Fellow at the Transport Research Institute, Edinburgh. His current research focuses on travel behaviour and its impacts, transportation and road network planning, evaluating and mitigating the environmental impacts, assessment of road transport on urban air quality, with a special focus on rehabilitation and resettlement planning, real-world driving cycle and vehicular emission using advanced instruments and developing emission factors based on onboard, microsimulation and chassis dynamometer. He supervises a number of under and post-graduate project students, besides research and consultancy research. He is a Life Member of the Indian Road Congress, and a Member of CILT UK. He has completed over 20 sponsored research and consultancy projects, published more than 40 research papers in various journals and presented at national and international conferences.

Errampalli Madhu is Principal Scientist in Central Road Research Institute (CRRI), New Delhi and has an experience of about 15 years in R&D and Consultancy activities in the field of Transport planning, Traffic flow modelling and Microscopic simulation, Intelligent Transportation Systems, Road safety audit, Computer application in transport modelling such as fuzzy logic, neural network, etc. He is a Recipient of Japanese Government Scholarship (Monbugakusho) 2004–2008 and completed PhD during this period at Gifu University, Japan. He has received Bronze Medal from IRC two times for the publications in the year 2004 and 2011. He has also received best article award received by ASRTU in 2009 for his publication in Indian Journal of Traffic Management and Session best presentation in SCIS & ISIS 2006, University of Tokyo, Japan. He has published about 80 research papers in various SCI, refereed and conference proceeding.

Amit Dahiya is MTech student in the field of Transportation Engineering (2013–2015) of Civil Engineering Department, National Institute of Technology Patna. He has completed BTech in Civil Engineering (2008–2012) with 1st division from M.M. Engineering College, Maharishi Markandeshwar University, Ambala, Haryana, India. He is Student Coordinator of 'Green Planet Saviours' society of MM University and Organiser in 'Sky Scrapers' society of Civil Engineering Department of MM University.

Sanjeev Sinha is presently Professor and Head of the Department of Civil Engineering at National Institute of Technology Patna, India. He had obtained his doctoral degree from Asian Institute of Technology, Thailand and his Master's degree from Indian Institute of Technology Roorkee, India. He has over 19 years of teaching experience at the bachelor's and master's level in the field of Traffic and Transportation Engineering. He is a Recipient of Khosla Commendation Award of IIT Roorkee for the year 2002. He had published over two dozen research papers in various international and national journals and conferences. He had guided about 20 master's dissertation and presently he has three doctoral research scholars and six master's student. He is the State Technical Agency (STA) Coordinator for PMGSY (A central government scheme for construction of rural roads in India) and also the Coordinator for the World Bank project of Technical Education Quality Improvement Program (TEQIP) for National Institute of Technology Patna. He has been principal investigator for various research and consultancy related projects.