JUET Research Journal of Science & Technology
5 (1), January 2019, 14-26
http://www.publishingindia.com/juet

Route and Mode Choice Analysis for Sustainable Transport Through Multimodal Mobility Pattern in Hill Town of Shimla

Puneet Sharma[1*], Dharmendra[2] and Sumit Gandhi[3]

[1]Assistant Professor, Department of Architecture, NIT Hamirpur, Himachal Pradesh, India.
E-mail: architect.puneet@gmail.com
[2]Assistant Professor, Department of Civil Engineering, NIT Hamirpur, Himachal Pradesh, India.
[3]Associate Professor & Head, Department of Civil Engineering, JUET, Guna, Madhya Pradesh, India.
*Corresponding Author

Abstract: Shimla, a hill town, has emerged as a major tourist destination in the last decade. The city is facing major breakdown in its transportation system due to high inflow of floating population. Conjunction in core city area along its major spine and connectivity between old and new transit terminals are the most intense transport related problems of the city. This research aims at finding out alternative routes and modes to overcome these issues. It is an attempt to explore the impact of multimodal network in this hill town. First half of research deals with identification of new routes by using multi criteria analysis whereas second half identifies the preferred mode choice for public transport through people choice survey. Integrated results related to route feasibility and mode choice indicate huge saving in terms of travel time, transport energy and GHG emissions.

Keywords: Energy usage, Hilly region, Mode choice, Transport system.

I. Introduction

Shimla is a well-known tourist destination in northern region of India. Pleasant weather conditions, immense natural beauty and rich cultural heritage have attracted tourists from across the world in recent years. Being the capital town of Himachal Pradesh the city is playing multiple roles ranging from administrative, recreational, educational and commercial (Shekhar, 2011). Nearly 15000 tourists visit the city during peak tourist seasons (TCP, 2014) as per the latest survey. This huge inflow of tourists is posing immense pressure on its transport system. In order to cater huge floating population and continuous growth there is an urgent need of implementing sustainable modes and alternate routes in inner city transport network. In Shimla only 20% trips are by bus and 55% are on foot (TCP, 2014), thus there is a huge scope of integration of movement pattern through new routes and feasible alternative modes. It is important to implement context based development strategies in achieving decisive sustainable development which responds to the existing settlement pattern (Hickman, 2007). In hill towns, due to their topography transport network acts as the life line of the city and its urban form revolves around it. Henceforth, it acts as the most critical element for sustainable development. As per government of India, urban mobility is defined as one of the core of sustainable solutions (MUD, 2015). This research aims at finding out a multimodal network for Shimla that takes into account both the people choice and environmental aspects on a uniform basis. The research also focuses on the psychology of the transport users who are now perceived as active agents in planning of the transport system. In today's world the role of personal choice in decision to use public transportation is very crucial for sustainable development (Bamberg, 2007). Transport policy measures are relatively more successful if capabilities and perceived constraints of users are taken into account (Gehlert 2013). The focus of this research is to enhance city image, traveling experience and travel quality through introduction of latest means of travel modes and multimodal network in hill town. Scope of introducing new transit modes and corridors in Shimla city will help in creating sustainable urban form. Existing city conditions of Shimla give an opportunity to frame the guidelines for a future urban form guided by sustainable multimodal transport. It is an investigation that reveals the choices to be made for public transport in hill towns toward energy, environmental and economic perspective. Research finally demonstrates the significance of mixed mobility pattern in public transport to generate sustainable and energy efficient urban form in hill towns.

II. Literature Review

Relationship between transport system and mode choice has been studied under different heads by the researchers in the past. According to Gibson (1997) the urban movement system along with its qualities (both mode and route design) and the other demands of city is a measure of urban sustainability. Ewing and Cervero (2001) derived that explanatory and control variables are often measured on richer ratio measurement giving these variables a predictive edge in statistical analyses over the land-use and design variables. Cervero (2002) concluded that built environment has three core dimensions namely density, diversity and design. Travel-related choices, to a great extent, depend on perceived qualities (Targa, 2004). Kenworthy (2006) anticipated an array of travel alternatives focused on walking and public transport for smart and sustainable development. Another important aspect of sustainable mobility is travel behaviour. Mode choice is usually treated as rational choices to maximize personal utility or net benefit (Small, *et al.*, 2005). Many past studies on the travel behavior have expressed the influences of generalized costs on mode choice. Few researchers have even included safety, prestige and autonomy (Curtis, 2006) as factors on mode choice in their respective research. As an alternative approach, sustainable mobility should focus on social dimensions, accessibility and people (Banister, 2008). Such interventions should have local scale and vision for cities. Witte (2013) has defined model choice as a decision process between different alternatives, determined by socio-demographic, spatial and socio-psychological factors. Analysis showed that perceptional variables are rarely studied for travel behavior whereas socio demographic variables are studied by large number of researchers giving an edge to later ones. Environmental variables are important predictors of walking for transport network (Saelens, 2009). Sustainability, in Indian context, needs to be evaluated from place to place bases. Studies in India advocated the role of multi modal transport system for sustainable development (Reddy *et al.,* 2000; Satmohini *et al.,* 2001). For sustainable development in hill areas (Nesamani, 2003) promotion of public transport is a must. Chattopadhyay (2008) suggests that multi-modal urban region may provide some solution with the help of transport, which should be environmentally sustainable. Das (2014) suggested implementation of public transport through cable car, Sky Bus, Mono Rail as Light Mass Rapid Transit System in hill towns of India. In recent years public transportation modes (ropeways and funicular railway) have emerged as preferred choice of travel (Hoffmann, 2006; 2009) within hill regions. Enormous reduction in energy consumption and green house gas emission can be achieved by introducing alternative feasible modes over car and bus in hill areas. From literature appraisal variables can be categorized as socio-demographic variables (gender, age, income and educational status), design variables (imageability, legibility, context and environment) and psycho-social variables (safety, easement, travel time and social interaction). Along with other variables role of regional geography and energy consumption play a vital role in achieving sustainable development. Although there is a broader literature related to urban form and travel behaviour, limited works are related to hill towns. Due to very limited empirical work, particularly in case of hill towns, this research acts as the starting point in this direction. A wide and comprehensive study on available literature helped in identifying the variables and understanding their impact. Present research is based upon understanding and response of city resident's on variables like safety, imagebility, legibility, quality of travel, speed, environment, climate and social interaction towards multimodal system.

III. Research Methods and Techniques

Clifton *et al*., 2001, augmented that without recognition of the qualitative research techniques in travel behaviour research, we will make little meaningful progress towards improving our fundamental understanding of travel behavior. Doing qualitative research is more challenging than the quantitative transportation research. The nature of qualitative research raises several issues concerning theoretical framework, data collection, and analysis. This research tries to include more qualitative aspects in the analysis for predicting mode choice. As per government of India one way to understand the scope of developing new infrastructure is to do feasibility studies (MEF, 2010; DOT, 2015). Some of the methods like Environment Impact Assessment (EIA), cost assessment and Cost-Effectiveness Analysis (CEA) are used for feasibility analysis and revealed from literature are Environment and Social Impact Assessment (ESIA) and cost assessment, Multi Criteria Analysis (MCA). Most of these research approaches for route feasibility usually move around cost analysis. These instruments have their utility but they fail to incorporate the points of view of the users and restrict the analysis to specific criteria for monetary values (Macharis, 2012). According to Tsamboulas (1999) these approaches are less effective in the context of sustainability as several objectives are difficult to quantify and certainly in terms of monetary values (e.g., quality of public transport, value of city image, comfort and ease of usage etc.). Some researchers advocated that the appraisals of large transport projects can be effectively supported using a combination of CBA and MCA (Barfod *et al.,* 2011). Macharis (2010) used Multi-Criteria Analysis as a methodology to evaluate different policy measures in terms of mobility. Although a full CBA takes into account demand forecasts and the social benefits of travel time savings but fails to calculate number of factors like impact of heat island effect, imagebility of city, spillover effects due to environmental loss, climatic change (excessive heat waves, cloud burst), change in temperature forcing city dwellers to have pay more for comfort living and unaccounted loss caused due to natural incidents. Development of sustainable transport in hill regions starts with the basic understanding regarding geography, climate, culture and economic conditions. While considering public transport projects for successful and sustainable model it is important to involve users and consider their viewpoint. Methods and techniques for such research ranges from field studies, case studies (Kengpol *et al.,* 2012), survey (Kuppam *et al.,* 1999) and user studies through informative techniques. Few of the tested approaches like visual analysis (Winston *et al.,* 2004) and people perception survey were also employed in the past to reveal the users perception towards mode choice.

IV. Methodology

Researchers in the past have used the survey and case study to carry out the research related to mode choice and similar approaches have been applied in present study. From literature it is evident that in mode choice analysis, generally used techniques are multi-criteria analysis, correlation, multi nominal logit regression, probit analysis, delphi method, weighted average and chi-square test. Review also indicates that multi-criteria analysis and delphi analysis are among few preferred research tools to identify the relationship. An important advantage of multi-criteria analysis is that it supports the final decision by inclusion of different points of concerns leading to a general prioritization of the proposed policy measures. As the research concentrates on the multimodal network, it was essential to do the route feasibility while considering permutation and combination with different modes. In present context research framework is organized in three phases due to diverse objectives. In first phase case study method has been used to identify latest modes that are in use for public transportation in hill areas. For comparing different modes, aspects like carrying over all capacity, speed and unit design were considered. Phase two was carried out by analyzing secondary data collected through observation, mapping and field survey for multimodal network through multi criteria analysis. For identification of alternative routes and appropriate mode combinations, study of site and different aspects related to mode played most critical role. Appraisal of study area helped in extracting the possible route options and framing the image of city in the mind of respondent for mode choice questioner. For route selection different aspects like demographics, land use, visual qualities, ecological and climatic settings were considered. Data related to land use, demographic profile, mode choice and trip length were sorted out by means of field survey and available secondary data at city level. Different maps related to study area were drawn as part of analysis carried out to find the possible alternative routes between main transit nodes in Shimla core area. Desirability function has been used in the present study to determine the optimum parameters to achieve optimized values of route and mode combination. The values of the variables with maximum total desirability were considered to be the optimal route condition. According to Sayers, (2003) this analysis method has the merit of allowing an appropriate degree of both consistency and flexibility with respect to the relative weights of the various criteria. It opened the way to a more flexible, transparent and user-friendly method of choosing and ranking transport route options. For the last objective related to mode choice in hill regions, survey is conducted and analyzed using chi square test. For successful public transport model it is important to involve users and consider their point of view. Results of the research are incorporated in terms of travel time, energy consumption and GHG emissions on the identified combination of desirable route and mode choice.

V. Alternative Transport Modes on Hills

Alternative public transport modes were identified from case studies which suggest that there are basically four alternatives for public transport in hill areas namely ropeways, funicular rail, escalators, and inclined lift. These modes are operational all over world and suit the study area for multimodal movement network. According to NUTP, 2014, various modes which can be adopted by Hill cities are cable car systems, funicular rails and inclined elevators (MUD, 2014). Ropeways are rational choice in many cases as they can follow shortest way where buses or trams would have to make long detour (Bergerhoff, 2013). These modes were considered for public transportation in hill areas as an alternate to bus in present research. Important criterion for adopting a transport system is its efficiency and impact on the environment and city functions. The attributes for transport modes ranges from capacity, speed, efficiency, quality to energy use and GHG emissions. Further it was observed that there is a relation between these attributes of identified modes of transportation. The carrying capacity of lifts with common specifications and having load of 8 persons with a travelling speed of 1.6 m/s. is estimated to be less than 500 passengers per hour in each direction for a 25-metre rise (COD, 2006). The carrying capacity of escalators varies from 4500 to over 13,000 passengers per hour according to their width and travelling speed (between 0.5 and 0.75 metres/second). The modern funiculars operate at relatively high speeds up to 6 m/s in Asturias. Their carrying capacity ranges from 1300 pph to 8000 pph depending on the size of the vehicle, its speed and the gradient. The capacity of car can be up to 400 passengers and move up to a speed of 14 m/s (Niksic, 2010).The ropeways operate at relatively high speed ranging from 5 m/s to 12 m/s. Their carrying capacity ranges from 2400 pph to 4200 pph depending on the size of the car and its speed. Modern installations carry up to 5,000 passengers per hour along one direction.

VI. Appraisal of Study Area and Its Feature

Shimla is the capital city of Himachal Pradesh, India. Hill town of Shimla is composed around seven small hills with core area around Bantony hill (Sooden, 2007). Main movement axis of city is in east west direction along its ridge line. Due to partial accessibility (mainly pedestrian traffic) Chandigarh - Shimla- kaurick NH 22 (Cart road) acts as lifeline of the city. In order to establish the relationship between route feasibility, travel mode choice and travel energy pattern in hill towns, study area was confined to core area of Shimla town. Core area can be distinguished as main commercial, recreational and administrative zone. As the main spine NH 22 (Cart road) crosses the city core, maximum problems related to traffic are faced on the same corridor. The multifunctional activities in the core area are putting heavy stress and congestion all along this stretch. As per landuse pattern 60% of the land is occupied by forest, 20% is used for agriculture, 4% is used for traffic and transportation, 9% is used for residential purposes and remaining 7% is used for other activities (MUD, 2013).

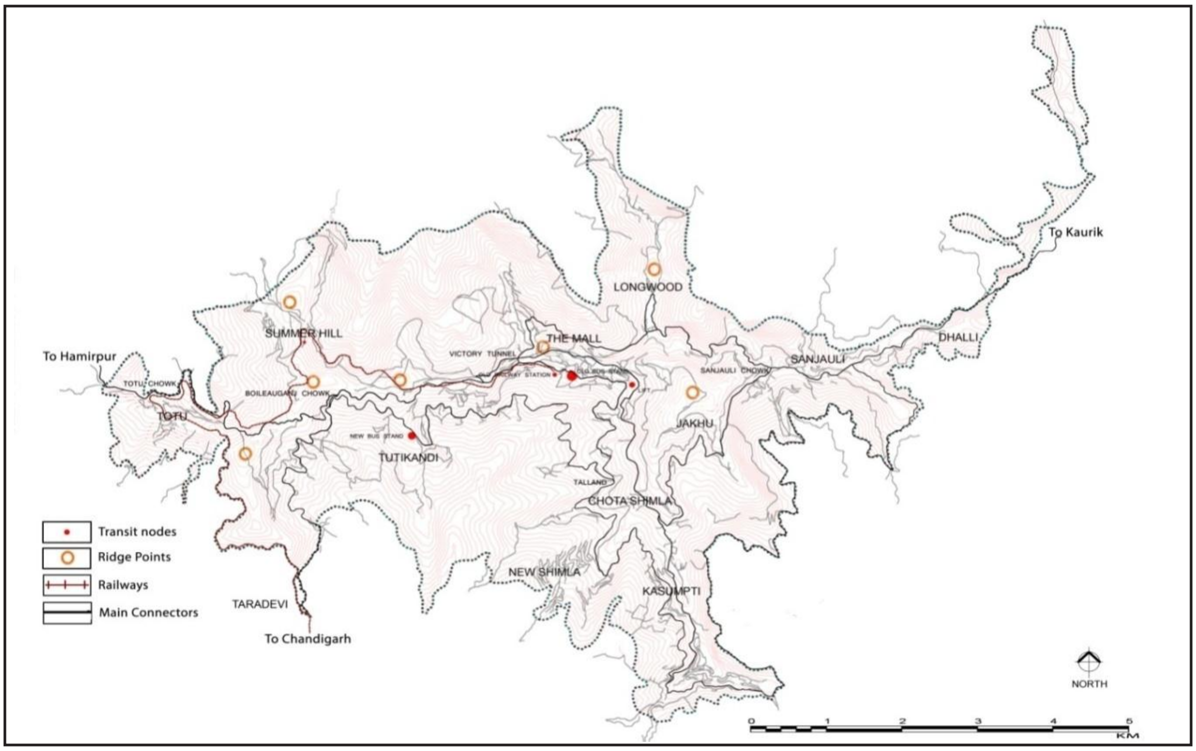

Fig. 1: Map of Transit Nodes - Shimla

Present city population is 1.7 million with an additional floating population of nearly 2.5 million (Shaker, 2014). The major land-uses are located on the southern face of Shimla due to gradual slopes and sunny side. Here usual slopes are above 30^0 and some areas are having 60^0 slopes also.

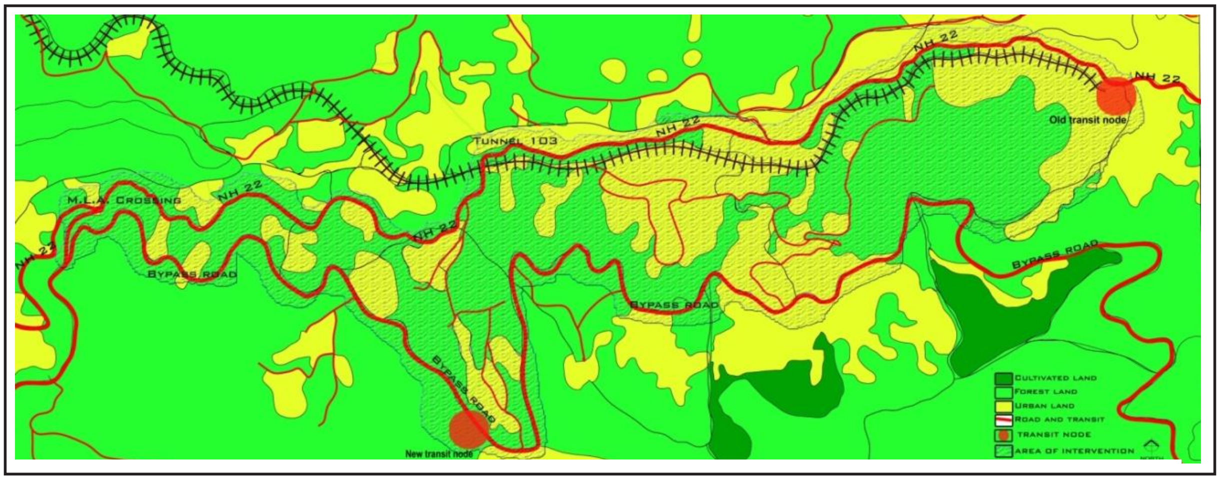

Fig. 2: Land Use Map of Precinct

The major tourist attractions in Shimla include The Ridge, The Mall, Jakhoo Temple, Sankat Mochan Temple, State Museum, Prospect Hill and Chadwick Fall (KPMG, 2012). Fig. 1 shows the main transit nodes within city limits. From the land use and demographic pattern of town shown in Fig. 2 it is evident that concentration of activities is mainly along the main corridors whereas density is high in core area. From the Fig. 2 it is also clear that old transit terminal acts as the city core whereas new transit terminal lacks the context for active transit node. Shimla is one of the most popular hill station and tourist destinations in India and accounts for almost a quarter of all tourists arriving in Himachal. The immense natural and climatic diversity of Shimla has attracted both domestic and international tourists. About 30 million tourists visited Shimla in the year 2013 with maximum visitors up to 15000 per day in month of May and about 5% of them constituted foreign tourists. The average stay was about 1.35 days (TCP, 2014).

VII. Transportation Scenario in Shimla

Shimla allows both horizontal as well as vertical movement to city dwellers. Horizontal movement is primarily by arterial roads and vertical mobility options are lifts (between Mall road and NH 22) and pathways / staircases connecting various streets. As per latest survey conducted by Town & Country Planning Department 20% persons use buses as mode of transport, 25% use their own private vehicles and 55% move to Shimla Town on foot (TCP, 2014). With the present traffic scenario city faces lot of traffic problems due to lack of space and increased population. With major roads overloaded beyond their capacity, on-street parking causing congestion and increasing floating population demand major interventions in transportation system of city (MCS, 2011). Among observed problems related to traffic and transport system latest city development plan has tried to resolve the issues by introducing more buses, elevator and parking lots. But the major issue of connecting major transit nodes has not been dealt at any level. This research finally narrows down to this area while taking into consideration the role of multimodal movement pattern. Public transport being the predominant mode of travel (MUD, 2008) with an average trip length of 3 km per person gives an opportunity to introduce alternative modes and routes in city using multimodal system.

VIII. Alternative Routes for Multimodal Transport Network

Alternative routes were considered in a way so that they will influence the existing fabric to a very limited extent. In total five such options shown in Fig. 3 were finalized. Route 1 is the existing connector between old and new bus terminal where bus is operational. Route 2 is moving along the residential area of Lalpani and joins the by-pass road (NH- 5) and finally meets the new transit terminal.

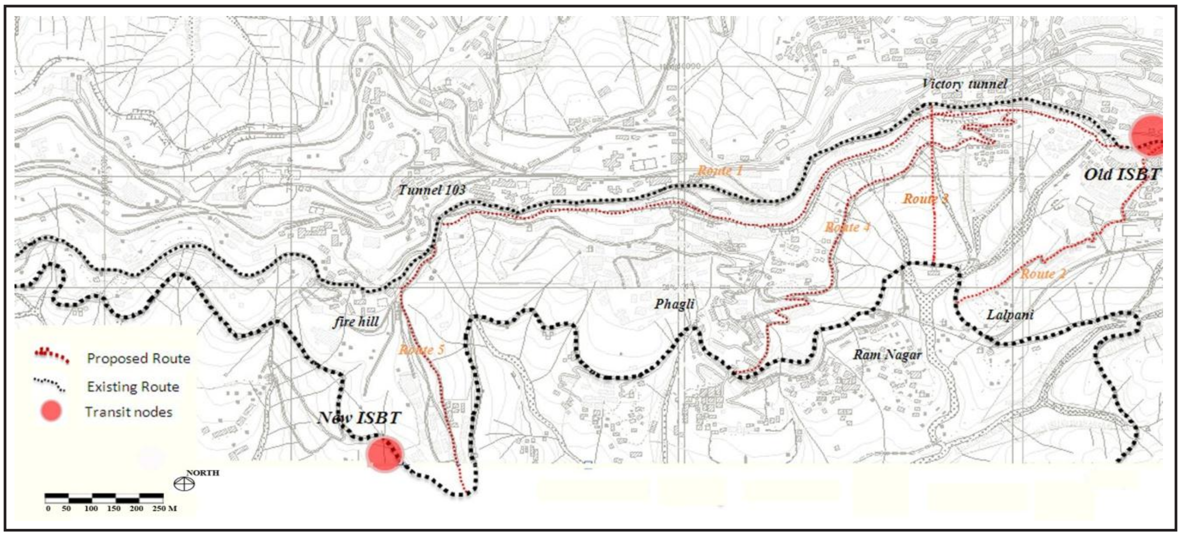

Fig. 3: Alternative Routes for Multimodal Network

Route 3 acts as a direct connector between main cart road and by-pass road (NH- 5) through green area by ropeway. Route 4 starts from the major traffic junction i.e. victory tunnel and moves along Phagli residential zone to meet the by-pass road (NH- 5). Route 5 was demarcated along existing railway line from old ISBT till tunnel-103 and further connected to main transit terminal from Tutikandi residential zone. These routes are partially along the already developed road network, hence allowing limited intervention / destruction. Challenges related to engineering complexities (slope, land required, connectivity) and environmental impacts (green cover, land stability, visual impact) were considered for identifying alternate routes.

IX. Multi Criteria Analysis for Multimodal Transport Network

Multi-criteria analysis was used in the research so as to take account of environmental and social concerns. Travel is considered as a valued activity as well as a derived demand, quality of travel, travel time, integration of people, and level of associability play important role in achieving sustainable mobility. Henceforth a multi-criteria problem was dealt with multi criteria analysis. Table I shows some of the criteria requisite for determining the suitability of multimodal network in a city. This MCA of different available options is a key point for decision making because a specific / cost effective combination that addresses some criteria might not reach the target for another one. Such approaches create an environment friendly transport system and activity places accessible within rational time (Chattopadhyay, 2008). These criteria possess different attributes as listed in the table below.

TABLE I: CRITERIA FOR MULTI-CRITERIA ANALYSIS

Sr. No.	Criteria	Attributes
1	Population and demographic character	Population, Age and Gender
2	Travel to and from the concerned area	Distribution among modes
3	Concentration of pedestrian streams	Adjoining paths and functions
4	Public transport alternative	Existing options (Site study)
5	Town-planning of areas and activity	Land use and building use
6	Topographic features	Slope and green cover

X. DESIRABILITY ANALYSIS

Contextual and precinct level study and analysis were used to identify new corridors between old and new transit terminals. In this study, ten different responses for the routes (variables) were given specific importance. Attributes like population, slope, width, distance, adjoining roads, time and major activities were derived from literature study. Analysis has been done by considering five corridors (one existing corridor and four new proposed corridors) along with five set of multimodal modes. Combinations of modes are referred as EB, EF, RB, RF and R where E represents Escalator, B represents Bus, F represents funicular railway and R represents ropeway. Optimization of route was done by means of factorial analysis. From analysis of available data combination of 25 permutations were generated in total. Out of these 14 permutations only 8 values were considered in desirability chart. For analysis purpose all responses were given same importance level. Fig. 4 shows the route 1 and route 5 having good desirability level and route 5 shown in blue has various combinations such as 5RF i.e. combination of ropeway and funicular, 5RB i.e. combination of ropeway and bus along route 5.

Fig. 4: Shows the Route 1 and Route 5 having Good Desirability Level.

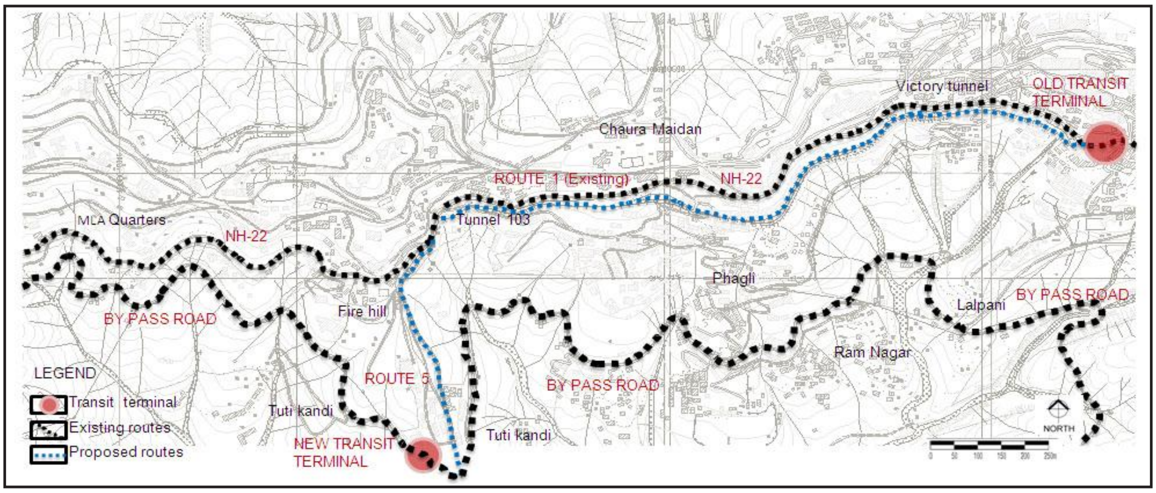

Fig. 4: Existing and Proposed Routes for Desirability Analysis

TABLE II: DESIRABILITY ANALYSIS OF ROUTES ALONG WITH THEIR ATTRIBUTES

Number	Route	Dis-tance	Stops	Time	Green Belt	Infra-structure	Ad Roads	Activi-ties	Stop Time	Popula-tion	Energy	Carbon Emission	Desir-ability
1	5RF	2.4	4	5.76	200	1800	6	6	6	30470	0.376	11.28	0.685
2	5RB	2.4	4	7.34	200	800	6	6	6	30470	0.308	62.11	0.674
3	5F	2.4	5	5.76	200	5200	6	6	7.5	30470	0.432	12.96	0.641
4	5FB	2.4	5	7.34	200	4200	6	6	7.5	30470	0.364	63.79	0.637
5	5EF	2.4	5	19.63	200	3800	6	6	7.5	30470	0.46	13.8	0.631
6	5RE	2.4	4	39.38	200	7600	6	6	6	30470	0.444	13.32	0.531
7	1RB	4.5	4	13.4	00	800	8	6	6	31725	0.562	103.94	0.001
8	1FB	4.5	5	13.4	00	1000	8	6	7.5	31725	0.698	108.02	0.001

E (Escalator), B (Bus), F (Funicular railway), R (Ropeway), 1 (Existing), 2, 3, 4, 5, (Options) for Routes

Design-Expert 7.1 was used for optimization as it has a mathematical multiple response optimization option and was helpful in determining a set of conditions that is a compromise to all the defined goals. Goals and limits were chosen individually for each response in order to determine their impact on the desirability. A minimum level was provided as a goal for each response characteristic which was to be optimized. In Table II desirability level has been calculated by using full factor analysis. Concise description of different attributes used in desirability analysis is as follow. Distance has been calculated as per the route concerned, green belt refers to total length that falls under preserved forest along particular corridor, infrastructure refers to new land area that one needs to develop by calculating distance and width (for ropeways only tower installation area has been considered), additional roads refer to major adjoining corridor and population has been calculated by considering 250 m walking distance on either side of path along residential zones. For estimating the overall energy consumption by different alternatives and modes attributes (speed, energy consumption and CO_2 emissions) were derived from available research work. For bus diesel was considered as fuel and energy resource, whereas hydro electricity was considered for operation of remaining modes. Average speed of ropeways is 25 km/h (Hoffman) and they consume 0.1 kWh per passenger-kilometer (Doppelmayr), hence CO_2 emissions will be nearly 3.4 g per passenger-km. Escalators usually run at a speed of 0.75 m/s (Behm, 2010). Studies show that escalators consume 0.22 kWh per passenger-km hence escalators CO_2 emissions will be nearly 7.5 g per passenger-km. In present context speed for railway was considered as 25 km/h. Considering Hydro electricity for operation purpose, energy consumption will be nearly 0.18 kWh per passenger-km with CO_2 emissions up to 6.12 g per passenger-km. From desirability analysis Route 5 options are most desirable, having half of distance along existing railway line (till tunnel 103) and remaining distance along residential and green area. The introduction of multimodal transport network on this route will help in development of parks along corridor due to existing context. Next phase of research was to recognize user choice for multimodal network. Choice of private or public modes of transportation depends how preferences are constructed (Jacquet *et al.,* 2010). For the purpose mode choice survey was conducted and analyzed using socio demographic, urban design and physiological variables. This analysis approach is an attempt to connect citizen / users within planning strategies and making them an integral part of development strategies. Such actions also help in capturing minds and prepare the citizen those using city facilities (Madden, 2010).

XI. Mode Choice Analysis and Result

After recognizing alternative corridor (Route 5) for multimodal network next thing was to identify most preferential modes. For analyzing the people perception towards alternative modes of public transport, survey was carried out through a questioner. Simple random sampling method was opted and sample size was calculated using confidence interval of 5 and 95% confidence level (Panneerselvam, 2013). Mode choice outlook related to different variables was extracted from these questioners along with basic socio demographic information. Survey was conducted in the city core area considering sample from all economic groups, gender and people with different education level (UDPFI, 1996). In total 385 persons participated (sample size calculated for city population) in survey and provided information related to mode choice based upon different attributes. The response rate turned out very high. Nearly with 90% of targeted users who responded well resulting in total 350 questioners filled in all respects. Participants were asked to rate some of the aspects of the visual quality, safety and comfort on alternative travel modes. In pilot survey participants found it difficult to rate the modes on a scale i.e. 1-4. Henceforth in final survey it was decided to frame questions for the best preferred mode with respect to the specific variable in questioner. Response to these variables by different set of groups based upon age, gender, education level and income (socio-demographic variables) was then predicted with remaining variables.

XII. Delphi Technique for Ranking

The Delphi method was especially useful for this research due to long-range forecasting (20-30 years) needs, as expert opinions were the only source of information available. The main purpose of the Delphi method was to acquire the most reliable consensus of a group of expert's opinion. In this qualitative research, which aims to determine the importance of items / attributes ranking was used to gather the experts opinions. Five-point or seven-point scale is common but in this case eight point scale was used. E1, E2, E3….E10 shown in Table III represents the experts from various field. Expert E1, E2, E3 and E4 are from the field of urban design, E5 and E6 highly educated professionals and citizen of Shimla town, E7 and E8 are experts from the field of environment and energy respectively whereas E9 and E10 are experts from the field of hill architecture and transport engineering respectively. As per classical Delphi technique the first round adopted an inductive approach where participants were given complete freedom in their responses. In second round consensus shown in Table III was built among different experts and attributes were ranked accordingly. Kendall's coefficient of concordance was utilized to determine the agreement and end of the Delphi technique. Kendall‘s coefficient of concordance (Kendall‘s W), a consensus criterion representing the level of consensus between the participants, was calculated along with the mean rank and standard deviation. Kendall‘s coefficient of concordance ranges from 0 to 1, indicating the degree of consensus reached by the panel (strong consensus for $W > 0.7$; moderate consensus for $W = 0.5$; and weak consensus for $W < 0.3$). Kendall's coefficient of concordance is also a scale for determining the level of coordination and agreement between several ranks of n phenomenon. This scale shows a rank correlation between m ranking set. It was used to determine the inter-judge reliability.

Kendall's coefficient of concordance indicated that those who have ordered several categories according to their importance have used the same criteria to judge the importance of each category and in this regard, they agree to each other. In present study questionnaire was discussed and ranked by ten experts from the field of urban design, energy, transportation and environment. In total two rounds of discussion were held with experts through mail and telephonic conversation. Results of the Delphi method are shown for comparative understanding. Kendall's coefficient of concordance shown in Table IV was calculated along with the mean rank and standard deviation for round two.

Table III: Round 2 Score of Various Attributes from Delphi Method

Attributes	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	Mean	Median	Std. Dev.
Speed	1	3	3	1	2	1	1	3	1	1	1.7	1.0	0.95
Easement	7	7	8	6	8	7	8	8	7	6	7.2	7.0	0.79
Imagebility	4	2	2	2	4	3	4	4	4	4	3.3	4.0	0.95
Legibility	2	4	4	4	3	4	2	2	3	3	3.1	3.0	0.88
Context	5	6	5	7	6	5	6	5	6	7	5.8	6.0	0.79
Environment	6	5	7	5	5	6	5	6	5	5	5.5	5.0	0.71
Safety	8	8	6	8	7	8	7	7	8	8	7.5	8.0	0.71
Social Int.	3	1	1	3	1	2	3	1	2	2	1.9	2.0	0.88

Table IV: Kendall'S Coefficient of Concordance for Round 2

Correlations											
		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
E1	Cor.Coff.	1.00	.643*	.571*	.643*	.714*	.857^	.857^	.714*	.857^	.786^
	Sig.	.	.026	.048	.026	.013	.003	.003	.013	.003	.006
E2	Cor.Coff.	.643*	1.00	.786^	.714*	.786^	.786^	.643*	.643*	.786^	.714*
	Sig.	.026	.	.006	.013	.006	.006	.026	.026	.006	.013
E3	Cor.Coff.	.571*	.786^	1.00	.500	.714*	.714*	.571*	.714*	.571*	.500
	Sig.	.048	.006	.	.083	.013	.013	.048	.013	.048	.083
E4	Cor.Coff.	.643*	.714*	.500	1.00	.643*	.786^	.643*	.500	.786^	.857^
	Sig.	.026	.013	.083	.	.026	.006	.026	.083	.006	.003
E5	Cor.Coff.	.714*	.786^	.714*	.643*	1.00	.714*	.857^	.857^	.857^	.786^
	Sig.	.013	.006	.013	.026	.	.013	.003	.003	.003	.006
E6	Cor.Coff.	.857^	.786^	.714*	.786^	.714*	1.00	.714*	.714*	.857^	.786^
	Sig.	.003	.006	.013	.006	.013	.	.013	.013	.003	.006
E7	Cor.Coff.	.857^	.643*	.571*	.643*	.857^	.714*	1.00	.714*	.857^	.786^
	Sig.	.003	.026	.048	.026	.003	.013	.	.013	.003	.006

*. Correlation is significant at the 0.05 level (2-tailed)

^. Correlation is significant at the 0.01 level (2-tailed)

In order to obtain their weightage in mode choice ranks were given value on a scale of 10. The result revealed that speed got the maximum score followed by easement and context. Weights were assigned on basis of ranks derived from Delphi. Here ranking is based upon the median value derived from the analysis. Use of median rather than mean is preferred to avoid any conflict due to abnormality. Based upon the derived Delphi results Table V shows the weight assigned to each variable.

TABLE V: RANKING FOR DIFFERENT VARIABLES

	Speed	Easement	Imagebility	Legibility	Context	Environment	Safety	Social Interaction
Ranks	8	2	5	6	3	4	1	7
Weights assigned	1.25	8.75	5	3.75	7.5	6.35	10	2.5

From principle component analysis, significance of each variable was obtained and on its basis variables were ranked from 1-8 based upon their contribution. Variable like speed and easement had more contribution hence were rated as 1 and 2 respectively, whereas safety and social interaction contributed least they were rated as 8 and 7 respectively. In order to obtain their weightage in mode choice ranks were given value on a scale of 10 and related frequencies for each mode option was multiplied to get the final scores. Table VI shows the final scores obtained by each mode. The result revealed that railways got the maximum score followed by ropeway, escalator and lift. From the overall analysis it is evident that if we consider lift as base, then in comparison to lift 20% more people have opted for escalators, 20% more people have opted for ropeways and 20% more people have opted for railways. When we look in terms of comparative analysis for mode choice different variables show high inclination towards ropeways and railways than escalators.

TABLE VI: WEIGHTED AVERAGE ANALYSIS FOR MOST PREFERRED MODE

Mode	Variables Weightage										
	Safety	Easement	Imagebility	Legibility	Context	Environment	Speed	Social Int.	Total Mode Weightage	Weighted Mean	Weighted User Preference Percentage of Mode Choice
Lift	490	490	230	161	450	298	54	113	2286	228	14.84
Ropeway	490	438	835	495	780	1289	118	143	4587	443	28.89
Railway	1780	1540	395	341	983	337	188	473	6035	568	37.02
Escalator	740	595	290	315	413	298	79	148	2877	295	19.23

From Fig. 5 overall response towards modes can be easily observed. Analysis also shows that ropeway and funicular railways are more preferred modes. From environmental and visual point of view ropeway is most preferred mode whereas from social interaction, safety and easement of use funicular railway is most favored mode.

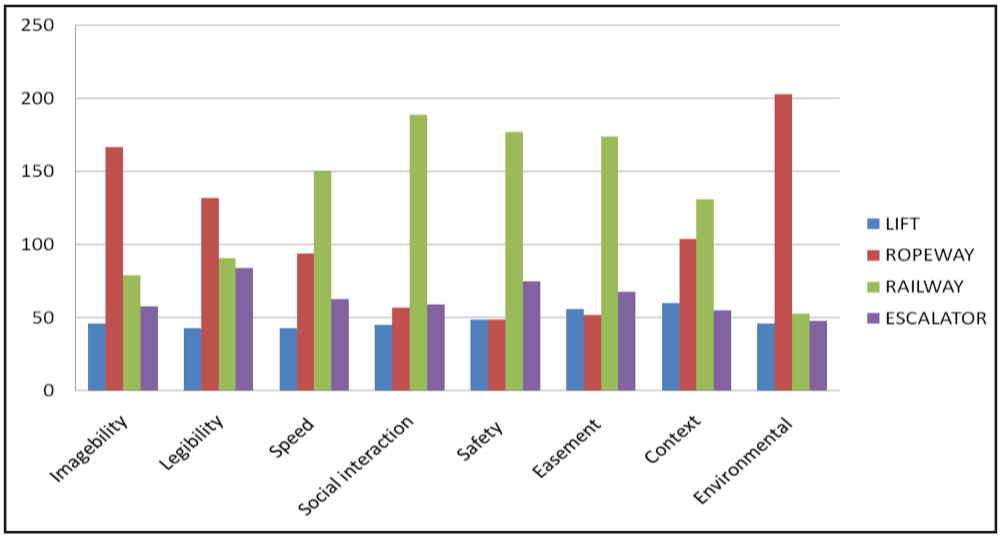

Fig. 5: Mode Choice Response for Different Variables

Nearly 37% choice options are for funicular railway and 31%, 18% and 14% are for ropeway, escalator and lift respectively. As the result of overall analysis route number 5 has emerged as most desirable route and mode choice analysis shows railway and ropeways as preferred modes for multimodal network. Combination of these results has been proposed as alternative corridor between major transit nodes.

XIII. Chi-Square Test

As the variables are ordinal in scale, cross-tabulation has been implied to infer the strength of their relationship. Variables are nonparametric in this case i.e. name only (e.g., gender, education level, safety and imagebility etc.) and are not given numerical value except arbitrarily (e.g., 1 = male, 2 = female or 1 = lift, 2 = ropeway etc.). Impact of social demographic variables on mode choice has been calculated by identifying their significance level with respect to all other attributes. Significance is retrieved by observing the calculated value and value from Chi-Square table. Two tailed significance has been assumed in the analysis and degree of freedom varies from variable to variable. A significance level of 95% has been assumed in the analysis. Each question in the questioner considers the objective that relates to a specific variable. As case-specific indicators- monthly income, age, gender and education of the respondent were used for analysis. The gender was coded as 1 if female and 0 if male; female was the base category. A four category variable for the family income was applied in which Rs. 1000 to Rs. 15000 group was regarded as the base. The age level of the respondents ranges from 16 to 67 and the average age in the sample was 22 years. Of the 350 respondents, there were 223 male (approximately 63%) while female accounted for 127 (approximately 37%). As per the education level, 189 were under graduate, 65 were post graduate, and remaining 96 were at graduate level. Average monthly income of the respondent and his family was Rs. 28000. Finally, family size is very different, with a spread from 2 persons to 13 persons with an average of 4 persons.

Table VII: Relation Among Variables as Per Significance

Relationship Variables		p Value	Remarks
Gender	Legibility	0.007***	Significant
	Social int.	0.000***	Significant
Education	Safety	0.013**	Significant
	Imagebility	0.018**	Significant
	Legibility	0.000***	Significant
	Context	0.004***	Significant
	Environment	0.000***	Significant
	Speed	0.000***	Significant
	Social int.	0.002***	Significant
Family size	Safety	0.003***	Significant
	Imagebility	0.046**	Significant
	Speed	0.018**	Significant
Age	Safety	0.044**	Significant
	Imagebility	0.017**	Significant
	Environment	0.001***	Significant
	Speed	0.010***	Significant
	Social int.	0.028**	Significant
Income	Safety	0.046**	Significant
	Imagebility	0.024**	Significant
	Legibility	0.001***	Significant
	Context	0.033**	Significant

** Chi-Square is significant at 0.05 level

*** Chi-Square is significant at 0.01 level

Results obtained from Chi-square test for significance are tabulated in Table VII. Chi-square analysis confirms that there is a relationship between socio demographic variables and urban design variables for mode choice, using a significance level of 0.01. Wherever the value of the calculated Chi-Square statistic falls within the acceptance region, we accept the null hypothesis that the mode preference understanding of specific variable for all the categories / groups is same. Wherever the value of the calculated Chi-Square statistic does not fall in the acceptance region, we reject the null hypothesis that the mode preference understanding of specific variable for all the categories / groups is not the same. Hence we can see that a wide number of urban design variables, including some that have had little consideration in the literature previously, are important in the mode choice. As it is evident from the results that few variables have significant relation whereas some of them are not affecting the mode choice preferences.

XIV. Energy and GHG Emission Analysis

A comparative analysis between alternative modes and existing mode (bus) was done by considering attributes like speed, time, distance, energy consumption and CO_2 emissions. For bus diesel was considered as fuel and energy resource, whereas hydro electricity was considered for operation of remaining modes. Average speed of ropeway, railway, escalator and bus is 25 km/h (Hoffman), 25 km/h (Shimla-kalka rail line), 0.75 m/s (KONE) and 25 km/h (HRTC) respectively. Energy consumption per passenger per kilometer for ropeway, railway, escalator, and bus is 0.1 kWh (Doppelmayr), 0.18 kWh (Weisser), 0.22 kWh (KONE) and 0.14 kWh (HRTC) respectively in analysis. From the above data and analysis, average energy consumption and CO_2 emissions for each mode were calculated and are given in Table VIII. The information was later on used for predicting the average CO_2 emissions by different modes on most desirable connector i.e. Route 5.

Table VIII: Average Energy Use and CO_2 Emissions by Mode

Sr. No.	Mode	Energy Use (kwh) per Passenger-Km	Fuel	CO_2 Emissions (g) per Passenger-Km
1	Bus	0.14*	Diesel	35.3
2	Railways	0.18**	Hydro-Electricity	6.1
3	Ropeways	0.1***	Hydro-Electricity	3.4
4	Escalators	0.22****	Hydro-Electricity	7.5

Source: M.J. Bradley & Associates / field study*, Daniel Weisser**, Doppelmayr Cable Car***, KONE ****

Table IX shows the comparative analysis of existing and proposed corridor having huge saving in terms of time, energy and CO_2 emissions. Combinations of rail and ropeway for multimodal network on proposed Route 5 consumes minimum travel time and have lowest CO_2 emissions. In comparison to the existing bus service, energy consumption on proposed route with mode combination can be reduced by 33%. Results indicate that there is huge reduction in travel time as waiting time and time lost during traffic jams will not be part of total travel time anymore. Use of electricity (Hydro) will result in huge reduction in carbon emission. Due to high efficiency and per hour carrying capacity of ropeways and funicular quality of travel experience will also improve. This result is a clear indication that how multimodal network can be useful in improving energy consumption pattern for sustainable transport. On the basis of research, a complete urban design plan for this connector was visualized for preserving the green as well as functional character of city core.

Table IX: Energy Use and CO_2 Emissions by Multimodal Transport on Alternate Route

Route	Mode	Distance (km)	Speed (km/h)	Time (Min.)	Energy (kwh) / Passenger-Km	CO_2 Emissions (g) / Passenger-Km
Existing	Bus	4.5	18	15	0.63	158.85
Route 5	Rail and Ropeways	1.7, 1.1	25, 25	6.72	0.42	14.144
Route 5	Rail and Escalators	1.7, 1.1	25, 2.7	28.52	0.55	18.632
Route 5	Bus and Escalators	1.7, 1.1	18, 2.7	30.1	0.48	68.238
Route 5	Bus and Ropeways	1.7, 1.1	18, 25	8.3	0.35	63.75

XV. Results

As a result of visual survey and MCA analysis, Route 5 emerged as most desirable route for multimodal network. From the analysis of attributes for mode choice it is evident that funicular rail and ropeways have emerged as the most preferred choices. Due to safety considerations lifts have been opted by very less number of users. Result also indicates that ropeways are the best alternate modes and caters to visual and environmental character leading to recover city Imagebility. Due to high efficiency and per hour carrying capacity of ropeways and funicular quality of travel experience will also improve. From the results of Chi square test we can conclude that there is strong impact of education and age on mode choice whereas gender has very little significance. Variables like family size and income have a modest impact on mode choice decisions. Of the eight variables, the safety variable has the strongest impact, suggesting that safety of travel mode is one of the most crucial criteria when considering mode choice and this completely matches the reality. Comparative analysis of existing and proposed corridor shows virtually half time diminution in terms of travel time and 33% reduced energy usage in projected intervention. Results indicate that there is huge reduction in travel time as waiting time and time lost during traffic jams will not be part of total travel time anymore. This result is also a clear indication how multimodal network can be useful in reducing carbon emissions. This result is a clear indication how multimodal network can be useful in improving energy consumption pattern.

XVI. Conclusion

The study has tried to understand the view point of users toward new commuting modes within the core city area of Shimla town. Variables identified from literature review were used as base for survey and analysis. Case study of alternative public transport modes and urban design study of Shimla town helped in identifying most suitable substitute modes and routes for commuting. From the understanding of relation between sustainable mobility and energy, one can conclude that urban development of hill city with multi modal transport network and pedestrian friendly structure will help in modifying existing cities in their performance. The study has tried to understand the view point of users toward new commuting modes within the core city area of Shimla town. Considering users as part of decision making will help in better utilization of public transport system and reduce dependency on private modes. As per the result of significance, safer transport mode is more likely to be chosen by tourists. On the other hand, in the condition that all other factors hold true, a mode that departs and arrives at a destination punctually, provides tourists with more comfort, and offers quality service and merges with city image is more likely to be chosen. Therefore, modes that add to safe, comfortable, and image building should be considered as alternative travel modes. New route will not only reduce the time and energy consumption in movement but will also add quality in traveling experience between main transit nodes in Shimla city. This research base is the starting point of investigation in improving quality of mobility corridors in hill regions for sustainable development. Multimodal movement as an alternate will help in enhancement of hill town imagebility and achieve sustainable growth.

References

[1] S. Bamberg, M. Hunecke, and A. Blobaum, “Social context, personal norms and the use of public transportation: Two field studies,” *Journal of Environmental Psychology*, vol. 27, no. 3, pp. 190-203, 2007.

[2] M. Barfod, K. Salling, and S. Leleur, “Composite decision support by combining cost-benefit and multi-criteria decision analysis,” *Decision Support Systems*, vol. 51, no. 1, pp. 167-175, 2011.

[3] J. Bergerhoff, and J. Perschon, “The role of ropeways to reshape urban mobility in developing countries,” *Journeys*, pp. 13-21, 2013.

[4] K. Behm, and H. Tonteri, “The life cycle assessment of KONE TransitMaster™ 120 escalator,” Research Report No VTT-R-02318-10, VTT, Espoo, Finland, 2010.

[5] D. Banister, “The sustainable mobility paradigm,” *Transport Policy*, vol. 15, no. 2, pp. 73-80, 2008.

[6] R. Cervero, “Built environments and mode choice: Toward a normative framework,” *Transportation Research Part D*, vol. 7, no. 4, pp. 265-284, 2002.

[7] B. Chattopadhyay, “Sustainable urban development in India: Some issues,” 2008. Retrieved from: http://www.niua.org/Publications/discussion_paper/basudha_paper.pdf, 16th feb.2014

[8] K. Clifton, and S. Handy, “Qualitative methods in travel behaviour research,” in *International Conference on Transport Survey Quality and Innovation*, Kruger National Park, South Africa, 2001.

[9] Corporation of Donostia (COD), Public Vertical Transport, Mobility Department, San Sebastian, Spain, 2006.

[10] C. Curtis, and T. Perkins, “Travel behavior: A review of recent literature,” Urbanet, Working Paper No 3, 2006.

[11] P. Das, “Mass tourism & environ-infrastructural crises of Shimla city: A case study,” *International Journal of Science and Research (IJSR),* vol. 3, no. 11, pp. 1781-1790, 2014.

[12] Department of Tourism, Kotappakonda Aerial Ropeway Project, vol. II - Project Information Memorandum, Government of Andhra Pradesh, 2015.

[13] Doppelmayr, Ropeways in the Urban Environment, Urban Solutions, Doppelmayr Cable Car GmbH & Co KG Report, 2014.

[14] R. Ewing, and R. Cervero, “Travel and the built environment: A synthesis,” *Transportation Research Record*, vol. 1780, pp. 87-114, 2001.

[15] T. Gehlert, K. Dziekan, and T. Gärling, “Psychology of sustainable travel behavior,” *Transportation Research Part A*, vol. 48, pp. 19-24, 2013.

[16] G. L. Gibson, New Urbanism: The Movement System and Mixed-Use Town, Community Design Service, Cardiff, 1997. Retrieved from: abstracts.aetransport.org/paper/download/id/533.

[17] R. Hickman, and D. Banister, “Transport and reduced energy consumption: What role can urban planning play?,” Transport Studies Unit Oxford University Centre for the Environment, Working Paper No 1026, 2007.

[18] K. Hoffmann, “Recent developments in cable-drawn urban transport systems,” *FME Transactions*, vol. 34, pp. 205-212, 2006.

[19] K. Hoffmann, “Oscillation effects of ropeways caused by cross-wind and other influences,” *FME Transactions*, vol. 37, pp. 175-184, 2009.

[20] I. Satmohini, R. Srivastava, and V. Vaidya, “Planning for sustainable urban form for Indian cities,” *Urban India Journal*, 2011.

[21] P. Jacquet, R. K. Pachauri, and L. Tubiana, (eds.), *Cities: Steering Towards Sustainability*, Teri Press, 2010.

[22] J. R. Kenworthy, “The eco-city: Ten key transport and planning dimensions for sustainable city development,” *Environment and Urbanization*, vol. 18, pp. 67-85, 2006.

[23] A. Kengpol, W. Meethom, and M. Tuominen, "The development of a decision support system in multimodal transportation routing within Greater Mekong sub-region countries," *International Journal of Production Economics*, vol. 140, no. 2, pp. 691-701, 2012.

[24] KPMG International, "Tourism in Himachal Pradesh and the way ahead," PHD-KPMG in India Report, 2012.

[25] A. Kuppam, R. Pendyala, and S. Rahman, "An analysis of the role of traveler attitudes and perceptions in explaining mode choice behavior," in Annual Meeting of the Transportation Research Board, Washington, 1999.

[26] C. Macharis, A. D. Witte, and L. Turcksin, "The Multi-Actor Multi-Criteria Analysis (MAMCA) application in the Flemish long-term decision making process on mobility and logistics," *Transport Policy*, vol. 17, no. 5, pp. 303-311, 2010.

[27] C. Macharis, L. Turcksin, and K. Lebeau, "Multi Actor Multi Criteria Analysis (MAMCA) as a tool to support sustainable decisions: State of use," *Decision Support Systems*, vol. 54, no. 1, pp. 610-620, 2012. DOI: 10.1016/j.dss.2012.08.008

[28] Ministry of Environment & Forests, Environmental Impact Assessment Guidance Manual for Aerial Ropeways, Government of India, New Delhi, 2010.

[29] Ministry of Urban Development, Traffic and Transportation Policies and Strategies in Urban Areas in India, Government of India, Wilbur Smith Associates Report, 2008.

[30] Ministry of Urban Development, Capacity Building for Urban Development, Rapid Baseline Assessment Shimla City, Government of India, Draft Report, 2013.

[31] Ministry of Urban Development, GOI, National Urban Transport Policy, 2014. Available: www.iutindia.org

[32] Ministry of Urban Development, GOI, India, Smart City Mission Transformation, Mission Statement and Guidelines, Government of India, Report, 2015.

[33] Municipal Corporation Shimla, City Sanitation Plan for Shimla, GIZ ASEM Report, 2011.

[34] K. S. Nesamani, "Sustainable transportation development in hill towns - A case of Darjeeling," *Indian Journal of Transport Management*, vol. 27, no. 3, pp. 2-10, 2003.

[35] M. Niksic, and S. Gasparovic, "Geographic and traffic aspects of possibilities for implementing ropeway system in passenger transport," *Traffic and Transportation*, vol. 22, no. 5, pp. 389-398, 2010.

[36] R. Panneerselvam, *Research Methodology*, 11th ed., PHI, India, 2013.

[37] T. M. Sayers, A. T. Jessop, and P. J. Hills, "Multi-criteria evaluation of transport options-flexible, transparent and user-friendly?," *Transport Policy*, vol. 10, no. 2, pp. 95-105, 2003. DOI: 10.1016/s0967-070x(02)00049-5

[38] S. Shekhar, "Urban sprawl and other spatial planning issues in Shimla, Himachal Pradesh," *Institute of Town Planners, India Journal*, pp. 53-66, 2011.

[39] K. A. Small, C. Winston, and J. Yan, "Uncovering the distribution of motorists' preferences for travel time and reliability," *Econometrica*, vol. 73, no. 4, pp. 1367-1382, 2005.

[40] M. Sooden, and N. S. Bist, District Human Development Report, Shimla, Planning Department, Himachal Pradesh, 2007.

[41] A. K. N. Reddy, Y. P. Anand, and A. D'Sa, "Energy for a sustainable road/rail transport system in India," *Energy for Sustainable Development*, vol. 4, no. 1, pp. 29-44, 2000.

[42] F. Targa, and K. Clifton, "Integrating social and psychological processes into the land use-travel behavior research agenda: Theories, concepts and empirical study design, *7th International Conference on Travel Survey Methods*, Los Suenos, Costa Rica, 2004.

[43] Town and Country Planning, Shimla City Development Plan, ILFS Report, India, Production, 2014. Available: http://jnnurm.nic.in/wp-content/uploads/2010/12/CDP_Shimla.pdf

[44] D. Tsamboulas, G. Yiotis, and K. Panou, "Use of multi criteria methods for assessment of transport projects," *Journal of Transportation Engineering*, vol. 125, no. 5, pp. 407-414, 1999.

[45] UDPFI, Ministry of Urban Affairs & Employment, GOI, New Delhi, vol. 1, 1996.

[46] D. Weisser, A guide to life-cycle Greenhouse Gas (GHG) emissions from electric supply technologies," *Energy*, vol. 32, no. 9, pp. 1543-1559, 2007. DOI: 10.1016/j.energy.2007.01.008

[47] A. D. Witte, J. Hollevoet, F. Dobruszkes, M. Hubert, and C. Macharis, "Linking modal choice to motility: A comprehensive review," *Transportation Research Part A*, vol. 49, pp. 329-341, 2013.

[48] E. E. Winston, and R. S. Handy, "The built environment and active travel: Developing measures of perceptual urban design qualities," in 83rd Annual Meeting of the Transportation Research Board, Washington, D.C., 2004.