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Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2019 Mumbai 26-31 May 2019

Gender and income based variability in travel choices in Vishakhapatnam, India

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Abstract

We propose three tiers of disaggregation to study variation in travel behavior across socio-economic groups. The first tier of disaggregation helps in studying variation in travel choices by gender and SEWS group independently. The second tier of disaggregation helps in studying the variation in travel choices between SEWS group within gender groups. This helps in understanding the issues related to affordability and accessibility related to income while controlling for gender. The third tier of disaggregation is used to study the variation between gender group within each SEWS group. This helps in identifying the differences in access to resources with regard to gender. We have also evaluated the application of interaction term between gender and income levels to model travel choices for the city of Vishakhapatnam. Socio-economic wellbeing score (SEWS) is used as the proxy of income determined using Principal Component Analysis (PCA) on asset ownership data. The study shows the need to understand within group variabilities in travel behaviour based on both income and gender. This highlights affordability and accessibility related issues for income-based disparities and safety, security and empowerment concerns for gender-based inequalities. However, no significant improvement in the variability is explained by the models when the interaction term between gender and income is used as one of the independent variables.

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Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY

Keywords: cross-sectional analysis; socio-economic groups; travel behaviortrip length; mode choice; trip purpose

1. Introduction

Sustainable mobility planning requires identifying the groups of society who have mobility constraints, measure their mobility and accessibility and designing policies and strategies accordingly (Jain and Tiwari, 2017; Sweet and Kanaroglou, 2016). This requires measuring variation in travel choices with respect to different socio-economic groups. The method also helps in identifying the groups of society that are moving towards or away from the overall sustainable mobility goals and therefore identify specific strategies to encourage the use of low carbon modes (Amekudzi et al., 2009; Buchs and Schnepf, 2013).

Two types of disaggregation i.e. income and gender have been commonly used to understand the variations in travel behavior and choices (Lawson et al., 2013; Matsuo, 2016; Scheiner and Holz-Rau, 2012; ZHANG et al., 2008; Zhou, 2012). Studies show that the people belonging to lower income groups and females have comparatively less mobility and are more dependent on non-motorized transport (NMT). There is also a difference in travel patterns of the two gender groups belonging to the same income level (Carlsson-Kanyama and Linden, 1999; Mahadevia and Advani, 2016; Matsuo, 2016; Scheiner & Holz-Rau, 2012; 2016). The variation in mobility choices within the same income groups highlights the difference in social roles and economic power of women. Economic and Social Council (2008) discusses the difference in travel pattern of women based on incomes, age, household type, education levels, ethnicity, and employment status. The report emphasizes on the need to look at these differences for a better understanding of the issues associated with different gender groups.

Measuring within group variabilities helps in identifying specific areas of interventions to achieve social equity and reducing overall burden of transport sector on the environment and society. Sweet & Kanaroglou (2016), identify the need for accessibility-oriented transportation-land use planning instead of travel time saving to increase subjective wellbeing index for different individuals. Similarly, Mahadevia & Advani (2016) shows the difference in trip length and mode choice between females belonging to different income groups in Rajkot. The study shows that the gender gap increases with increase in income in Rajkot. The research raised question on the type of infrastructure required to encourage women to travel more by sustainable modes of transport. Manoj et al. (2015) measured the difference in travel behavior between females and males belonging to different economic groups defined by housing tenure status i.e. house-owners versus renters. As per the study, female renters are comparatively less dependent on Motorized Two Wheeler (MTW) and are more dependent on cars as compared to the female house-owners. The authors identified the need for integrated transport – land use strategies to encourage public transport (PT) and NMT in Bangalore for work trips. Similarly, Boarnet and Hsu (2015) measured the difference in chauffeuring trips between females and males belonging to different types of households defined by marital status and household size using the data from Southern California Household Travel Survey (2001). The study helps in identifying specific development related strategies to reduce chauffeuring burden for females.

These studies show that the mobility of females belonging to the lower income groups of society is marginalized having an impact on their wellbeing. We propose the application of three tiers of disaggregation based on socio-economic profile of individuals (gender and income) to measure variation in travel choices. This can help in identifying mobility constraints of a specific group of individuals and causes contributing to the constraints. In the study, we also explore the application of interaction term between gender and income to model travel choices for the city of Vishakhapatnam.

The following paper is further divided into five sections. In the first section, we present the literature review to identify the factors contributing to the differences in travel choices between income and gender groups. The second section describes the data used for conducting the study. In the third section, we use descriptive and chi-square test to understand the variation in travel pattern across income and gender for the proposed three tiers of disaggregation. The fourth section of the paper presents the trip purpose, trip length and mode choice models with socio-economic

variables like age, gender, and income as independent variables. In the last section, discuss the application of the three tiers of disaggregation in travel behavior studies and issues associated with socioeconomic disparity in travel behavior for Vishakhapatnam.

2. Literature review

2.1. Income-based inequalities

Income-related variations in travel behavior are observed because of the affordability of households to own and use personal motorized vehicles (PMV) that includes both cars and MTW (Cheng et al., 2013; de Palma and Rochat, 2000; Li et al., 2015; Scholl, 2002; Tirumalachetty et al., 2013). Often people with less access to resources have less available to them to spend on transport. Therefore, they are more dependent on walking even for longer distances to meet their travel needs (Cheng et al., 2013; Murakami and Young, 1997; Srinivasan and Rogers, 2005). Even public transport (PT) is not affordable to them (Carruthers et al., 2005; Falavigna and Hernandez, 2016; Tiwari, 2002).

The variation in travel behavior between different income groups is also determined by the location of households with regard to the opportunities and accessibility to the PT system. As per Srinivasan & Rogers (2005), lower income group of people living close to the central business district (CBD) travel shorter distances, had a higher trip frequency, spent less time and money for commuting and are more dependent on NMT than the same income group living away from the CBD in Chennai. Similarly, Li et al. (2015), shows the spatial distribution of income across the city of Brisbane and its impact on the transport related expenditure and affordability. As per Cui et al. (2019), lower income groups travel for shorter durations and are more dependent on the slow modes of transport as compared to the higher income groups in three largest Canadian metropolitan regions. The study also shows a stronger negative impact of accessibility to jobs near origins on commute time for lower income groups than the higher income groups. Measuring the differences in accessibility and travel characteristics by location and income require spatial data that is rarely available in the developing countries.

2.2. Gender-based inequalities

Variation across genders is related to the involvement of males and females in the different type of activities that is largely governed by the triple roles that women play i.e. earning, domestic and community management responsibilities (Economic and Social Council, 2008; Matsuo, 2016; Olabarria et al., 2013; ZHANG et al., 2008). For example, females spend more time in domestic-related activities, childcare, shopping, and entertainment in Canada, whereas, men spend more time for working and engaging in sports and hobbies {Sweet, 2016 951 /id}. Similarly, females tend to make more maintenance related trips as compared to the males in Cologne, Germany who tend to make more work and education related trips (Best and Lanzendorf, 2005). Trips made by females are generally more complex involving multiple stops made for other than work activities like picking children from school (Ma et al., 2014; Scholl, 2002). The need for incorporating multiple trips results in reducing overall dependency on PT. This has an impact on the frequency of trips, trip purpose, trip timings, distance traveled and mode choice (Adeel et al., 2017; Kawgan-Kagan and Popp, 2018; Xianyu, 2013; Ye et al., 2007).

Level of difference in access to vehicles and resources (Dobbs, 2005; Scheiner & Holz-Rau, 2012) influence destination choices, distances traveled and mode choice. Men travel longer and more as car drivers than the females who are essentially either car passengers or pedestrians in India, Sweden and The United States of America (Frandberg and Vilhelmson, 2011; Mahadevia & Advani, 2016; Matsuo, 2016; Shirgaokar, 2018). Gender-specific issues like personal safety and security also affect the choice of NMT and PT for the females (Borjesson, 2012; Delbosc and Currie, 2012; Loukaitou-Sideris, 2014; Schmucki, 2012; Shirgaokar, 2018; Stradling et al., 2007). The embarrassments and harassments experienced by the women in public spaces deter them from using PT (Stark and Meschik, 2018). Lack of appropriate infrastructure also constraints women from bicycling in The United States of America (Emond et al., 2009). The social-cultural conventions of a society and dress codes are also found to have an impact on the bicycle mode choice (Dickinson et al., 2003; Peters, 2002).

Low level of mobility and poor access to transport services impact the accessibility of females to employment opportunity, health and education services for women and their wellbeing (Sweet & Kanaroglou, 2016; Uteng, 2011). This problem is more aggravated in developing countries. Areas that are served with poor transport infrastructure have less attendance of the girls in school as compared to the boys (Economic and Social Council, 2008).

2.3. Discussion

The impact of income and gender on travel choices varies by the context related variables like availability of infrastructure and affordability, the socio-economic construct of the society and safety and security perception associated with the different modes of transport. In contrast to the findings that the lower income group of the society is more dependent on NMT, the study by Matsushita et al. (2015) show that the men belonging to higher income groups are more involved in travel-related physical activity than the lower income groups in Japan. de Palma and Rochat (2000) shows the insignificant impact of income on the mode choice in Geneva, however income influence the number of vehicles owned by the households. Murakami & Young (1997), Manoj & Verma (2015) and Cheng et al. (2013) highlight that people belonging to lower income groups walk longer distances in the United States of America, Bangalore (India) and Huzhou (China) respectively. Whereas, in Vishakhapatnam, people belonging to lower socio-economic wellbeing score (SEWS) are more dependent on NMT, however, the walking distance does not vary significantly by the SEWS (Jain and Tiwari, 2019).

Similar variations are also observed with regard to the travel choices made by males and females. Males are comparatively more dependent on PT while females walk more in Great Britain (Hamilton et al., 2005). However, Dickinson et al. (2003) show that women are more likely to use cars for work than the males in the United Kingdom. As per Mahadevia & Advani (2016) females travel less by PMV and are more dependent on PT and walk than the males in Rajkot, India. Therefore, the results and findings from one study cannot be generalized for another geographical context.

3. Data and Methodology

The study is based on the household data collected for Visakhapatnam by ITRANS, India in 2012 – 2013 under the project "Promoting Low Carbon Transport in Medium Size Indian Cities" funded by United Nation Environment Programme. The city is located on the eastern coast of India having a population of 1.73 million (Census of India, 2011). In terms of the city transport infrastructure, only 7% of the roads have footpaths with no infrastructure for bicycles. The city has a bus fleet of 521 buses operated by the state agency and a fleet of 25,000 registered auto-rickshaws serving as inter-mediate paratransit (IPT) (Arora et al., 2014). In Vishakhapatnam, 53% of the trips are made by non-motorized transport (NMT) and 17% by bus. Sixty-three percent of the total trips in the city are shorter than 2 km and 79% of the trips are shorter than 5 km (Tiwari et al., 2016).

A valid sample of 2623 households and 10,118 individuals is used for this study (Jain & Tiwari, 2019). The survey captures household related information like income, assets owned, vehicles owned and relative distance of a house from basic services and individual related information - demography of individuals and their travel behavior. Of the total sample collected, 50% are female. Fifty-four percent of the total households surveyed had reported their monthly income less than INR 10,000 and only 2% have more than INR 50,000 monthly income.

Earlier studies show that the direct income reported in household surveys are either unreliable or are not reported (Balen et al., 2010; Cordova, 2008; Devkota, 2014; Diaz Olvera et al., 2015; Fry et al., 2014; Harttgen and Vollmer, 2013; Lee, 2009; Saha et al., 2014). Of the valid survey of 2623 households in Vishakhapatnam, 2% of the households did not respond to the question related to income and for others, reliability of the quoted income was questionable (Balen et al., 2010; Diaz Olvera et al., 2015; Lee, 2009; Saha et al., 2014). To account for this no reporting and unreliability, we have used Principal Component Analysis (PCA) on asset ownership data for the valid

sample data. Durable assets like air conditioner, computer, fridge, type of vehicle owned and access to basic services like the toilet, kitchen, and tap water are considered. Factor loadings obtained for the first principal component is used to determine factor scores of households as it explains maximum variance (26.4%) in the data to estimate socio-economic wellbeing score (SEWS) of the households. Using mean values of the factor scores, households are classified as low, low-middle, middle-high and very-high SEWS groups. Based on this 32%, 31%, 25% and 13% of the households are classified as low, low-middle, middle-high and very-high SEWS group, respectively (for more details refer paper (Jain & Tiwari, 2019)).

3.1. Research methodology

We propose the application of three tiers of disaggregation to study travel behavior across different segments of society. The first tier of disaggregation is by income and gender independently. This helps in identifying the vulnerable groups of society having less access to the transport system in the city, constrained mobility and less accessibility to opportunities. The second tier of disaggregation addresses differences in travel pattern (trip rates by trip purpose, trip lengths, and mode choice) between incomes within same gender group. This is useful to highlight differences in affordability and accessibility of high and low income while controlling for mobility gaps between genders. For example, issues related to affordability are identified if women from high-income group use more PT as compared to the women from low-income. The third tier of disaggregation accounts for the differences between gender groups within the same income level. This is useful in understanding the differences in safety, security and comfort perception related to walk and use of PT in the city while controlling for affordability related constraints. Issues related to the socio-cultural conventions that restrict females to use certain modes like bicycles can also be highlighted through the third tier of disaggregation.

Table 1: Variables used in different models

<table>
<tr><th colspan="2">Model 1</th><th colspan="2">Model 2</th><th colspan="2">Model 3</th></tr>
<tr><th colspan="2">Trip purpose</th><th colspan="2">Trip length</th><th colspan="2">Mode Choice</th></tr>
<tr><th>Model 1a</th><th>Model 1b</th><th>Model 2a</th><th>Model 2b</th><th>Model 3a</th><th>Model 3b</th></tr>
<tr><td>Female</td><td>Low SEWS – female</td><td>Female</td><td>Low SEWS – female</td><td>Female</td><td>Low SEWS – female</td></tr>
<tr><td>Male (dummy)</td><td>Low SEWS – male (dummy)</td><td>Male (dummy)</td><td>Low SEWS – male (dummy)</td><td>Male (dummy)</td><td>Low SEWS – male (dummy)</td></tr>
<tr><td>Low SEWS</td><td>Low – Middle SEWS - female</td><td>Low SEWS</td><td>Low – Middle SEWS - female</td><td>Low SEWS</td><td>Low – Middle SEWS - female</td></tr>
<tr><td>Low-Middle SEWS</td><td>Low – Middle SEWS – male (dummy)</td><td>Low-Middle SEWS</td><td>Low – Middle SEWS – male (dummy)</td><td>Low-Middle SEWS</td><td>Low – Middle SEWS – male (dummy)</td></tr>
<tr><td>Middle – High SEWS</td><td>Middle-High SEWS – female</td><td>Middle – High SEWS</td><td>Middle-High SEWS – female</td><td>Middle – High SEWS</td><td>Middle-High SEWS – female</td></tr>
<tr><td>Very-High SEWS (dummy)</td><td>Middle-High SEWS – male (dummy)</td><td>Very-High SEWS (dummy)</td><td>Middle-High SEWS – male (dummy)</td><td>Very-High SEWS (dummy)</td><td>Middle-High SEWS – male (dummy)</td></tr>
<tr><td>Age 0 – 14</td><td>Very-High SEWS – female (dummy)</td><td>Age 0 – 14</td><td>Very-High SEWS – male (dummy)</td><td>Age 0 – 14</td><td>Very-High SEWS – male (dummy)</td></tr>
<tr><td>Age 15 – 24</td><td>Very-High SEWS – male (Dummy)</td><td>Age 15 – 24</td><td>Very-High SEWS – female (Dummy)</td><td>Age 15 – 24</td><td>Very-High SEWS – female (Dummy)</td></tr>
<tr><td>Age 25 – 59</td><td rowspan="2">(Along with other variables defined in model 1a)</td><td>Age 25 – 59</td><td rowspan="6">(Along with other variables defined in model 2a)</td><td>Age 25 – 59</td><td rowspan="6">(Along with other variables defined in model 3a)</td></tr>
<tr><td>Age > 59 (dummy)</td><td>Age > 59 (dummy)</td><td>Age > 59 (dummy)</td></tr>
<tr><td></td><td></td><td>Trip purpose = work</td><td>Trip purpose = work</td></tr>
<tr><td></td><td></td><td>Trip purpose = education</td><td>Trip purpose = education</td></tr>
<tr><td></td><td></td><td>Trip purpose = Others (dummy)</td><td>Trip purpose = Others (dummy)</td></tr>
<tr><td></td><td></td><td></td><td>Distance</td></tr>
</table>

We have studied the variation in travel pattern – trip purpose, trip length and mode choice across different segments of society. For the purpose of the study, only intra-city trips are considered. The first variable, trip purpose helps in identifying the differences in activity involvement by different groups of individuals. Three major trip

purposes are identified from the survey i.e. work, education and other. Trips for other purpose include visits for social/recreational activities like leisure, entertainment or visiting friends and relatives and visiting religious places like temple, church, and mosque. Disaggregating trip length by socio-economic groups helps in identifying the physical sphere of activity involvement for different groups and understanding the difference in spatial accessibility. Modal share is one of the key indicators that help in understanding the difference in access to resources to use PT and PMV among different groups of society. It also helps in identifying the segment of a society that has lesser physical accessibility to PT infrastructure and the group of society that is imposing a burden on the environment.

For the purpose of the study, first, we have used descriptive analysis along with chi-square test to understand if the three indicators (trip purpose, trip length and mode choice) vary with respect to the gender and SEWS groups across the three tiers of disaggregation. Later, we have used linear regression to model trip length and multinomial logit to model trip purpose and mode choice. For each of the models, two sub-models are developed - one with independent SEWS groups and gender variables and second with an interaction term between SEWS groups and gender (Table 1). For both trip length and mode choice models, trip purpose is also included as an independent variable. For the mode choice model trip length or distance is also included as an independent variable.

4. Travel pattern by three tiers of disaggregation

4.1. First tier of disaggregation by income and gender

Approximately 30% of the females stay at home as compared to 10% males (Figure 1a). Of the total females in the survey, 40% are likely to travel for other purposes that include leisure, entertainment, shopping and religious activity as compared to 7% males. Our study shows that the females are less likely to travel for work (8%), whereas 56% of males are likely to travel for work. However, less variation in activity involvement is observed when compared across SEWS groups (Figure 1b). Chi-square test shows that the involvement in activities does not vary significantly by SEWS group at 95% confidence interval.

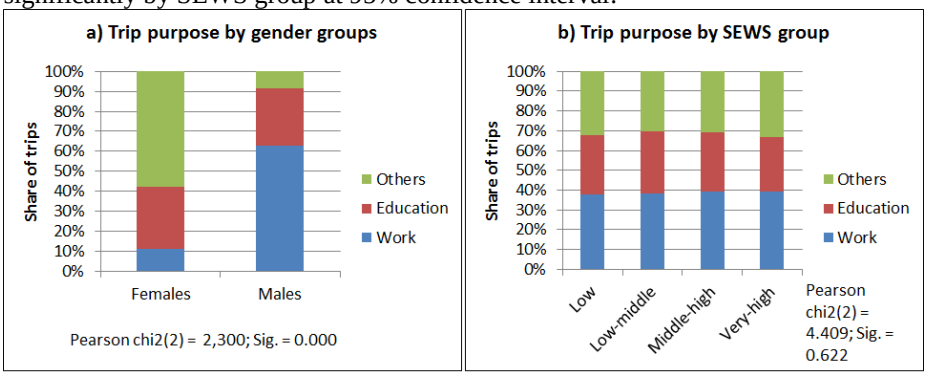

Figure 1: Trip purpose by socio-economic groups of society

As shown in Figure 2 distances traveled varies by both gender and SEWS. As per Figure 2a and Table 2, females are likely to travel shorter distances (average = 3.70 km, std. dev. = 3.10 km) as compared to males (average = 4.15km, std. dev. = 4.70 km). People belonging to low and low-middle SEWS group are likely to travel shorter distances as compared to the middle-high and very-high SEWS group. Seventy-one percent of the people in the low SEWS group travel less than 2 km as compared to 50% of the people in the very-high SEWS group (Figure 2b).

Table 2: Summary statistics of distance traveled

		Mean	Std. Dev.
Gender groups	Female	2.08	3.10
	Male	4.15	4.70
SEWS groups	Low SEWS	2.72	3.90
	Low-middle SEWS	2.96	3.90
	Middle-high SEWS	3.69	4.42
	Very-high SEWS	3.95	4.69

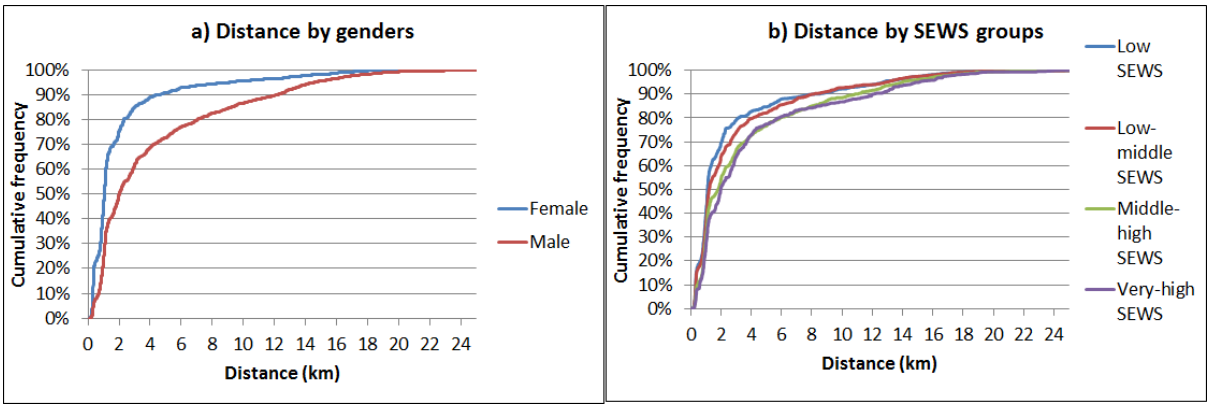

Figure 2: Distance by socio-economic groups of society

Table 3: ANOVA test for variation in trip length

		Sum of Squares	df	Mean Square	F	Sig.
Gender	Between Groups	6684.469	1.000	6684.469	411.230	0.000
	Within Groups	101884.071	6268.000	16.255		
	Total	108568.539	6269.000	17.318		
SEWS group	Between Groups	1394.353	3.000	464.784	27.170	0.000
	Within Groups	107174.187	6266.000	17.104		
	Total	108568.539	6269.000	17.318		

Table 4: Post-hoc multiple comparisons: trip lengths by SEWS group

		Low	Low-Middle	Middle-high
Low-middle	Mean difference (Row - Column)	0.239		
	Significance	0.412		
Middle-high	Mean difference (Row - Column)	0.975	0.735	
	Significance	0.000	0.000	
Very-high	Mean difference (Row - Column)	1.235	0.995	6.259
	Significance	0.000	0.000	0.925

As per the ANOVA test, there is a significant difference between the distances traveled by the gender groups and SEWS groups (Table 3). Multiple post-hoc analysis shows that the trip length does not vary significantly between low and low-middle SEWS groups and middle-high and very-high SEWS groups (Table 4). However, there is a significant difference in the trip length between low and middle-high, low-middle and middle-high and low and very-high SEWS groups.

Gender-based analysis shows that males are more dependent on motorized transport as compared to the females. As per the chi-square test, there is a significant association between modal share and SEWS group at 99% confidence interval. Dependency on NMT decreases with increasing SEWS levels (Figure 3).

Highest variation is observed in the choice of MTW followed by the walk with respect to both gender and income (Table 5). Walking is the most preferred mode by females and people belonging to low SEWS group. Bicycle is mostly used by the people belonging to low-middle SEWS group and car is used only by the people belonging to very-high SEWS group. Use of MTW increases with an increase in SEWS and from females to males.

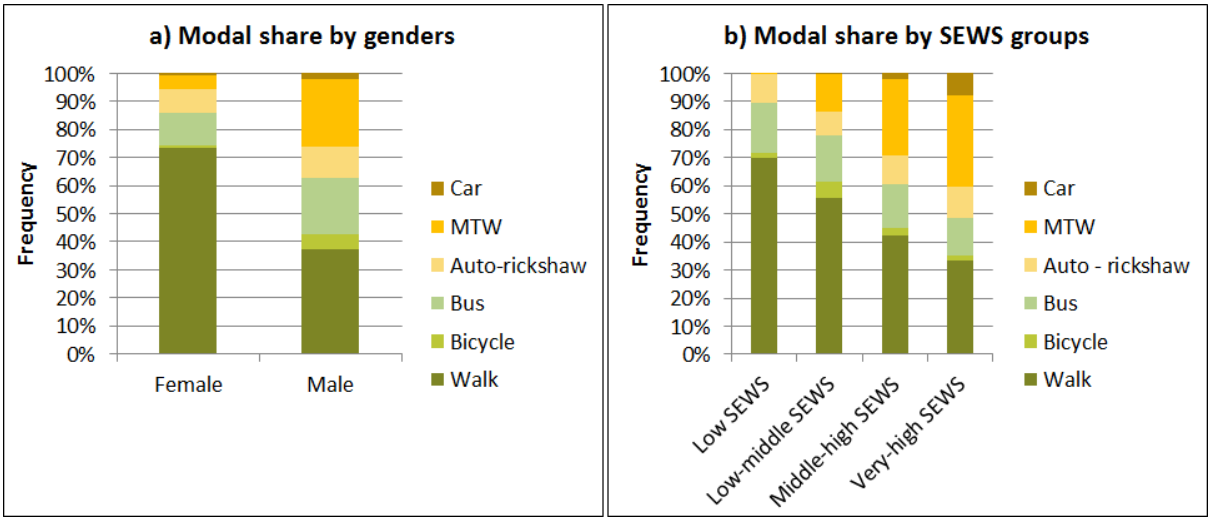

Figure 3: Modal share by socio-economic groups of society

Table 5: Cells Pearson chi-square values for association between mode choice and socio-economic groups of society

Categorical variables		Cells Pearson chi-square						
		Walk	Bicycle	Bus	TSR	MTW	Car	Total
Gender group	Females	199.4	53.6	34.5	6.1	207	9.3	510
Pearson $chi^2(5) = 953.998$	Males	173.6	46.7	30	5.4	180.2	8.1	444
Sig. = 0.000	Total	373.1	100.3	64.5	11.5	387.2	17.4	954
SEWS group	Low SEWS	90.5	9.1	2.1	0.4	286.8	31.7	420.6
Pearson $chi^2(15) = 3200$	Low-middle SEWS	0.9	33.9	0.1	3.4	3.9	16.3	58.4
Sig. = 0.000	Middle-high SEWS	41.5	1.2	0.4	0.4	159.1	1	203.6
	Very-high SEWS	60.7	7.7	3.6	1	162.7	198.4	434.3
	Total	193.5	51.9	6.3	5.2	612.5	247.4	1116.8

Trip length and mode choice significantly vary by both gender and SEWS groups whereas, trip purpose varies only by gender. The analysis shows that affordability of motorized modes including PT (bus) in Vishakhapatnam has impact on the mode choice by different SEWS group. There is also a difference in the choice of modes by gender group, however, it is not evident, if this difference is because of availability, accessibility, and affordability of the mode or because of the socio-cultural conventions.

4.2. Second and third tier of Disaggregation

As observed in Figure 4, much variation is not there in the type of activities involvement with regard to SEWS groups within gender groups. Although, chi-square test show significant variation in trip purpose by both the level of disaggregation. Compared to other SEWS groups, females belonging to very-high SEWS group are more likely to travel for work. Negligible variation is observed in other trip purpose with regard to SEWS group amongst females as cells Pearson chi-square value is less than one (Table 6). Similarly, less variation is observed in work trip purpose with regard to SEWS amongst males. Males belonging to very-high SEWS group are likely to travel more for other purpose than the males belonging to other SEWS groups.

Within the same SEWS groups, the choice of trip purpose varies between gender groups. However, this variation is observed only for the involvement in a work trip and other trips. The analysis shows that females are less likely to travel for work in Vishakhapatnam as compared to males in all the SEWS group. There is an insignificant difference in education trip purpose between males and females in Vishakhapatnam.

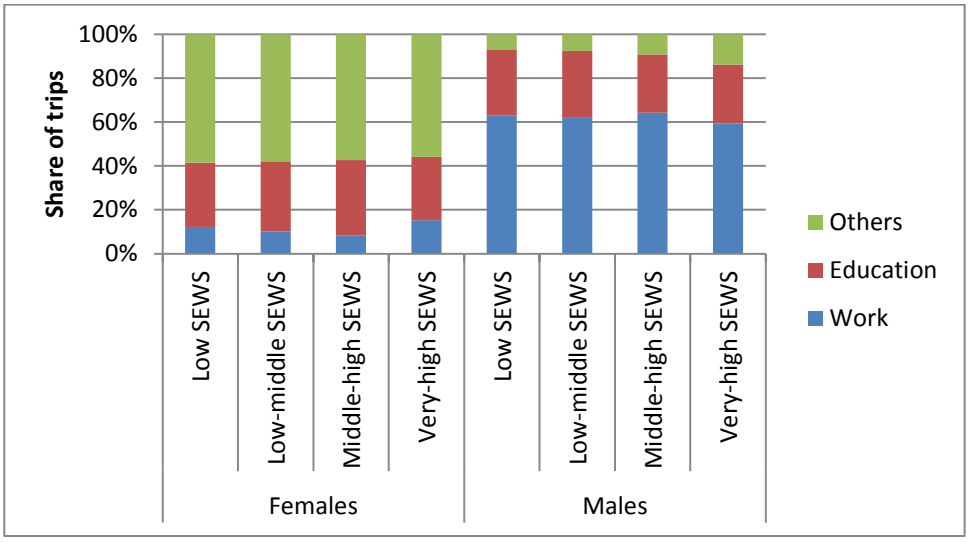

Figure 4: Variation in involvement in activities amongst SEWS group by gender

Table 6: Cells Pearson chi-square values for association between activity involvement and socio-economic groups of society

Grouping variable = Gender	SEWS Groups	Pearson chi-square values			
		Work	Education	Others	Total
Females	**Low SEWS**	1.1	1.1	0.1	2.3
Pearson chi^2(6) = 16.164	**Low-middle SEWS**	0.6	0.1	0	0.7
Pr = 0.013	**Middle-high SEWS**	4.5	2.2	0	6.7
	Very-high SEWS	5.7	0.7	0.2	6.6
	Total	11.8	4	0.3	16.2
Males	**Low SEWS**	0	0.4	2.8	3.2
Pearson chi^2(6) = 21.942	**Low-middle SEWS**	0.1	1	1.3	2.3
Pr = 0.001	**Middle-high SEWS**	0.4	1.6	0.4	2.3
	Very-high SEWS	0.7	0.5	12.8	14
	Total	1.2	3.5	17.2	21.9

Grouping variable = SEWS groups	Gender	Pearson chi-square values			
		Work	Education	Others	Total
Low SEWS	**Female**	175.9	0	209.7	385.6
Pearson chi^2(2) = 758.148	**Male**	170	0	202.6	372.5
Sig. = 0.000	**Total**	345.9	0	412.3	758.1
Low-Middle SEWS	**Female**	181.9	0.2	216.9	399
Pearson chi^2(2) = 729.840	**Male**	150.8	0.1	179.9	330.9
Sig. = 0.000	**Total**	332.7	0.3	396.8	729.9
Middle-High SEWS	**Female**	167.6	4.4	156.3	328.3
Pearson chi^2(2) = 596.340	**Male**	136.9	3.6	127.8	268.3
Sig. = 0.000	**Total**	304.5	8	284.1	596.6
Very-High SEWS	**Female**	51.5	0.2	55.4	107
Pearson chi^2(2) = 197.705	**Male**	43.6	0.1	46.9	90.7
Sig. = 0.000	**Total**	95.1	0.3	102.3	197.7

Figure 5, Table 7 and Table 8 shows that trip length varies significantly between genders within each SEWS group and also between SEWS group amongst females and males. People belonging to a higher level of SEWS are likely to travel longer distances while controlling for gender. We interpret that the females belonging to low SEWS and low-middle SEWS group have mobility constraints and therefore the number of opportunities in reach to them may be limited. A study to assess the number of opportunities accessible to different groups of society needs to be conducted to confirm to the analysis. Post-hoc multiple comparisons between SEWS group amongst females and

males shows that there is an insignificant variation in trip length between low and low-middle SEWS group (Table 8). However, there is a significant variation in trip length between low and middle-high SEWS group, middle-high and very-high SEWS group and low and very-high SEWS group amongst females. The trip length also does not significantly vary between middle-high and very-high SEWS group amongst males. Therefore, it can be interpreted that both females and males belonging to low and low-middle SEWS group are accessing opportunities at shorter distances as compared to the females and males belonging to higher SEWS group. The variations in trip length between SEWS group amongst females and males are also likely to be because of the observed variations in trip purpose amongst different segments of society. The analysis also highlights the difference in spatial mobility between females and males in all SEWS groups (Table 7). Females are likely to travel shorter distances than males in each SEWS group.

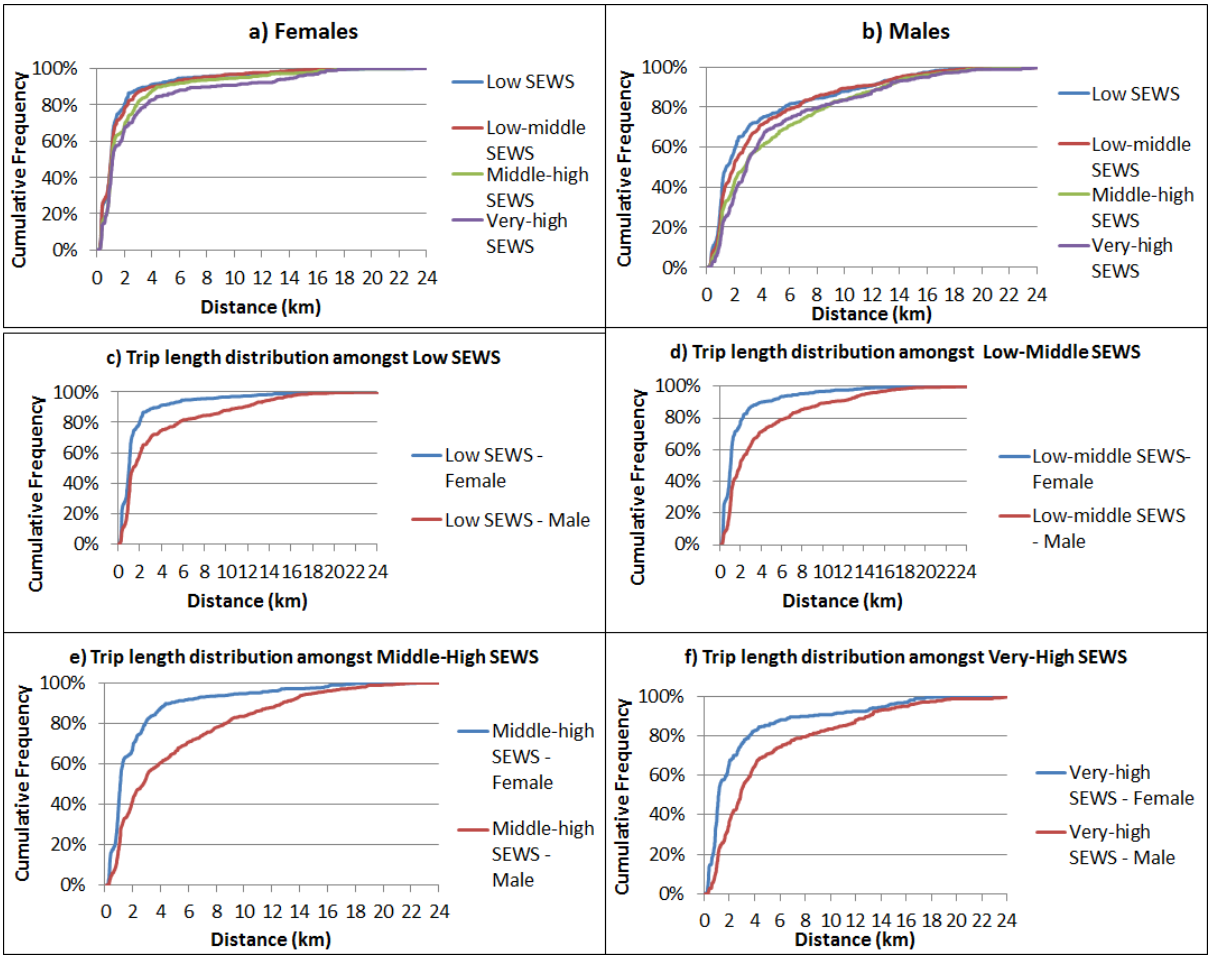

Figure 5: Trip length distribution between SEWS group amongst gender groups (a-b) and between gender groups amongst SEWS groups (c-f)

Amongst females walking is less preferred by those belonging to very-high SEWS group as compared to other groups. Walk shares for women belonging to low, low-middle, middle-high and very-high SEWS groups are 83%, 78%, 63%, and 54%, respectively. Consecutively, dependency on the bus and auto-rickshaw increases for women with an increase in SEWS while, for men it decreases. The analysis also shows that the use of PMV increases with an increase in SEWS group for both males and females.

Table 7: ANOVA test for variation in trip length between different segments of society – tier II and tier III disaggregation

			Sum of Squares	df	Mean Square	F	Sig.
ANOVA test for variation in trip length between SEWS group amongst gender groups	Female	Between Groups	404.057	3	134.686	14.210	0.000
		Within Groups	27612.386	2914	9.476		
		Total	28016.443	2917	9.605		
	Male	Between Groups	955.101	3	318.367	14.620	0.000
		Within Groups	72912.527	3348	21.778		
		Total	73867.628	3351	22.043		
ANOVA test for variation in trip length between gender amongst SEWS groups	Low SEWS group	Between Groups	1676.595	1	1676.595	116.21	0.000
		Within Groups	29243.002	2027	14.427		
		Total	30919.597	2028	15.247		
	Low-Middle SEWS group	Between Groups	1901.439	1	1901.439	133.770	0.000
		Within Groups	27375.807	1926	14.214		
		Total	29277.246	1927	15.193		
	Middle-High SEWS group	Between Groups	2352.620	1	2352.620	130.790	0.000
		Within Groups	27682.848	1539	17.987		
		Total	30035.468	1540	19.503		
	Very-High SEWS group	Between Groups	718.620	1	718.620	34.110	0.000
		Within Groups	16223.254	770	21.069		
		Total	16941.874	771	21.973		

Table 8: Post-hoc multiple comparisons: trip length variation between SEWS group amongst males and females: tier II disaggregation

		Female			Male		
SEWS group		Low	Low-Middle	Middle-high	Low	Low-Middle	Middle-high
Low-middle	Mean difference (Row - Column)	0.074			0.250		
	Significance	1.000			1.000		
Middle-high	Mean difference (Row - Column)	0.533	0.459		1.198	0.948	
	Significance	0.003	0.020		0.000	0.000	
Very-high	Mean difference (Row - Column)	1.111	1.037	0.578	1.229	0.979	0.031
	Significance	0.000	0.000	0.024	0.000	0.002	1.000

Modal split varies significantly between males and females within each SEWS group and between SEWS group amongst females and males (Figure 6). Walk mode share is high for all the females irrespective of SEWS groups as compared to their male counterparts while the use of the bicycle is negligible by females as compared to the males irrespective of SEWS group. Females belonging to low and low-middle SEWS group use less bus as compared to the males belonging to the same SEWS group. Similarly, there is also a difference in MTW and car share between females and males belonging to middle-high and very-high SEWS group (Table 9). Tier III disaggregation, therefore, reveals that there is a difference in access to the types of mode between females and males irrespective of SEWS group. The females are more restricted to have access to costlier modes of transport as compared to males in all the SEWS groups.

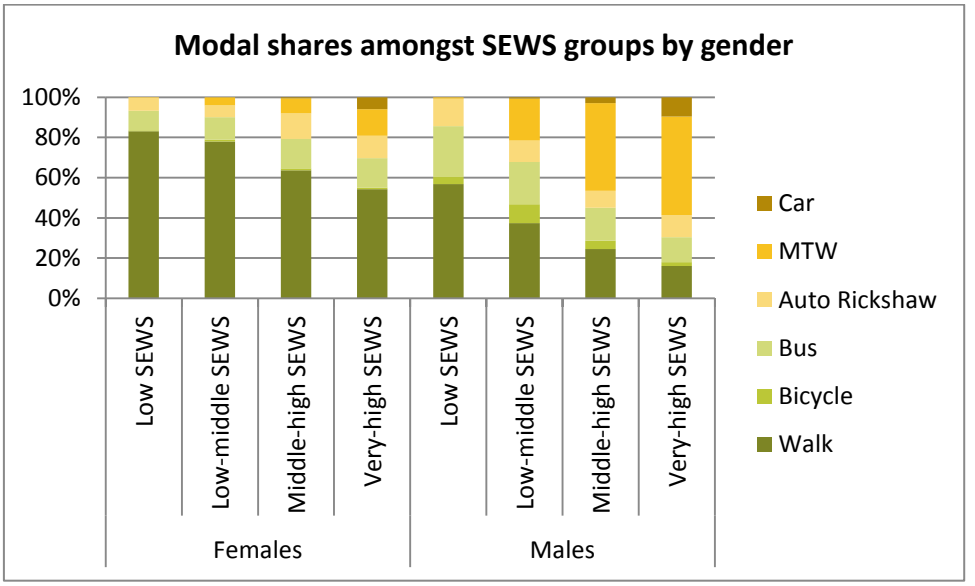

Figure 6: Modal shares amongst different segments of society- tier II and tier III disaggregation

Table 9: Cells Pearson chi-square values for association between mode choice and different segments of society – tier II and tier III disaggregation

	Grouping variable	Groups	Pearson chi-square values						
			Walk	Bicycle	Bus	Auto-Rickshaw	MTW	Car	Total
Association between mode choice and SEWS group amongst females and males	**Females Pearson chi2(15) = 321.583 Sig. = 0.000**	**Low SEWS**	12.8	1.9	4.2	3.5	44.1	8.5	75
		Low-middle SEWS	2.4	0.6	0.4	6.4	0.7	7.5	18.1
		Middle-high SEWS	9.1	0.4	4.3	15	12.4	0.6	41.8
		Very-high SEWS	17.8	0	2.4	2.8	57.3	106.4	186.7
		Total	42	3	11.3	27.6	114.5	123.1	321.6
	Males Pearson chi2(15) = 909.936, Sig. = 0.000	**Low SEWS**	6	13.6	22.5	232.5	6.4	103.1	384.1
		Low-middle SEWS	32.4	0.4	9.7	4.2	0.2	0	47
		Middle-high SEWS	2.3	5.7	2.3	137.2	5.3	37.8	190.5
		Very-high SEWS	9.2	12.1	104.9	111	0	51.2	288.3
		Total	49.9	31.8	139.4	484.9	11.9	192.1	909.9
Association between mode choice and gender groups amongst low, low-middle, middle-high and very-high SEWS group	**Low SEWS Pearson chi2(4) = 174.704 Sig. = 0.000**	**Female**	25.7	12.9	35.6	12.4	2.2	0.0	88.9
		Male	24.8	12.5	34.4	12	2.1	0.0	85.8
		Total	50.6	25.4	70	24.4	4.3	0.0	174.7
	Middle- Low SEWS Pearson chi2(5) = 350.064 Sig. = 0.000	**Female**	77	32.6	15.4	6.9	55.8	3.6	191.4
		Male	63.8	27	12.8	5.8	46.3	3	158.7
		Total	140.8	59.7	28.2	12.7	102	6.6	350.1
	Middle-High SEWS Pearson chi2(5) = 351.800 Sig. = 0.000	**Female**	76.2	7.5	0.4	3.6	99.6	6.3	193.6
		Male	62.3	6.1	0.4	2.9	81.4	5.1	158.2
		Total	138.5	13.6	0.8	6.5	181	11.4	351.8
	Very-High SEWS Pearson chi2(5) = 163.980 Sig. = 0.000	**Female**	45.2	0.8	0.4	0.0	40.7	1.7	88.8
		Male	38.2	0.7	0.3	0.0	34.4	1.5	75.2
		Total	83.4	1.5	0.7	0.0	75.1	3.2	164

5. Travel behavior models using socio-economic variables

In the section, we present the results of the models estimated for the trip purpose (Table 10), trip length (Table 11) and mode choice (Table 13). The shaded cells in the tables show independent variables having an insignificant impact at both 95% and 90% confidence interval. The estimates help in understanding the effect of individual variables on travel behavior and measuring differences between different segments of society.

5.1. Trip purpose

Multinomial logit models are estimated for trip purpose – work, education, and others with other trip purpose as the base (Table 10). There is no significant difference between the variability explained by model 1a and model 1b. However, the strength of effect for each independent variable varies between the two estimated models.

As per model 1a, propensity for traveling to education increases with an increase in SEWS level as compared to traveling for other trip purposes. SEWS does not have a significant impact on the choice of work trips. Whereas, as per model 1b, SEWS does not have a significant impact on the choice of trip purpose except for the work trip. Here, the model shows that the people belonging to low SEWS group are likely to travel more for work purpose than other purposes as compared to the people belonging to very-high SEWS group. Both the models show that the males are likely to travel more for work than other trip purpose.

Model 1b also shows that the females differ significantly from males in each SEWS group with regard to the propensity of traveling for work purpose. We also interpret that the propensity for traveling to work reduces significantly amongst females from low to middle-high SEWS group.

Table 10: Multinomial model estimates for trip purpose

Parameters		**Trip purpose**	**Model 1a**		**Model 1b**	
			Coef.	**z**	**Coef.**	**Z**
Age (base > 60)	Age (0 - 14)	Education	10.303	0.000	10.242	0.000
		Work	2.254	0.000	2.221	0.000
	Age (15 - 24)	Education	6.880	0.000	6.816	0.000
		Work	2.163	0.000	2.125	0.000
	Age (25 - 59)	Education	1.990	0.008	1.926	0.010
		Work	2.522	0.000	2.476	0.000
SEWS group (base = Very-High SEWS group)	Low SEWS	Education	-0.837	0.000	-0.454	0.161
		Work	0.027	0.850	0.431	0.042
	Low-Middle SEWS	Education	-0.688	0.001	-0.223	0.488
		Work	-0.147	0.310	0.289	0.166
	Middle-High SEWS	Education	-0.385	0.074	-0.058	0.862
		Work	-0.234	0.116	0.218	0.302
Gender (base = female)	Male	Education	2.440	0.000	2.017	0.000
		Work	4.023	0.000	3.333	0.000
Income-Gender group (base = Low SEWS – male, Low-Middle SEWS male, Middle-High SEWS male, Very-High SEWS female, Very-High SEWS – Male)	Low SEWS - Female	Education	Omitted		-0.468	0.269
		Work			-0.740	0.009
	Low-Middle SEWS female	Education			-0.600	0.156
		Work			-0.776	0.006
	Middle-High SEWS female	Education			-0.339	0.444
		Work			-0.915	0.002
Constant		Education	-6.233	0.000	-6.093	0.000
		Work	-3.935	0.000	-3.576	0.000
Model summary	Number of parameters		14		20	
	LR chi2		8146.910		8158.410	
	Prob > chi2		0.000		0.000	
	Log-likelihood model		-2775.534		-2769.783	
	Pseudo R^2		0.5948		0.596	

5.2. Trip length

As per model 2a, males are likely to travel significantly more distance by 0.669 km than females irrespective of SEWS group (Table 11). The model also shows that the trip length increases significantly with an increase in SEWS level. These interpretations are as per the analysis discussed in section 4. However, there is no difference in the variability explained by both the model 2a and 2b (adjusted R-square = 0.16). There is also a less difference in the effect size of independent variables between the two models. In model 2b, the interaction term between gender and SEWS group does not have a significant impact on trip length. Since model 2a use lesser number of parameters and is easier to interpret therefore we propose the application of this model.

Table 11: Trip length model

Parameters		**Model 2a**		**Model 2b**	
		Coef.	**z**	**Coef.**	**z**
Age (base > 60)	Age (0 - 14)	-2.228	0.000	-2.213	0.000
	Age (15 - 24)	0.836	0.001	0.851	0.000
	Age (25 - 59)	0.615	0.002	0.626	0.002
SEWS group (base = Very-High SEWS group)	Low SEWS	-1.158	0.000	-1.327	0.000
	Low-Middle SEWS	-1.026	0.000	-1.101	0.000
	Middle-High SEWS	-0.282	0.094	-0.144	0.527
Gender (base = female)	Male	0.669	0.000	0.757	0.007
Income-Gender group (base = Low SEWS – male, Low-Middle SEWS male, Middle-High SEWS male, Very-High SEWS female, Very-High SEWS – Male)	Low SEWS - Female	Omitted		0.347	0.282
	Low-Middle SEWS female			0.162	0.619
	Middle-High SEWS female			-0.309	0.359
Trip purpose (base = Others)	Education	3.168	0.000	3.172	0.000
	Work	2.730	0.000	2.729	0.000
Constant		1.543	0.000	1.484	0.000
Model Summary	R^2		0.165		0.166
	Adj. R^2		0.163		0.164
	Root MSE		3.806		3.805
	F		137.020		103.390
	Sig.		0.000		0.000

5.3. Mode choice

Similar to the trip purpose and trip length model, we have estimated two multinomial logit models for mode choice with MTW as the base. Both the models explain the same level of variability in mode choice (Table 12). Table 13 shows the estimated coefficients for the independent variables. Both the models 3a and 3b reveal that the choice for the walk and bus reduces from females to males and from low to very-high SEWS level. Model 3b shows that the interaction term between gender and SEWS group does not have a significant impact on mode choice except for low-middle SEWS – female group. As per the analysis only within low-middle SEWS group, the choice for bus and auto-rickshaw varies between genders. Females belonging to low-middle SEWS group are less likely to use bus and MTW as compared to the males. Coefficient estimates for all other independent variables vary negligibly between the two models. Model 3b does not provide a better understanding of variation in mode choice between different segments of society than model 3a. Therefore, model 3a is used for further analysis.

Table 12: Model summary for mode choice

Model summary	Model 3a	Model 3b
Number of parameters	50	65
LR chi2	7156.640	7179.430
Prob > chi2	0.000	0.000
Log-likelihood model	-4667.920	-4656.528
Pseudo R2	0.434	0.435

Table 13: Mode choice models

Parameters		Modes	Model 3a Coef.	Model 3a z	Model 3b Coef.	Model 3b z
Distance		Walk	-1.652	0.000	-1.650	0.000
		Bicycle	-0.257	0.000	-0.254	0.000
		Bus	0.121	0.000	0.122	0.000
		Auto-rickshaw	-0.001	0.927	0.001	0.973
		Car	0.055	0.010	0.054	0.011
Age (base => 60)	Age (0 - 14)	Walk	0.739	0.044	0.746	0.042
		Bicycle	-0.729	0.170	-0.758	0.155
		Bus	-0.831	0.027	-0.851	0.024
		Auto-rickshaw	0.934	0.023	0.917	0.026
		Car	-1.178	0.173	-1.188	0.169
	Age (15 - 24)	Walk	0.227	0.427	0.233	0.416
		Bicycle	-0.255	0.566	-0.278	0.532
		Bus	0.071	0.819	0.056	0.858
		Auto-rickshaw	0.103	0.772	0.090	0.800
		Car	-1.441	0.006	-1.433	0.006
	Age (25 - 59)	Walk	-0.277	0.216	-0.278	0.214
		Bicycle	-0.706	0.056	-0.737	0.047
		Bus	-0.446	0.095	-0.474	0.077
		Auto-rickshaw	-0.237	0.437	-0.260	0.394
		Car	-1.290	0.000	-1.324	0.000
Trip purpose (base = Others)	Education	Walk	-0.552	0.063	-0.564	0.057
		Bicycle	2.873	0.000	2.879	0.000
		Bus	2.205	0.000	2.202	0.000
		Auto-rickshaw	1.271	0.000	1.271	0.000
		Car	-0.814	0.270	-0.820	0.266
	Work	Walk	-1.606	0.000	-1.614	0.000
		Bicycle	1.401	0.010	1.395	0.011
		Bus	-0.107	0.601	-0.120	0.556
		Auto-rickshaw	-0.404	0.060	-0.406	0.059
		Car	-0.408	0.197	-0.434	0.174
SEWS group (base = Very-High SEWS group)	Low SEWS	Walk	6.326	0.000	6.391	0.000
		Bicycle	5.137	0.000	5.326	0.000
		Bus	5.191	0.000	5.380	0.000
		Auto-rickshaw	5.026	0.000	5.039	0.000
		Car	-12.172	0.972	-13.391	0.986
	Low-Middle SEWS	Walk	2.100	0.000	2.094	0.000
		Bicycle	2.456	0.000	2.668	0.000
		Bus	1.497	0.000	1.712	0.000
		Auto-rickshaw	1.087	0.000	1.182	0.000
		Car	-1.838	0.000	-1.494	0.000
	Middle-High SEWS	Walk	0.707	0.000	0.753	0.001
		Bicycle	0.984	0.005	1.105	0.007
		Bus	0.490	0.003	0.552	0.007
		Auto-rickshaw	0.277	0.112	0.062	0.783
		Car	-1.117	0.000	-0.943	0.001
Gender (base = female)	Male	Walk	-1.500	0.000	-1.577	0.000
		Bicycle	0.140	0.599	-0.537	0.448
		Bus	-1.094	0.000	-1.420	0.000
		Auto-rickshaw	-1.109	0.000	-1.096	0.000
		Car	-0.486	0.099	-0.849	0.014
Income-Gender group (base = Low SEWS – male, Low-Middle SEWS male, Middle-High SEWS male, Very-High SEWS female, Very-High SEWS – Male)	Low SEWS - Female	Walk	Omitted		-0.719	0.518
		Bicycle			-1.081	0.436
		Bus			-0.976	0.382

		Auto-rickshaw			-0.596	0.595
		Car			1.214	0.999
	Low-Middle SEWS female	Walk			-0.349	0.329
		Bicycle			-1.329	0.101
		Bus			-0.912	0.013
		Auto-rickshaw			-0.670	0.087
		Car			-14.278	0.983
	Middle-High SEWS female	Walk			-0.078	0.821
		Bicycle			-0.457	0.583
		Bus			-0.078	0.827
		Auto-rickshaw			0.468	0.209
		Car			-1.120	0.546
Constant		Walk	4.368	0.000	4.448	0.000
		Bicycle	-3.533	0.000	-2.982	0.000
		Bus	-1.217	0.000	-0.985	0.004
		Auto-rickshaw	-0.733	0.026	-0.692	0.063
		Car	0.079	0.822	0.386	0.307

Table 14 shows the estimated odds ratio for different segments of society for work trips using the estimates from model 3a. Odds of walking are more for females than males. Females have fewer odds of using motorized transport with respect to males across all SEWS groups. The probability of using bus increases for females with respect to males with an increase in SEWS level whereas odds of using the bus for males reduces with an increase in SEWS level. As expected, the model also reveals that the odds of using PMV increase for both females and males with an increase in SEWS level. The analysis shows that within the same SEWS groups; females have comparatively less access to PMV as compared to the males. This finding is consistent with the study of Scheiner and Holz-Rau (2012).

Table 14: Odds ratio for different segments of society estimated using model 3a for work trips and distance = 1 km

	SEWS group	Walk	Bicycle	Bus	Auto-Rickshaw	Car	MTW
For females with respect to males within each SEWS group	Low SEWS	1.76	0.23	0.69	0.70	0.38	0.23
	Low-middle SEWS	2.82	0.26	0.81	0.82	0.44	0.25
	Middle-high SEWS	3.33	0.34	1.03	1.05	0.56	0.25
	Very-high SEWS	3.36	0.42	1.28	1.30	0.67	0.28
For SEWS groups with respect to very-high SEWS group within females	Low SEWS	10.86	0.46	0.48	0.40	0.003	0.002
	Low-middle SEWS	4.39	2.04	0.77	0.50	0.03	0.14
	Middle-high SEWS	2.01	1.64	1.00	0.59	0.19	0.55
For SEWS groups with respect to very-high SEWS group within males	Low SEWS	20.68	0.85	0.89	0.75	0.005	0.003
	Low-middle SEWS	5.23	3.30	1.21	0.79	0.04	0.16
	Middle-high SEWS	2.03	2.05	1.23	0.74	0.23	0.61

6. Discussion

Both descriptive analysis and travel behavior models for the trip purpose, trip length and mode choice highlights the significant difference between genders and SEWS groups of society. The analysis also emphasizes the need to consider the interaction between gender and SEWS group for understanding social differences in travel choices. Based on the study, we highlight aspects with regard to achieving social cohesion and environmental sustainability in Vishakhapatnam.

1. Social cohesion
    a. Females travel less for work-related activity in Vishakhapatnam highlighting the difference in work participation rate between gender groups in the city. Although this difference reduces with an increase in

SEWS level. However, within middle-high SEWS and very-high SEWS, the females are less likely to travel for work than the males.

b. Females and people belonging to low SEWS are likely to travel shorter distances and they are more dependent on NMT that constraints their spatial accessibility and mobility.
c. Lesser females use bicycles in the city as compared to the males, therefore, highlighting the socio-cultural conventions of the society that restricts females from using certain modes of transport.
d. Within the very-high SEWS group, females have comparatively less access to cars for meeting their travel needs. Also within lower SEWS groups, females have less access to PT and paratransit than the males. Therefore, it can be interpreted that within the same income levels, the females have comparatively less access to resources than the males.

2. Environmental sustainability
   a. People belonging to higher SEWS groups are more dependent on cars and motorized modes of transport and travel longer distances to access opportunities. They, therefore, impose burden on environment by consuming more fuel and contributing more to carbon emissions from transport sector.
   b. Amongst the people belonging to high SEWS level, males are more dependent on motorized transport and travel long distances. The strategies need to be designed to attract males to travel shorter distances and use more NMT and PT.

With regard to the application of three tiers of disaggregation and application of the interaction term between gender and SEWS group following observations are made –

1. The first tier of disaggregation shows that there is a difference between the travel patterns of people based on SEWS groups and gender. However, this analysis does not highlight relevant issues.
2. The second tier of disaggregation shows that there is a need to cater to the demand of both females and males belonging to high SEWS levels within short distances. This requires community specific land use planning. The analysis shows that the people belonging to low SEWS group travel short distances and are more dependent on walking. Hence, it is essential to improve pedestrian infrastructure. This will also attract potential pedestrians. Third, strategies are required to attract males belonging to middle-high and very-high SEWS group to use the bus. This would require the provision of an efficient and reliable PT system in the city.
   The third tier of disaggregation shows that males travel longer than females across all SEWS groups. This is likely to be because of the differences in activity pattern between the two gender groups. More walk shares and equal use of PT by women as compared to men highlights that gender-specific issues like safety and security related to the use of PT and walk do not exist in Vishakhapatnam. Socio-cultural conventions may be a factor that is restricting women from using the bicycle. Women use less motorized transport as compared to men. This is either due to the differences in access to motorized transport or to the differences in the distances traveled between men and women. Both the questions need to be analyzed further.
3. Both descriptive analysis and travel behavior models have been useful in understanding the differences between different segments of society. The analysis, however, shows that the travel behavior models with the interaction term between genders and SEWS groups does not significantly add to the variability explained by the base models. Therefore, it is recommended that for descriptive analysis the three tiers of disaggregation should be used to understand the variation in travel choices. However, models with independent gender and SEWS/income group variables are useful to estimate the effect size of the independent variables on travel choices.

7. Conclusion

In the study, we have proposed the application of the three tiers of disaggregation and interaction term between genders and income group to study the differences in the travel choices of people. We have used SEWS as the proxy of income determined using PCA on asset ownership data. We propose three tiers of disaggregation for the purpose of the study. In the first tier, we propose studying travel behavior with regard to independent gender and SEWS group. This helps in understanding the conventional differences in the choices with regard to gender and SEWS independently. The second tier of disaggregation deals with the differences in travel choices by SEWS group within females and males. This, therefore, helps in identifying the variation in choices with regard to affordability and

physical accessibility of the modes to different segments of society. The third tier of disaggregation highlights the differences between gender group within each SEWS group. Therefore, it helps in understanding the socio-cultural convention of society that restricts accessibility of females to resources for females.

In the study, we have used descriptive analysis along with chi-square test to study the variation in travel choices between different segments of society for the three tiers of disaggregation. We have also estimated models for the trip purpose, trip length and mode choice. For each of the models, two sub-models have been estimated – one with independent gender and SEWS group variables and other with the interaction term between genders and SEWS group variable. The study highlights that there is a significant difference in travel choices based on genders, SEWS group and genders within same SEWS group. However, the estimated models explain equal variability when we use independent variables and interaction terms. Therefore, we conclude that it is necessary to study the differences in travel choices by using the interaction between genders and SEWS group. Cross-sectional study of trip characteristics can help in devising effective strategies to attain the goals of overall sustainability. However, a model with the independent genders and SEWS group variables are sufficient to explain the necessary variability and effect size on travel choices.

The study highlights the existing gender-based disparity in travel behavior in Vishakhapatnam. There is also a significant difference in travel choices by SEWS levels while controlling for gender. The analysis shows that females and people belonging to low SEWS group are likely to travel shorter distances and are dependent more on NMT. They, therefore, have restricted spatial mobility and accessibility when compared with males and people belonging to higher SEWS levels. While males and people belonging to higher SEWS level are contributing to negative environmental impacts in the city. It is also likely that both females and people belonging to low and low-middle SEWS group have less access to opportunities. Based on the analysis, we interpret that there is a need for design strategies to encourage males and people belonging to higher SEWS groups to travel shorter distances and use more PT and NMT. In the study, we have not been able to account for location-based factors affecting accessibility and mobility. Spatial planning related interventions may also be required to provide equal opportunity to the people belonging to low and low-middle SEWS group within short distances as they have resource constraints. This needs to be further analyzed.

8. References

Adeel, M., Yeh, A.G., & Zhang, F. 2017. Gender inequality in mobility and mode choice in Pakistan. *Transportation*, 44, (6) 1519-1534

Amekudzi, A.A., Jotin Khisty, C., & Khayesi, M. 2009. Using the sustainability footprint model to assess development impacts of transportation systems. *Transportation Research Part A: Policy and Practice*, 43, (4) 339-348

Appleton, B., Davies, M., Tansey, J., Atwal, P., Dore, G. P., & Muzyka, D. 2008, *GreenApple Canada 2008: SMART Transportation Ranking Report*, Appleton Charitable Foundation.

Arora, A., Gadepalli, R., Sharawat, P. K., Vaid, A., & Keshri, A. 2014, *Low - carbon Comprehensive Mobility Plan: Vishakhapatnam*, UNEP DTU Partnership, Technical University of Denmark.

Balen, J., McManus, D.P., Li, Y.S., Zhao, Z.Y., Yuan, L.P., Utzinger, J.+., Williams, G.M., Li, Y., Ren, M.Y., Liu, Z.C., Zhou, J., & Raso, G. 2010. Comparison of two approaches for measuring household wealth via an asset-based index in rural and peri-urban settings of Hunan province, China. *Emerging Themes in Epidemiology*, 7, 7

Best, H. & Lanzendorf, M. 2005. Division of labour and gender differences in metropolitan car use: An empirical study in Cologne, Germany. *Journal of Transport Geography*, 13, (2) 109-121

Boarnet, M.G. & Hsu, H.P. 2015. The gender gap in non-work travel: the relative roles of income earning potential and land use. *Journal of Urban Economics*, 86, 111-127

Borjesson, M. 2012. Valuing perceived insecurity associated with use of and access to public transport. *Transport Policy*, 22, (0) 1-10

Buchs, M. & Schnepf, S.V. 2013. Who emits most? Associations between socio-economic factors and UK households' home energy, transport, indirect and total CO2 emissions. *Ecological Economics*, 90, (0) 114-123

Carlsson-Kanyama, A. & Linden, A.L. 1999. Travel patterns and environmental effects now and in the future: implications of differences in energy consumption among socio-economic groups. *Ecological Economics*, 30, (3) 405-417

Carruthers, R., Dick, M., & Saurkar, A. 2005, *Affordability of Public Transport in Developing Countries*, World Bank, Washington D. C..

Census of India 2011, *Primary Census Abstract*, Government of India.

Cheng, L., Bi, X., Chen, X., & Li, L. 2013. Travel Behavior of the Urban Low-income in China: Case Study of Huzhou City. *Procedia - Social and Behavioral Sciences*, 96, 231-242

Cordova, A. 2008. Methodological Note: Measuring Relative Wealth using Household Asset Indicators. *Americas Barometer Insights*, 6,

Cui, B., Boisjoly, G., El-Geneidy, A., & Levinson, D. 2019. Accessibility and the journey to work through the lens of equity. *Journal of Transport Geography*, 74, 269-277

de Palma, A. & Rochat, D. 2000. Mode choices for trips to work in Geneva: an empirical analysis. *Journal of Transport Geography*, 8, (1) 43-51

Delbosc, A. & Currie, G. 2012. Modelling the causes and impacts of personal safety perceptions on public transport ridership. *Transport Policy*, 24, 302-309

Devkota, J.U. 2014. Principal components analysis of the socioeconomic conditions of biogas users-with example from Nepal. *International Journal of Renewable Energy Research (IJRER)*, 4, (3) 655-664

Diaz Olvera, L., Plat, D., & Pochet, P. 2015. Assessment of mobility inequalities and income data collection. Methodological issues and a case study (Douala, Cameroon). *Journal of Transport Geography*, 46, 180-188

Dickinson, J.E., Kingham, S., Copsey, S., & Hougie, D.J.P. 2003. Employer travel plans, cycling and gender: will travel plan measures improve the outlook for cycling to work in the UK? *Transportation Research Part D: Transport and Environment*, 8, (1) 53-67

Dobbs, L. 2005. Wedded to the car: women, employment and the importance of private transport. *Transport Policy*, 12, (3) 266-278

Economic and Social Council 2008, *The Inland Transport Committee and gender issues in transport*, ECONOMIC COMMISSION FOR EUROPE: INLAND TRANSPORT COMMITTEE , Geneva, ECE/TRANS/2009/7.

Emond, C.R., Tang, W., & Handy, S.L. 2009. Explaining gender difference in bicycling behavior. *Transportation Research Record*, 2125, (1) 16-25

Falavigna, C. & Hernandez, D. 2016. Assessing inequalities on public transport affordability in two latin American cities: Montevideo (Uruguay) and C+¦rdoba (Argentina). *Transport Policy*, 45, 145-155

Frandberg, L. & Vilhelmson, B. 2011. More or less travel: personal mobility trends in the Swedish population focusing gender and cohort. *Journal of Transport Geography*, 19, (6) 1235-1244

Fry, K., Firestone, R., & Chakraborty, N.M. 2014. Measuring equity with nationally representative wealth quintiles. *PSI, editor.Washington, DC*

Hamilton, K., Jenkins, L., Hodgson, F., & Turner, J. 2005, *Promoting gender equality in transport*.

Harttgen, K. & Vollmer, S. 2013. Using an asset index to simulate household income. *Economics Letters*, 121, (2) 257-262

Jain, D. & Tiwari, G. 2017. Sustainable mobility indicators for Indian cities: Selection methodology and application. *Ecological Indicators*, 79, 310-322

Jain, D. & Tiwari, G. 2019. Explaining travel behaviour with limited socio-economic data: Case study of Vishakhapatnam, India. *Travel Behaviour and Society*, 15, 44-53

Kawgan-Kagan, I. & Popp, M. 2018. Sustainability and Gender: a mixed-method analysis of urban women's mode choice with particular consideration of e-carsharing. *Transportation research procedia*, 31, 146-159

Lawson, A.R., McMorrow, K., & Ghosh, B. 2013. Analysis of the non-motorized commuter journeys in major Irish cities. *Transport Policy*, 27, (0) 179-188

Lee, N. 2009, *Measurement Error and Its Impact on Estimates of Income and Consumption Dynamics*, INSTITUTE OF ECONOMIC POLICY RESEARCH, UNIVERSITY OF SOUTHERN CALIFORNIA.

Li, T., Dodson, J., & Sipe, N. 2015. Differentiating metropolitan transport disadvantage by mode: Household expenditure on private vehicle fuel and public transport fares in Brisbane, Australia. *Journal of Transport Geography*, 49, 16-25

Loukaitou-Sideris, A. 2014. Fear and safety in transit environments from the women's perspective. *Security Journal*, 27, (2) 242-256

Ma, J., Mitchell, G., & Heppenstall, A. 2014. Daily travel behaviour in Beijing, China: An analysis of workers' trip chains, and the role of socio-demographics and urban form. *Habitat International*, 43, (0) 263-273

Mahadevia, D. & Advani, D. 2016. Gender differentials in travel pattern: The case of a mid-sized city, Rajkot, India. *Transportation Research Part D: Transport and Environment*, 44, 292-302

Manoj, M. & Verma, A. 2015. Activity-travel behaviour of non-workers belonging to different income group households in Bangalore, India. *Journal of Transport Geography*, 49, 99-109

Manoj, M., Verma, A., & Navyatha, M. 2015. Commute travel and its effect on housing tenure choice of males and females living in the urban and rural areas of Bangalore city in India. *Journal of Transport Geography*, 45, 62-69

Matsuo, M. 2016. Gender differences in mobility of Hispanic immigrants. *Transport Policy*, 52, 209-230

Matsushita, M., Harada, K., & Arao, T. 2015. Socioeconomic position and work, travel, and recreation-related physical activity in Japanese adults: a cross-sectional study. *BMC Public Health*, 15, (1) 916

Murakami, E. & Young, J. Daily Travel by Persons with Low Income, *In African American Mobility Symposium*, Tampa, Florida.

Olabarria, M., Pérez, K., Santamariña-Rubio, E., Aragay, J.M., Capdet, M., Peiró, R., Rodríguez-Sanz, M., Artazcoz, L., & Borrell, C. 2013. Work, family and daily mobility: a new approach to the problem through a mobility survey. *Gaceta Sanitaria*, 27, (5) 433-439

Peters, D. 2002, *Gender and Transport in Less Developed Countries: A Background Paper in Preparation for CSD-9* Berlin, Germany.

Saha, S., Roy, P., & Kar, S. 2014. Public and private sector jobs, unreported income and consumption gap in India: Evidence from micro-data. *The North American Journal of Economics and Finance*, 29, 285-300

Scheiner, J. & Holz-Rau, C. 2012. Gender structures in car availability in car deficient households. *Research in Transportation Economics*, 34, (1) 16-26

Schmucki, B. 2012. If I Walked on my Own at Night I Stuck to Well Lit Areas - Gendered spaces and urban transport in 20th century Britain. *Research in Transportation Economics*, 34, (1) 74-85

Scholl, L. 2002, *Transportation Affordability for Low Income Populations*, Public Policy Institute of California.

Shirgaokar, M. 2018. Operationalizing gendered transportation preferences: A psychological framework incorporating time constraints and risk aversion. *Transport Policy*

Srinivasan, S. & Rogers, P. 2005. Travel behavior of low-income residents: studying two contrasting locations in the city of Chennai, India. *Journal of Transport Geography*, 13, (3) 265-274

Stark, J. & Meschik, M. 2018. Women's everyday mobility: Frightening situations and their impacts on travel behaviour. *Transportation research part F: traffic psychology and behaviour*, 54, 311-323

Stradling, S., Carreno, M., Rye, T., & Noble, A. 2007. Passenger perceptions and the ideal urban bus journey experience. *Transport Policy*, 14, (4) 283-292

Sweet, M. & Kanaroglou, P. 2016. Gender differences: the role of travel and time use in subjective well-being. *Transportation research part F: traffic psychology and behaviour*, 40, 23-34

Tirumalachetty, S., Kockelman, K.M., & Nichols, B.G. 2013. Forecasting greenhouse gas emissions from urban regions: microsimulation of land use and transport patterns in Austin, Texas. *Journal of Transport Geography*, 33, 220-229

Tiwari, G. 2002. Urban Transport Priorities: Meeting the Challenge of Socio-economic Diversity in Cities, a Case Study of Delhi, India. *Cities*, 19, (2) 95-103

Tiwari, G., Jain, D., & Ramachandra Rao, K. 2016. Impact of public transport and non-motorized transport infrastructure on travel mode shares, energy, emissions and safety: Case of Indian cities. *Transportation Research Part D: Transport and Environment*, 44, 277-291

Uteng, T. P. 2011, *Gender and Mobility in the Developing World*, World Bank.

Xianyu, J. 2013. An Exploration of the Interdependencies between Trip Chaining Behavior and Travel Mode Choice. *Procedia - Social and Behavioral Sciences*, 96, (0) 1967-1975

Ye, X., Pendyala, R.M., & Gottardi, G. 2007. An exploration of the relationship between mode choice and complexity of trip chaining patterns. *Transportation Research Part B: Methodological*, 41, (1) 96-113

ZHANG, M., Quanxin, S.U.N., Jinchuan, C.H.E.N., & Jifu, G.U.O. 2008. Travel behavior analysis of the females in Beijing. *Journal of Transportation Systems Engineering and Information Technology*, 8, (2) 19-26

Zhou, J. 2012. Sustainable commute in a car-dominant city: Factors affecting alternative mode choices among university students. *Transportation Research Part A: Policy and Practice*, 46, (7)