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Effects of intra-household interactions on travel behaviour of working people: A study of Calicut city, India

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Abstract

Understanding of individual's travel behaviour is the foundation for travel demand modelling. Studies in activity-based travel demand modelling consider travel resulting from the need to pursue various activities. Since family is the base of a person's life, influences from household members in travel decisions is an area which requires momentous attention. Many researchers recognised the significance of incorporating household interactions in activity-based travel behaviour studies. This paper attempts to understand the influence of household interactions in terms of occurrence, extent of influence and change in mode choice in the travel behaviour of working people in the context of city in a developing country India. Household, personal, activity-travel details along with intra-household interactions on a weekday of working persons from Calicut city, Kerala State, India, formed the database for the present study. Face-to face interview technique was adopted for data collection. The types of intra-household interactions considered include dropping, picking, accompanying, allocated activities and taking care at home. Logit model framework is adopted for modelling the occurrence of intra-household interactions and shifts in mode choice. It is observed that female workers are less likely to alter their travel decisions in response to household needs, compared to male workers. Persons with longer commute time are found to be less likely to change their regular travel in spite of intra-household interactions. Presence of elderly persons in the house slightly reduces the interaction of worker with child. Employees are found to be shifting from public transport to personal modes, for the mandatory activity participation of spouse or children. Studies of this kind will provide better understanding of travel characteristics of the population and assist the planners in formulating effective policy decisions, such as flexible work hours for women employees.

Keywords: Intra-household interaction; Activity-based; Travel behaviour; Working people, Logit model

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1. Introduction

Ability to travel is one among the vital boons to human beings. Even though the most sophisticated facilities are available within the reach of hand, it is difficult for an individual to remain at the same place without a change of location and interaction with other people, which otherwise will turn like a 'golden prison'. Just like the flow of water on the earth and flow of blood through human body, travel has become an essential element in human's life.

Transportation related researches are primarily meant towards providing efficient transportation facilities and improving the quality of life of people. Development of more sophisticated travel demand models will assist the transport planners in precise forecast of travel demand and formulation of better demand management policy strategies. Over the years, various modelling principles and techniques evolved for travel demand estimation.

The 1990s marked the start of substantial progress in the development of activity-based models of travel demand to overcome the limitations of previous generations of models (Rasouli and Timmermans, 2014). The very basic assumption in activity based travel demand modelling is that people travel to perform various activities. The spatial and temporal distributions of activities in a person's life are the main motive behind his/her travel. In addition, travel pattern may be in relation to a person's role in the society and in the household. Household is the basic unit of an individual's personal life. In a long term perspective, people are earning a living to look after their family (in terms of food, clothing, shelter, standard of living etc.). The requirements of household members may add to the travel needs of an individual in a household context. These interactions from household could result in joint decisions about their daily activities and travel.

Most of the researches incorporating intra-household interactions in the activity-travel patterns of individuals studied the scenarios in developed countries. Similar studies in the context of developing countries are very few. Moreover, the differences with respect to region, culture, travel needs, time-monetary and personal constraints and commitments with family members are prominent between developed countries and developing countries. This paper attempts to investigate the intra-household interactions and travel behaviour in the context of a developing country, India.

The family in India is often understood as an ideal homogenous unit with strong coping mechanisms (Sonawat, 2001). Right from ancient times, family, caste, and community have dominated the entire texture of Indian society. India being a large and culturally diverse country with mixture of different socio-economic groups, individuals' travel behaviour cannot be assumed to be the same as that of developed countries and hence, it must be studied particularly. For the present study, a medium sized city, Calicut in Kerala State, in the Southern India is selected as the study area.

Family has been the dominating institution both in the life of the individual and in the life of the community. Traditionally, joint families were predominant in Kerala with large household sizes. The average household size of Calicut in the year 1971 was 7.20 and that in the year 2011 is 4.55 (Master Plan for Kozhikode Urban Area – 2035, draft report). In recent years due to urbanisation, a change is observed from joint family system to nuclear family system. The prevailing close-knit family relations could have important implications in its travel characteristics. For example, in many houses the students are accompanied by an elder member of the family in the travel segment for their educational activities. There are instances where, college students are dropped at

their educational institutes by parents, due to various reasons. In cases when, husband requires to drop wife at her workplace and child at school, he may prefer to use car or two-wheeler (depending on the availability) or else, he might have chosen bus.

Through this paper, the authors attempt to investigate whether intra-household interactions significantly exist in the study area and to understand the effects of household interactions on individual's travel characteristics. As part of the smart city initiative by the Government of India, there are many upcoming projects in this city, with a major focus on transportation. Study on the prevailing influences of intra-household interactions in travel behaviour will help the planners to better understand the circumstances in which people prefer to use personalised travel modes. This can subsequently assist in formulating family-friendly mobility schemes.

2. Background

Many researchers studied the influences of intra-household interactions on travel behaviour (Wissen, 1991; Golob and McNally, 1997; Bhat and Pendyala, 2005; Gliebe and Koppelman, 2005; Srinivasan and Bhat, 2006; Wang and Li, 2009; Arentze and Timmermans, 2009; Pinjari and Bhat, 2011; Ho and Mulley, 2015). Bhat and Pendyala (2005) provide valuable insights about intra-household interactions through their review paper. These studies focused on solo/ joint maintenance activity participation and daily activity-travel (tour) patterns.

The solo/joint out-of-home maintenance activity participation is found to be influenced by household role, gender and income (Srinivasan and Athuru, 2005). Auto availability also plays an important role in determining whether out-of-home activities are undertaken jointly or independently (Srinivasan and Athuru, 2005; Srinivasan and Bhat, 2005; Gliebe and Koppelman, 2005; Srinivasan and Bhat, 2006). Another important variable is the presence or absence of children in the household. Wissen (1991) reports that, presence of children decreases the time spent jointly in shopping and recreation, but not in visits. Srinivasan and Athuru (2005) and Gliebe and Koppelman (2005) also reveals strong evidence for the impact of presence of children on solo/joint activity participation. All these studies clearly document the relationship between joint activity-travel characteristics and household/individual socio-demographics.

Household interactions are modelled using a simultaneous linear equations approach for joint time allocation decisions (Wissen, 1991) and using structural model for interactions between household heads (Golob and McNally, 1997). Between 2000-2010, various modelling approaches are followed by researchers in order to understand the intra-household interaction characteristics in utility maximisation framework. Discrete choice approach is adopted for modelling the joint/solo activity participation and travel pattern by Srinivasan and Athuru (2005), Bradley and Vovsha (2005), Gliebe and Koppelman (2002, 2005) and Wang and Li (2009). Gliebe and Koppelman (2005) predicted the separate parallel choices of full-day tour patterns of two household members. Zhang et al. (2009), incorporated heterogeneous group decision-making mechanisms in modelling household discrete behaviour such as car ownership. Research undertaken by Zhang et al., (2002); Zhang et al., (2004); Zhang and Fujiwara, (2006) focused on developing a household utility-maximizing model of daily time use accommodating both independent and joint activity participation decisions of household heads in two adult households. Srinivasan and Bhat (2006) introduced a multiple discrete-continuous econometric structure for modelling the daily time-investment

decisions of couples in solo- and joint-discretionary activities incorporating intra-personal and inter-personal inter-dependencies. Vehicle availability was found to be positively influencing independent activity participation and presence of children negatively influences joint activity engagement with spouse.

In a micro-simulation framework, Vovsha et al. (2003) developed tour-based models, with different modelling techniques for fully and partially joined tours. Arentze and Timmermans, (2009) employed a need based concept for multi-day multi-person activity participation in a dynamic micro-simulation approach, as the need may vary over time. Roorda et al. (2009) adopted stress-based concept and stress is used as a feedback into the model of intra-household interaction in joint activity participation. Kang and Scott (2010) studied the day-to-day variability in activity time-use patterns of household members while incorporating variations in their interactions using structural equations modelling approach.

The studies mentioned above are mainly based on econometric models such as discrete choice models, seemingly unrelated regression models, micro-simulation models and structural equation models. All these studies report explicit recognition of intra-household interactions and group dynamics for activity and travel participation. Ho and Mulley (2015) provide an extensive literature review on intra-household interactions in transportation research. Hence, it is well recognised from various literatures that needs from one family member influence the travel characteristics of another member.

However, these researches are primarily focussed on the travel behaviour in developed countries. Moreover, variations can be generally expected for a person's activities and travel, due to influences from household members. Understanding and modelling of such changes in travel behaviour like change in choice of mode, time-of-day choice of trips, alterations in the activities performed in a day and so on, is an area which is yet to be explored. Therefore, in addition to modelling joint participation decisions, one of the areas identified for further exploration is the quantification of variations in a person's travel characteristics, particularly in the context of a developing country.

This kind of a cause-effect study is important because family is the major foundation in any person's life. It is particularly significant in India, since each of the members is bound to undertake specific role and responsibilities in their household and the family depend mostly on the earning members. Furthermore, the robustness of family relations is more prominent in India. The prevailing close-knit family relations and dependency in India will add more in-home and out-of-home responsibilities to a household member, which largely influence his/her travel behaviour. Exploring the interactions from household, which forms the base of a person's life, will enhance the ability of transportation professionals in understanding of travel decisions.

3. Study area description

Calicut, also known as Kozhikode, is one of the three major cities in Kerala State, in India. It is a medium sized city spread over an area of approximately 100 square kilometres. It is a very dynamic city with a large number of business and commercial establishments. It is well known for trading since very ancient times and still continues to be a major centre of flourishing domestic and international trade. It is also known as a city that has all types of educational institutions.

As per Census 2011, total population of the study area is 4.32 lakhs and male to female ratio is 0.91. There are 75 electoral wards under Calicut Municipal Corporation and these are considered as traffic analysis zones for the present study. Thirty five percent of Calicut's population is working group. They include government employees, persons employed in private sector, self-employed persons, daily wage group and people working in other countries. For this study, people working in Calicut city were identified as the interest group, assuming that the needs of household members are mainly taken care of by the employed person in the family and hence his/her travel is more likely to be influenced by intra-household interactions.

4. Database development

The data used in this study is collected through an activity-travel and intra-household interaction survey conducted between November 2014 and February 2015. The authors themselves contacted employees, residing within the limits of Calicut Corporation, at their work places and requested for their participation in the survey. Care was taken to ensure that the sample respondents were geographically distributed throughout the study area. The institutions/organisations selected for survey included government offices, private establishments like shops, shopping malls, educational institutions and private companies. Prior permissions were taken from the controlling officers/persons, before soliciting the responses from their employees. Employees of different levels from each organisation were surveyed so as to have a mix of respondents from different income levels. Face-to-face interview technique was adopted for survey and the information was recorded manually in the survey instrument. It took around 15 minutes to collect information from a person. The contact details of respondents were also noted for further clarifications, if needed.

The survey instrument designed for data collection included questions about the residence location, type of dwelling unit, number of household members and number and type of vehicle owned. Personal details such as relationship with the head of the household, gender, age, marital status, education, occupation, working hours, driving licence holding status and vehicle availability for exclusive usage of each member of the household were also asked. In addition to the above mentioned household and personal details, the respondents were inquired about their typical travel pattern for a weekday, and the details such as place of origin of trip, trip start time, destination, time of reaching destination, mode used, distance travelled, travel cost, activity for which travel is conducted and another household member participated in the activity and/or travel episode if any, were collected.

In order to capture the intra-household interactions, each respondent was specifically asked, whether their previous day's travel was affected by influences from household members, by any means, i.e., whether they were required to drop-off/ pick-up or accompany a family member or if they were required to perform an out-of-home activity on behalf of a household member (allocated activities), or they were required to take care of a family member at home, for which it was required to make alterations in their usual activity-travel pattern. If the respondent had experienced any of the above mentioned situations on the previous day, then further details such as with which member the interaction took place, the type of interaction, mode used for travel, change in the starting/reaching time from regular travel and the main activity undertaken by the interacted household member were collected. Persons, who regularly drop or pick any household member, were specifically asked to envisage their travel, in the absence of

such intra-household interaction circumstances and those travel details were also collected. Thus both the regular and occasional intra-household interaction situations are captured to the extent possible.

A total of 1020 individuals working in several organisations throughout the city were interviewed. The respondents willingly participated in the survey, which offered high response rate, except a few employees who couldn't participate due to their busy work schedule. The collected data were computerised manually in spread sheets. After checking for errors and inconsistencies, the final sample consisted of 802 individuals belong to 802 households, 2352 weekday travel episodes and 1369 out-of-home activity episodes.

5. Modelling framework

Many of the transportation research studies made use of discrete choice models, due to their ease of estimation, possibility for statistical validation and accuracy in modelling choice behaviour. As an initial effort to understand the intra-household interactions in the context of a medium sized city in a developing country, it is proposed to adopt discrete choice logit modelling framework, so as to make the model form simple and easily explicable.

A person, whose regular travel pattern is going to work place and back to home in bus, may use personalised vehicle, if he wanted to participate in his/her child's school meeting. Hence the activity to be participated influenced the travel mode choice, at the same time this activity is resulted from a household member. Similarly, the presence of an elderly person may induce medical trips. Any of the adult member of the family (employed or unemployed) has to take care of such household needs. It can also be the case that, the relative influence from spouse is different than that from children, or from a group of household members together. Moreover, the activity type of the household member (mandatory /maintenance/ leisure) can also be a determinant in making changes in the worker's travel behaviour. For example, a person may give more importance to education activities of the child, rather than the child's recreational activity. Hence, the research questions attempted here are: what are the household and personal circumstances that lead to intra-household interactions, how the influences of spouse, children or a group of household members are different and what make the worker to change his/her travel mode in response to such needs from households.

In order to model the occurrence of intra-household interactions, binary choice model is employed. The dependent variable in the model is whether an intra-household interaction situation occurred or not, i.e., whether the respondent performed a joint travel and/or an out-of-home activity with his/her family member and/or altered his/her travel decisions due to some need from a family member or such situations didn't occur. Changes in the usual travel mode, starting/reaching time by at least 30 minutes early or late and a minimum of 30 minutes difference in the work activity duration are considered as an variation from the normal travel pattern and these are identified using spread sheet functions.

To understand the extent of influence of family on a worker's travel decisions, household members are categorised (based on the relationship with respondent) into spouse, children and all members together. If there are more than two persons involved in the interaction situations, then it is considered to be 'all members together' category. Binary choice modelling is used to model the interaction with each of these categories. Several household, personal and activity-travel attributes were considered for

modelling. Change in commute mode choice was observed to be more frequent in the data, rather than changes in activity duration and start/end times of trips. Hence, models were developed to understand the likely shifts in commute mode choice resulted from intra-household interactions. Logit models were adopted for studying the changes from public transport (bus to auto-rickshaw/two-wheeler/car), change among private vehicles (two-wheeler to car), and change from non-motorised modes (walk to auto-rickshaw/two-wheeler).

6. Data exploration

This section deals with the exploration of survey data. Data were thoroughly checked for errors and inconsistencies. Exploration of socio-demographic characteristics was carried out, after proper data cleaning. In the sample population, 53 percent are females and 47 percent are males. Average household size is 4.19, with a minimum of 1 and maximum of 9. About 30% of the households are with size 5 or more. Nearly 80 percent of the households own at least one automobile. The number of employees per household ranges from 1 to 4 in the sample data. The household and personal details revealed that around 2 percent of employees are working abroad, 34.77 percent are working in government organisations, 34.04 percent in private sector, 20.31 percent are self-employed persons and 8.96 percent are daily wage group. 75 percent of respondents hold a driving licence and among this 78 percent are males. 45.37 percent of respondents have vehicle for their exclusive use.

The various out-of-home activities performed by the individuals are categorised into work, education, shopping, recreation, social visits, religious, medical and activities other than these. Work (61%) and shopping (8.92%) together constitute a major share of worker's daily activities. For convenience, activities are grouped into mandatory (work and education), maintenance (shopping, religious, medical) and leisure (recreation, social visits, other) activities.

Among the different types of interaction activities considered, 43 percent were reported to be of accompanying type, 33 percent dropping, 14 percent picking, 6 percent allocated and 4 percent taking care at home as shown in Figure 1. 38.35 percent of household interactions were observed to be with spouse, 34.82 percent with children and 16.26 percent with more than two household members together. This is depicted in Figure 2. Among the total reported trips, 31.36 percent were influenced from at least one household member, in which 28 percent had a shift in commute mode. The following section provides the modelling results and discussions.

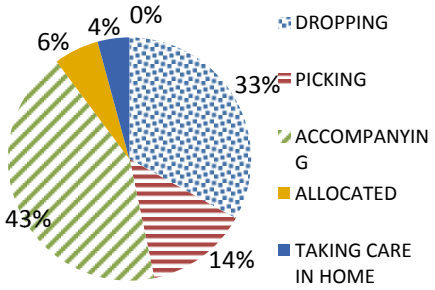

Figure 1: Types of interactions

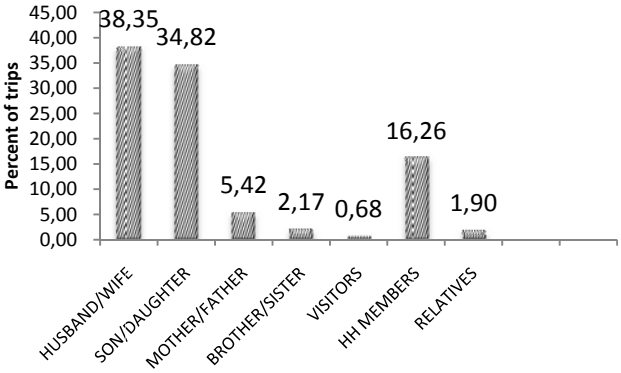

Figure 2: Interactions with-whom

7. Modelling results and discussions

This section deals with the modelling results and discussions on the occurrence of intra-household interactions, the extent of influence of household members on a working person's travel and the likely changes in their usual commute due to such interactions. Several household, personal and travel related variables were considered for model building. The summary statistics of variables and the coding adopted for categorical variables are listed in Table 1.

Table 1(a): Explanatory variables

Variables	Mean	Minimum	Maximum	Standard Deviation
Household size	4.19	1	9	1.331
Monthly household income (thousands, INR)	41579.28	1500	179823	29112.45
Number of employees	1.83	1	5	0.764
Number of students	1.20	0	5	0.963
Number of vehicles	1.29	0	4	0.916
Age	41.75	19	74	11.24
Number of trips	1.534	0	8	1.64
Commuting time (minutes)	24	2	75	14.22
Commuting distance (km)	5.07	0.4	5	3.53
Number of accompanying members	0.343	0	6	0.711

Table 1(b): Categorical variables and coding

Presence of persons of age>=75 yrs	(Yes=1, No=0)
Presence of infants	(Yes=1, No=0)
Gender	(Male=0, Female=1)
Marital status	(Unmarried=0, Married=1)
Education level	(school/graduation/ post-graduation and above)
Type of employment	(Government/Private/Self employed/Daily wageworker)
Ownership of driving license	(Yes=1, No=0)
Exclusive vehicle availability	(Yes=1, No=0)
Purpose of trip	(Mandatory/Maintenance/Leisure)
Travel mode	(Auto-rickshaw/Bus/Car/Cycle/Two-wheeler/Walk)
Interaction with whom	(Spouse/Children/all household members)
Type of interaction	(Accompanying/Dropping/Picking/Allocated/taking care at home)
Activity of the other person	(Mandatory/Maintenance/Leisure)

In addition to the variables mentioned in the table, many derived variables such as per capita household income (household income divided by household size), vehicles available per person (number of vehicles in household divided by household size) etc., were also considered in the model development stage.

7.1 Occurrence of intra-household interaction

The chance of influence from household members is modelled using binary choice system, with the choices being presence or absence (yes/no) of any kind of intra-household interactions. As mentioned in the database development section, if a worker's travel is affected by any household member's needs (drop-off/pick-up, accompanying, allocated activities, taking care at home), it is considered as an influence. This may be regular one or occasional. The influenced cases were coded as 1 (yes) and other cases were taken as 0 (no). Models were developed for all the respondents together and

separately for males and females, with the intuition that the possibility of influences will be different for males and females. The results are given in Table 2.

Table 2: Model for occurrence of household interactions

Variable	**All workers** Coefficient (Sig.)	**Male workers** Coefficient (Sig.)	**Female workers** Coefficient (Sig.)
Household size	-	-	-0.510(0.013)
Number of students	0.164(0.057)	-	0.445(0.043)
Presence of infants (yes=1)	0.925(0.009)	1.104(0.013)	-
Gender (female=1)	-0.557(0.001)	-	-
Commuting time (minutes)	-0.002(0.057)	-0.022(0.000)	-
Number of trips per day	0.621(0.000)	0.664(0.000)	1.010(0.000)
Commuting distance (km)	-	-	-0.067(0.044)
Per capita household income(in thousands, INR)	-	0.026(0.025)	-
Vehicles available per person	1.650(0.000)	-	-
Exclusive vehicle availability (yes=1)	-	0.536(0.011)	-
Number of vehicles in household	-	-	1.173(0.000)
Constant	-2.912(0.000)	-2.402(0.000)	-2.117(0.019)
Goodness-of-fit measures			
-2 Log likelihood	568.312	606.654	169.303
Cox & Snell R-Square	0.265	0.224	0.244
Nagelkerke R-Square	0.321	0.229	0.325
Hosmer and Lemeshow Chi-square	22.985 (0.063)	5.938 (0.654)	5.237 (0.732)
Percentage correctly predicted	69.5	70.3	73.2

When all respondents were considered for modelling, it is observed that activity-travel of females is less likely to be influenced from household interactions, compared to males. Working women seems to be less prepared to make more travel to cater to other household member's needs. This can be due to their in-home maintenance responsibilities such as childcare, cooking, housekeeping, etc. Hence, they may be constrained from participating in other out-of-home activities which necessitate travel. If the number of trips made by a person is more, the probability of his/her trips to have influence from household members increases by about 1.8 (e^0.621) times, as there is a chance that some of the trips are performed for other household members' needs.

Number of students in the household is observed to have a positive influence on interaction situations, resulting in more travel needs for the working people. This can be attributed to the out-of-home responsibilities such as dropping/picking child, going for meetings in educational institutes and so on. If the household own more number of vehicles, then the probability of interaction such as dropping/picking will be more and this is particularly observed for females. This can be due to either females may be driving to work places, or getting dropped by their spouse, depending on the vehicle availability at home. Exclusive vehicle availability is also found to have a significant positive effect on the possibility of household interactions occurrence for males. Availability of vehicle for exclusive usage for males increases their chances for catering to other household members' needs.

Commuting time and commuting distance are the two variables, which are negatively influencing the possibility of interaction occurrence. As the commuting time for work is more, the chance of catering to the activity/travel needs of household members is less. Greater travel time may be necessitating the worker to start sufficiently early to work place and thus, limit from catering to the travel needs of other household members for

their activities. The estimated parameters are within 95% confidence limit and the goodness-of-fit measures show reasonably good fit for the models.

7.2 Model for interaction with household members

For understanding the extent of influence of household members on worker's travel, logit modelling is adopted. Interactions with spouse, with children and with more than two household members together, were separately considered for modelling. Binary logit models (with the choices being interaction with spouse or not and so on) were developed.

A working male's interaction with his wife, children and with all household members were studied as three categories. Presence of infants, presence of persons of age greater than or equal to 75, availability of exclusive vehicle, type of employment (government/ private/ self employee/ daily wages) and activity type of the influential household member (mandatory /maintenance/ leisure) are considered as categorical. The coefficients and significance levels are presented in Table 3.

Table 3: Interactions with household members for male workers

Variable	**With wife**	**With children**	**With household members**
	Coefficient (Sig.)	Coefficient (Sig.)	Coefficient (Sig.)
Vehicles available per person	1.396(0.001)	-	-1.653(0.009)
Number of students	-0.407(0.000)	0.502(0.000)	-
Presence of infants(yes=1)	-	1.125(0.023)	1.709(0.001)
Presence of Persons of age>=75years (yes=1)	-	-2.378(0.005)	2.025(0.001)
Exclusive vehicle availability (yes=1)	-		-0.650(0.061)
Commuting time (minutes)	-0.004(0.014)	-.015(0.051)	-0.017(0.031)
[1]Activity of other household member (Mandatory=1)	0.883(0.000)	1.954(0.000)	-2.246(0.000)
[1]Activity of other household member (Maintenance=1)	0.573(0.057)	0.048(0.052)	-3.256(0.002)
[2]Government employee (yes=1)	-	-	1.026(0.026)
Self-employee (yes=1)	-	-	0.591(0.028)
Daily wage worker (yes=1)	-	-	1.595(0.001)
Constant	-0.091(0.791)	-1.872(0.000)	-1.526(0.000)
Goodness-of-fit measures			
-2 Log likelihood	200.782	493.086	290.409
Cox & Snell R-Square	0.215	0.263	0.234
Nagelkerke R-Square	0.257	0.352	0.396
Hosmer and Lemeshow Chi-square	14.542	13.983	20.583
(Sig.)	(0.69)	(0.82)	(0.8)
Percentage correctly predicted	77.3	74.4	89.0

[1]Activity of other household member, (Reference category-Leisure activity)
[2]Type of employment, (Reference category- Private employee)

From the model, it can be observed that, vehicles per capita in household and mandatory activity participation of wife significantly and positively influence male worker's travel. The possibility of worker's trips to get altered due to wife's needs decreases to some extent, with the number of students in the household and travel time

of the worker. As discussed in the earlier model, more the commute time, chance of modifications in travel is less. This is observed to be true with respect to interaction with wife or children or all household members together.

More the number of students in home, the probability of their influences in travel are more for male workers. Similar kind of influence is seen for children's mandatory (education related) activities. But this type of interaction also is less probable, when the travel time of the employee is more. One interesting observation is that presence of elderly persons slightly reduces the interaction of worker with child. The possible reason for this can be that the activity and travel needs of child are partly taken care by the grandparents.

Hence, it is seen that, the activities of household members significantly influence male worker's travel. They are more willing to change their travel pattern to accommodate a family member's need, if the activity to be performed by that member is mandatory type, than a leisure type one. This reveals the importance given by male workers to the other members of the family and their activities and travel needs. However, as the travel time increases the chances of changes in travel pattern due to interactions are less probable.

Models were estimated for female worker's interaction with husband, children and with all household members together. Along with the variables described previously, type of interaction (dropping, picking, allocated and taking care in home), household size and holding of driving license were also considered for model development. The variables included in the models and goodness-of-fit measures are given in Table 4. Nagelkerke R-square values for the models shows that the models fit well for the data.

Table 4: Interactions with household members for female workers

Variables	**With husband** Coefficient(Sig.)	**With children** Coefficient(Sig.)	**With household members** Coefficient (Sig.)
Interaction (Allocated=1)	-1.527(0.099)	3.166(0.099)	-
Interaction (Dropping=1)	1.748(0.001)	2.373(0.002)	-
Interaction (Picking=1)	0.928(0.144)	3.219(0.000)	-
Exclusive vehicle availability (yes=1)	-2.168(0.001)	2.055(0.004)	-
Per capita household income (in thousands, INR)	0.072(0.003)	-0.056(0.090)	-
Number of employees per household	-0.382(0.167)	-	-0.363(0.016)
Number of students per household	0.373(0.198)	-	-0.804(0.012)
Government employee (yes=1)	-	-3.628(0.001)	-
Self employee (yes=1)	-	-4.122(0.001)	-
Daily wage worker (yes=1)	-	-2.717(0.085)	-
Number of vehicles per household	-	-	-1.979(0.108)
Commuting time (minutes)	-	-	0.022(0.050)
Holding driving license (yes=1)	-	-	1.211(0.026)
Household size	-	-0.449(0.178)	0.981(0.000)
Constant	0.779(0.537)	0.712(0.733)	-7.547(0.000)
Goodness-of-fit measures			
-2 Log likelihood	119.655	94.036	105.743
Cox & Snell R-Square	0.384	0.378	0.283
Nagelkerke R-Square	0.512	0.546	0.423
Hosmer and Lemeshow Chi-square	20.7	17.6	14.9
(Sig.)	(0.540)	(0.345)	(0.75)
Percentage correctly predicted	78.2	87.2	76.0

[1]Activity of other household member, (Reference category-Leisure activity)
[2]Type of employment (Reference category- Private employee)

It can be observed that, if females have an exclusive vehicle, their interaction with husband is less. The availability of exclusive vehicle may enable females to carry out their out-of-home activities independently and hence the chances of interaction with husband are less. At the same time, the availability of exclusive vehicle significantly increases their interactions with children.

The model for occurrence of intra-household interactions on a worker's daily travel can be used for predicting the chances for a worker to change regular travel pattern due to influences from household members. The model which predicts the influence of household interaction of particular household member will help planners to determine to what extent a household member influences a worker's regular travel.

7.3 Travel mode shift due to household interaction

The exploratory study on the collected data shows that the intra-household interactions cause changes in travel attributes like change in commute mode, time of travel, activity participations etc. For example, a person using bus for travel to work may choose to go by car (depending on the availability of car), if he has to pick child from school in the evening. Such kind of shifts can be from public transport to private vehicles or vice versa. On the other hand, if a worker was not required to drop-off/pick-up a family member, then the person might have chosen a different commute mode. Understanding the intra-household circumstances in which a person is likely to use another travel mode is important, because it evidently influences the mode choice decision. These analyses are possible only in an activity-based perspective of travel behaviour modelling.

From the preliminary analysis, it was observed that 45 % of worker's travel decisions are influenced by interactions from different members of the family. Among this, 8% of persons are found to change their travel mode due to such interactions. Major share of change in travel mode observed is from public transport to private vehicles (63%). Shifts from two-wheeler to car (26%) and from non-motorised modes to motorised modes (11%) are also observed. This section discusses about the modelling of mode shifts due to household interactions in a multinomial logit framework.

Model for shift in mode choice from public transport

Shift from public transport to personalised vehicles due to intra-household influences is more compared to shift towards public transport. Individuals may prefer to use private vehicles, rather than using public transport, while travelling with household members. It may be attributed to the higher level of satisfaction during the travel that derived from the personal space available to the members and the comfort and convenience achieved.

Multinomial logit model is proposed for predicting the mode shifts from public transport (bus) to other modes such as auto-rickshaw, two-wheeler or car. Shift from auto-rickshaw to car was also observed in the data, but not considered for modelling due to less number of data sets. Various socio-demographic, activity/travel characteristics and interaction related information, along with attributes of the modes were used as explanatory variables. Modelling results are presented in Table 5. Availability of exclusive vehicle and interaction variables are found to be more significant with t-

statistic more than 1.96. Type of interaction, interaction with-whom, availability of exclusive vehicle and activity of household member are included as dummy variables.

Table 5: Mode shift models for worker's regular trips

Variables	**For all workers** Coefficient (t-statistic)			**Male workers** Coefficient (t-statistic)			**Female workers** Coefficient (t-statistic)		
	*B to AR	*B to TW	*B to C	B to AR	B to TW	B to C	B to AR	B to TW	B to C
Constant	-0.206 (-0.56)	-	-0.684 (-1.93)	2.644 (2.11)	-	-3.116 (-2.50)	3.422 (1.71)	-	-0.303 (-0.48)
Commuting time (minutes)	-0.118 (1.95)	-0.118 (1.95)	-0.118 (1.95)	-0.161(-1.97)	-0.161 (-1.97)	-0.161 (-1.97)	-0.071 (-1.98)	-0.071 (-1.98)	-0.071 (-1.98)
Type of interaction (Dropping=1)	-	2.293 (3.32)	2.293 (3.32)		2.100 (2.06)	2.100 (2.06)		1.303 (2.05)	1.303 (2.05)
Interaction with husband (yes=1)								2.834 (2.83)	2.834 (2.83)
Interaction with child (yes=1)					1.674 (1.96)	1.674 (1.96)			
Exclusive vehicle availability (yes=1)	-	1.780 (3.68)	1.780 (3.68)		4.016 (3.46)	4.016 (3.46)			
Number of vehicles								2.645 (1.96)	2.645 (1.96)
Activity of other member (mandatory=1)	1.084 (1.96)	1.084 (1.96)	-				0.907 (1.93)	0.907 (1.93)	
Goodness-of-fit measures									
Log likelihood function	-180.38			-90.65			-73.98		
R-squared value	0.341			0.627			0.354		
Adjusted R-squared	.322			0.602			0.315		
Percentage correctly predicted	69			79.16			61.29		

*B to AR – Bus to Auto-rickshaw, *B to TW – Bus to Two-wheeler, *B to C – Bus to Car

The utility equations for mode shift considering all the respondents (irrespective of gender) are given below.

U(B to AR) = – 0.206 – 0.118*commuting time+1.084*mandatory Equation (1)

U(B to TW) = 2.294*dropping – 0.118*commuting time+1.084*mandatory +1.78*exclusive TW Equation (2)

U(B to C) = – 0.684 +2.294*dropping – 0.118*commuting time + 1.78*exclusive Car Equation (3)

The variables, 'mandatory', 'dropping', 'exclusive TW' and 'exclusive Car' are categorical in nature and they will take a value of 1, wherever applicable, and 0 otherwise. The negative coefficient of commuting time in the utility equation indicates that, more the travel time, less likely the employee will shift to other modes. It was also

observed from the previous modelling efforts that the increased travel time decreases a worker's propensity to change travel decisions in response to household interactions. Exploring the effect of travel time on shift towards auto-rickshaw, two-wheeler or car indicated that, increase in travel time decreases the chance to shift from the regular mode. The positive coefficient for dropping type of interaction illustrates the employee is more likely to change to personal vehicles if he/she requires dropping spouse or children at their activity locations. Activity of the influential member is also found to be a significant variable. Mandatory activity participation requirement of household member increases the possibility of a worker to choose personal modes of transport.

Mode change in private vehicles and non-motorised mode

This section deals with the changes associated with private vehicles and in non-motorised travel. Regular two-wheeler users were observed to shift to car (based on car availability) and mode changes were observed from walk to two-wheeler or auto-rickshaw. Modelling for mode changes under these categories were done in binary logit framework and the results are presented in Table 6. Among the socio-demographic characteristics, travel and interaction variables, the significant ones are included in the model.

Table 6: Model for mode change in private vehicles and non-motorised mode

Variables	**Change among private vehicles(*TW to C)** Coefficient(t-statistic)	**Change from non-motorised mode(*W to AR)** Coefficient(t-statistic)
Constant	1.25 (0.471)	0.179 (1.20)
Commuting time (minutes)	-0.065 (-4.15)	-0.738 (-1.99)
Gender (female=1)	1.891 (4.21)	2.071 (2.32)
Per capita household income(in thousands, INR)	0.058 (3.49)	
Activity of other Household member (leisure=1)	0.731 (1.97)	
Interaction with spouse(yes=1)		1.596 (2.13)
Type of interaction (Dropping=1)		2.844 (1.91)
Goodness-of-fit measures		
Log likelihood function	-94.75	-39.09
R-squared value	0.241	0.303
Adjusted R-squared	0.246	0.264
Percentage correctly predicted	76.92	81.25

Note: *TW to C – Two-wheeler to Car *W to AR – Walk to Auto-rickshaw

Binary logit model is developed for predicting the change from the use of two-wheeler to car or not for facilitating household needs. It is observed that females are more likely to use car in case of household interaction situations. Income per capita also positively influences the shift towards car, as car ownership is positively related to household income. It can also be observed from the model that, if the person's trips are associated with leisure activity of other member, the chances for mode change are more. This may be attributed to the fact that the number of household members accompanying for leisure activity participation will be more. This also reveals the importance given by

individual to personal space, comfort and convenience while travelling for participating in leisure activities.

Model parameters for change from non- motorised mode are also given in Table 6. The two alternatives in the binary logit models are walk to auto-rickshaw and walk to two-wheeler. Change from walk to auto-rickshaw was taken as the base case and its probability can be predicted directly by the model. The probability of changing from walk to two-wheeler is 1 minus probability of changing walk to auto-rickshaw.

Among the significant variables given in the Table 6, similar to the previous model, travel time is observed to have a negative coefficient. Interactions with spouse in household and dropping activity are found to positively influence the mode change from walk. Due to interaction situations, workers may be required to drop other household members (particularly spouse and children) as observed from the model for interaction with other household members, explained previously.

The changes in mode choice due to household interactions are discussed in previous sections. These models describe the shift in travel mode of a commuter on a weekday. The estimation of utility associated with such changes will be helpful for predicting the mode which is likely to be used when some necessities from family members come into picture. Estimates of the likely usage of public/private vehicles will help the planners in formulating policy decisions about car occupancy level, in relation to the frequency of household interaction situations.

8. Conclusions

Understanding of individual's travel behaviour is a major step in travel demand modelling. Recently, many researchers recognised the importance of incorporating household interactions in travel behaviour studies. This paper aimed at understanding the effects of intra-household interactions on travel behaviour of working people, in Indian context. Understanding the possibility of occurrence of intra- household interactions on daily travel, the extent of influences from household members and the likely shifts from the regular travel modes are the primary objectives of this paper.

Household, personal, activity-travel details along with specific intra-household interaction situations of a weekday for 1020 working persons from Calicut city, in India formed the database for the present study. The types of household interactions considered are dropping, picking, accompanying, allocated (other household member's activities allocated to worker) and taking care of a household member at home.

Binary choice models were developed for predicting occurrence (yes/no) of household interactions. It was found that, compared to male workers, female workers' trips are less (by 0.56 times) likely to be influenced from household interactions, which can be attributed to their in-home maintenance responsibilities. The extent of influences of other household members on worker's travel was also studied. Males are more likely to alter their travel decisions, in response to the mandatory activity participation needs of wife and children. Availability of exclusive vehicle reduces females' interaction with husband, but significantly increases the possibility for their interactions with children.

Household interactions can produce certain changes in the regular travel characteristics of workers such as the commute mode choice behaviour. Logit models were developed to model the changes from public transport, change in private vehicles and change from non-motorised modes. Among the variables, dropping type of interaction and mandatory activity participation requirement of household member increase the possibility of a worker to shift to personal modes of transport. Tendency to

shift towards car is observed with increase in per capita income and leisure activity participation requirements of household members. Persons with longer commute times are less likely to be influenced by household interactions.

In any economy, the very base unit of a person is family. This study gives insights into the importance given by working people on their household members' needs. It is also to be noted that individuals shift from public transport to personal modes, for facilitating the requirements of family members. This study also revealed that working women are less prepared to make additional travel episodes in spite of the requirements from household members. Flexible work schedules may be provided for working women, so that they can balance both professional and in-home responsibilities, which will gradually lead to their contentment. Studies in this line will be helpful in formulating recommendations for improving public transport facilities, employing flexible work schedules, and occupancy specific tolling strategies etc, which enhance the quality of life of people in our society.

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