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ACTIVITY-TRAVEL PATTERNS OF WORKERS AND STUDENTS: A STUDY FROM CALICUT CITY, INDIA

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Abstract:

Travel behaviour studies in activity-based perspective treat travel as a result of individual's desire to participate in different activities. This approach is more significant in the context of developing countries, as the transportation problems are more severe here. Since, commuters contribute to a major share in the travel, understanding their travel behaviour is essential. This paper aims to explore the travel behaviour of commuters in Calicut city, Kerala State, India and thereby model their activity-travel patterns. Household, personal and activity-travel information from 12920 working people and 9684 students formed the database for this study. The data collection was performed by means of home-interview survey by face-to-face interview technique. From preliminary analysis, several simple and complex tours were identified for the study area. Working people's work participation and students' education activity participation decision are modelled as mandatory activity participation choice in a binary logit modelling framework. Results of this mandatory activity participation model revealed that male workers are more likely to engage in work compared to females. Presence of elderly persons is found to negatively influence the work participation decisions of workers. This may be due to the fact that, work activity may be partially or completely replaced with the medical requirements of the elderly. The chances for work activity participation increase with increase in number of two-wheelers at home. In the case of students, as the education level increases, they are found to be less likely to participate in education activities. Students are observed to follow simple activity-travel pattern. Complex tours are found to be performed by males, compared to females. Activity-travel pattern of the study group are predicted using the developed models. The percentages correctly predicted indicate reasonably good predictability for the models. These kind of studies are expected to help the town planners to better understand city's travel behaviour and thus to formulate well-organised travel demand management policies.

Key words:
workers, students, activity-based, travel pattern, developing country

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1. Introduction

Activity-based approach for travel demand modelling considers travel as a derived demand to pursue various activities. It is well acknowledged in literature that the activity-based approach provides a robust framework for travel behaviour modelling. It treats travel as result of the need to participate in various activities, which are distributed in space and time. The types of activities to be performed by a person are basically related to his/her occupation and lifestyle decisions.

Activity-based modelling seems to be more popular in developed countries than in the developing countries, whereas the transportation related problems such as congestion and air quality issues are more severe in developing nations (Yagi and Mohammadian, 2010). India, one among the third world nations, is well known for its social, cultural and geographic diversity. This diversity in socio-economic and demographic features results in different lifestyles and hence varying travel characteristics. In order to understand such travel characteristics, activity-based approach is essential in Indian context. Through this approach, a person's travel behaviour can be better studied and modelled. However, the progress in the development and implementation of activity-based travel models appear to be less in India, to the best of authors' knowledge.

The major share of any city's travel is by commuters. Understanding the travel behaviour of commuters is of vital importance in devising efficient travel demand management strategies. Through this paper, the authors aim to identify the travel patterns prevailing in Calicut city, Kerala State, India and thereby model the activity-travel patterns of working people and students. The out-of-home activity participation and related travel pattern of commuters are the primary focus of this paper. The remaining sections of this paper are organised as follows. The next section gives a brief review of previous researches in activity-based platform. Section 3 describes the details related to study area and method of data collection. In section 4, the important activity-travel patterns and the modelling framework adopted for this work are presented. The model estimation results and model applications are provided in section 5 and 6 respectively and section 7 concludes the paper.

2. Literature study

In activity-based approach, the major motive behind travel is considered to be activity participation. Quite a lot of studies have been conducted to investigate the relationship between activity participation and travel behaviour (Recker et al., 1986; Golob and McNally, 1997; Lu and Pas, 1999; Kitamura et al., 2000; Bowman and Ben-Akiva, 2000; Middelkoop et al., 2004; Yagi and Mohammadian, 2010; Rasouli and Timmermans, 2014). Travel is viewed as an input to activity decisions (Recker et al., 1986) which form an individual's daily activity pattern. Lu and Pas (1999) report that travel behaviour could be explained better by including activity participation endogenously in the modelling. In the trip generation model developed by Golob (2000), trips were generated in conjunction with out-of-home activities. Understanding the activity participation behaviour can be considered as the fundamental step for studying travel behaviour.

Most of the studies in activity-based approach make use of daily activity-travel patterns (DAPs) or a set of tours as the basic unit of analysis (Golob, 2000; Bowman and Ben-Akiva, 2000; Bhat and Singh, 2000; Yagi and Mohammadian, 2010). A tour is defined as the travel from home to one or more activity locations and back home again (Bowman and Ben-Akiva, 2000). In this tour-based structure, the interdependencies among trips are taken care of, which is not possible in traditional trip-based models. Further, an individual's activity choices and travel attributes can be represented as an activity pattern overarching a set of tours. The activity-pattern choice is controlled by the expected maximum utility derived from the available tour alternatives. Yagi and Mohammadian (2010) defined the DAP choices by primary tour activity, primary tour type, and number and type of secondary tours. This is a modified version of frameworks proposed by Bowman and Ben-Akiva (2000), Bowman et al. (1998) and Bradley et al. (1999).

Lu and Pas (1999) provided evidence for complex relationships among socio-demographics, activity participation and travel behaviour. Number/presence of children, household income, number of employed persons, age, gender, occupation and number of adult members in household are some of the key socio-demographic details that determine the activity participation and travel behaviour of individuals (Golob and McNally, 1997; Lu and Pas, 1999;

Golob, 2000; Bowman and Ben-Akiva, 2000; Bhat, 2001; Yagi and Mohammadian, 2010). Bhat (2001) found that, age is influencing the activity participation during evening commute and older individuals and individuals with small children in their household are more likely to go directly to home rather than participating in other activities in their home commute. Compared to men, women are more probable to engage in shopping and personal business activities (Bhat, 2001). Number of household vehicles (Golob and McNally, 1997; Lu and Pas, 1999), household vehicles per driver (Golob and McNally, 1997; Golob, 2000) and household income (Bhat, 2001) are also found to influence the activity participation behaviour. Ory and Mokhtarian (2005) included personality and attitudinal variables also in the modelling of work participation of individuals.

The modelling approaches adopted for the previous works may be broadly classified into discrete choice modelling and structural equation modelling. Discrete choice models, based on the utility maximization principle are used to predict several components of individuals' activity-travel decisions. As reported by Pinjari and Bhat (2011), the fundamental theory behind utility maximisation-based modelling comes from the economic theories of consumer choice (e.g., Becker 1965) that individuals make their activity-travel decisions to maximise the utility derived from the choices they make. Some of the discrete choice model applications include works by Bowman and Ben-Akiva (2000) and Yagi and Mohammadian (2010). Discrete choice models are widely used to model activity scheduling and daily activity pattern choices. Using econometric nested logit technique, activity type choice, time of day, mode and destination choice are modelled by Bowman and Ben-Akiva (2000). Discrete choice models are popular for their tractability, ease of use and solid theoretical foundation.

The present study attempts to contribute to the literature, by exploring the activity-travel behaviour of working people and students in the context of an Indian city, by adopting a discrete choice modelling framework. Workers and students being the regular travellers significantly influence the city's overall travel characteristics. More insight about the travel behaviour of commuters will assist the local and regional planning agencies to formulate efficient policy strategies to manage travel demand.

3. Data collection

The study area selected for this work is Kozhikode city. Kozhikode, also called as Calicut, is one among the three major cities in Kerala State, in the Southern India. The city consists of 75 electoral wards spread over an area of 100 square kilometres (approximately). As per 2011 Census of India, the total population is 0.61 million and male to female ratio is 0.92. Data requirements for this work include household details, personal details and one day activity-travel details of individuals. As the first step, the activity-travel diary was designed for data collection and a pilot survey was conducted to check its effectiveness. Necessary corrections and modifications were incorporated before the conduct of major survey. Enumerators were employed and given proper training for major survey. The enumerators collected details from different households, within the limits of Calicut city. Through this home-interview survey, household, personal and activity-travel details for the previous working day from all family members were collected. Care was taken to ensure that the samples were geographically well distributed in the study area. On an average, 150-200 samples were collected from each of the electoral wards, which are considered as TAZ (Traffic Analysis Zones) for this study. For data collection random sampling scheme is adopted. The untreated survey data consisted of information from around 10000 households in the study area. According to Bureau of Public Roads Standards (1956) for home interview survey, for an area having population of 0.5-1 million, 1 in 70 households are to be surveyed as a minimum. As per this, the minimum sample size required for the current study is calculated to be around 2190 households. However, since the data collected is sufficiently larger than the minimum, it is ensured that the sample is adequate to perform further analysis.

The details collected include residence location, type of dwelling unit, number of males and females in the household and number and types of vehicle owned, relationship of each member with the head of the household, gender, age, marital status, education, occupation, working hours, driving licence holding status and vehicle availability for exclusive use. Individual's travel 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,

participation of other household member in the activity/travel if any, were also collected along with contact information for future clarifications.
The enumerators recorded the responses in the activity-travel diary, which later on were entered manually in spreadsheets. Before analysing the data, thorough checks for typos and inconsistencies were performed. After discarding inappropriate samples, the final data set included details from around 9900 households (approximately 6.5% of total households), and activity-travel details of nearly 39600 persons. Details pertaining to 12920 workers and 9684 students were extracted from the main database, for carrying out this study.
Average household size of the study area is found to be 4, with a minimum of 1 and maximum of 13 members per household. About 57% of households own at least one automobile. In the survey sample, 51% are females and 49% are males. For travel, public transport is more used compared to the personalised modes. About 34% of the sample population are workers, out of these, 30% are working in private sector and 35% are self employed. 24% of sample are students. Distribution of trips by activity indicates that majority of the trips are made for work and education purpose. The distribution of household size and trips by activity type are given in Figure 1(a) and 1(b) respectively.

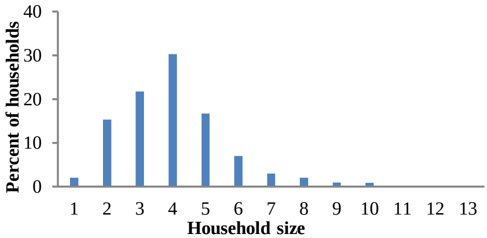

Fig. 1(a). Household size distribution

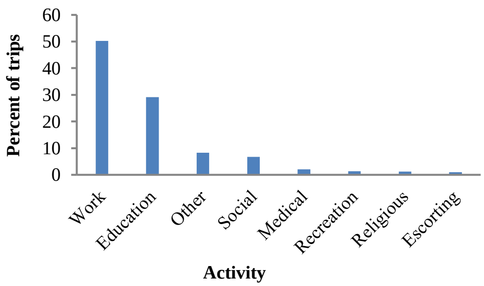

Fig. 1(b). Distribution of trips by activity type

Among working people, 43% are found to have not participated in work activity on the survey day and out of these 18% are participating in other activities. In an activity-based perspective, participation in different activities can be thought of as the primary motive behind travel. Hence, the decision of commuters to engage in their regular work/education activities is the very first step in their travel pattern modelling. The proposed modelling framework and various travel patterns are described in the following section.

4. Activity-travel patterns and modelling framework

This section describes the activity-travel patterns identified for the study area and proposed modelling framework. Activity-based approach considers travel as a derived demand to participate in different activities. In this perspective, the sequencing and scheduling of various activities over a 24-hour period result in diversified travel needs. This approach treats one-day travel of a person in terms of a tour, which may be defined as a chain of trips with starting and ending at the same place (Ortuzar and Willumsen, 2011). A tour is assumed to have a primary activity which is the major motivation of the journey. Daily activity participation decisions of individual, which lead to trip chaining, were studied by Wainaina and Richter (2002). Using travel survey data, the activity chains of homogeneous behavioural groups were presented in their study.
Similar to the classification of Bowman and Ben-Akiva (2000), the travel patterns observed in the study area are grouped into simple and complex activity-travel patterns. Simple activity pattern is that, the person goes directly to his/her major activity location, without participating in any other activity in that day and returns home (for e.g., going to work in the morning and returning back to home in the evening). When a person performs more than one out-of-home activities in a day, it is categorised into complex activity pattern (e.g., a person drops child at school on the way to work, or, goes for shopping after coming home in the evening). Examples for simple and complex patterns are given in Figure 2(a) and 2(b). The number represents the order of trips performed.
Majority of the patterns are found to be simple in nature. The different activity- patterns observed in the study area and their descriptions are given in Table 1.

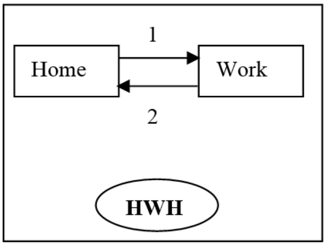

Fig. 2(a). Simple pattern

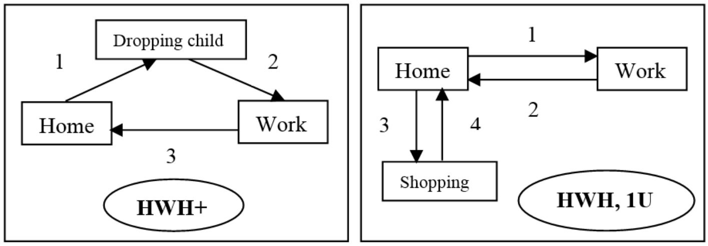

Fig. 2(b). Complex patterns

Table 1. Types of simple and complex pattern identified for the study area

Sl. No.	Pattern	Description	Frequency (%)
Simple activity-travel patterns			
1	HWH	Home – Work – Home	43.52
2	HEH	Home – Education – Home	29.74
3	HOH	Home – Other – Home	7.33
4	HSH	Home – Shopping – Home	6.3
5	HMH	Home – Medical – Home	1.84
6	HESH	Home – Escorting – Home	1.58
7	HREH	Home – Recreation – Home	1.34
8	HRLH	Home – Religious – Home	1.2
Complex activity-travel patterns			
9	HWHWH	Home –Work – Home –Work – Home	2.03
10	HWH+	HWH with 1 intermediate stop for another activity	1.20
11	HEH+	HEH with 1 intermediate stop for another activity	0.78
12	HWH,1U	HWH, 1 secondary tour for an unconstrained activity	0.54
13	HOH+	HOH with 1 intermediate stop for another activity	0.52
14	HSH+	HSH with 1 intermediate stop for another activity	0.34
15	HW+WH	Home –Work –Work related sub tour – Home	0.27
16	HOH,1U	HOH, 1 secondary tour for an unconstrained activity (e.g., shopping)	0.26
17	HEH,1C	HEH, 1 secondary tour for a constrained activity (e.g., tuition)	0.19
18	HWH,1C	HWH, 1 secondary tour for a constrained activity	0.15
19	HEH,1U	HEH, 1 secondary tour for an unconstrained activity	0.09
20	HSH,1U	HSH, 1 secondary tour for an unconstrained activity	0.07
21	HRLH+	HRLH with 1 intermediate stop for another activity	0.06
22	HWH+,1U	HWH+, 1 secondary tour for an unconstrained activity	0.06

In order to model the travel pattern, the initial step is to model the decision to participate in work/education. The data revealed that some workers and students have not performed their mandatory activity, i.e., work/education respectively, on the survey day. For this, it is proposed to develop a work/education activity participation model in a binary logit (Yes/No) framework. If a person is predicted to participate in his/her mandatory activity, then the travel pattern is modelled for that person as the next step. In case, the person is not performing work/education activity, then in the 'other activity participation step', the probability estimates for activities other than mandatory activities are computed. Based on the cumulative probability values, the type of other activity participated is predicted. Subsequently the activity-travel pattern will be assigned. For computational simplicity, the workers' activity-travel patterns are grouped into 'HWH' (Home-Work-Home), 'HWH,T' (Home-Work-Home and one or more constrained or unconstrained tours) and 'HWH+' (HWH with 1 intermediate stop for another activity). The percentages observed for each pattern types are 66.25% (HWH), 16.14% (HWH, T) and 17.61% (HWH+). The study framework adopted for generating the activity-travel pattern is given in Figure 3.

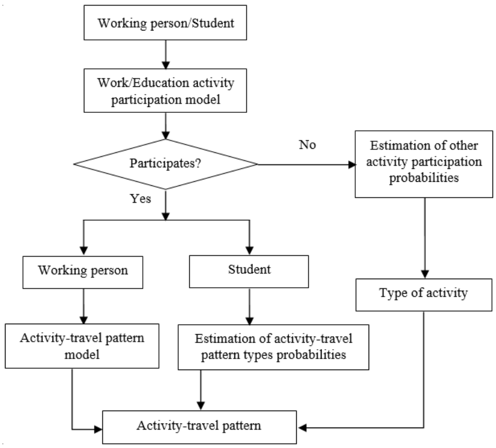

Fig. 3. Study framework

5. Results and discussions

This section provides the modelling results and discussions. Modelling results of commuters' mandatory activity participation followed by activity-travel pattern are discussed here. The independent variables considered for modelling are given in Table 2, along with their descriptions.

5.1. Mandatory activity participation model

For worker's work participation choice, gender, number of employed persons, presence of elderly person, number of motorised two-wheelers at home and type of employment (daily wage, government employee, private employee, self employed, and marketing group) are found to be the most influencing variables. 'Self employed' category of workers is selected as the reference category. In the case of students, the major influencing variables identified for education activity participation are income level of household and the student's education level. The estimated model parameters for working people and students are given in Table 3.

Table 2. Description of variables used in modelling

Variable	Description
GEND	Gender (Male=1, Female=0)
DLYWG	Daily waged person (dummy variable, 1 if yes, 0 otherwise)
GOVEMP	Government employee (dummy variable, 1 if yes, 0 otherwise)
MRKPRO	Marketing professional (dummy variable, 1 if yes, 0 otherwise)
PVTEMP	Private employee (dummy variable, 1 if yes, 0 otherwise)
EMPNUM	Number of employed persons at home
ELDPRE	Presence of elderly persons (>75 years) at home (dummy variable, 1 if yes, 0 otherwise)
TWNUM	Number of two-wheelers in the household
HHINC	Monthly household income level
PGSTU	Post graduate student (dummy variable, 1 if yes, 0 otherwise)
DGSTU	Degree student (dummy variable, 1 if yes, 0 otherwise)
HGSTU	Higher secondary student (dummy variable, 1 if yes, 0 otherwise)
HSSTU	High school student (dummy variable, 1 if yes, 0 otherwise)
LPSTU	Lower primary student (dummy variable, 1 if yes, 0 otherwise)
KGSTU	Kindergarten student (dummy variable, 1 if yes, 0 otherwise)
EDDG	Education: Degree (dummy variable, 1 if yes, 0 otherwise)
EDHG	Education: Higher Secondary (dummy variable, 1 if yes, 0 otherwise)
EDHS	Education: High school (dummy variable, 1 if yes, 0 otherwise)
FEMPNUM	Number of employed females in the household
STUNUM	Number of students in the household

Among workers, males are more likely to participate in work activity compared to females. This may be due to the familial responsibilities of females. As the number of employed persons in the house increases, the chance of work participation for an employee decreases. This may be attributed to the fact that, among the workers, some are likely to take care of the household responsibilities. The presence of elderly persons also exhibits negative influence on work participation decision of a worker. The probable reasons can be taking care of the elderly at home or to take the elderly to hospital. As the number of two-wheelers available in a household increases by one unit, the chance of a worker to participate in work increases by 1.172 times.

Table 3. Mandatory activity participation model for workers and students

Variable	Workers		Students	
	Coefficient (Sig.)	Exp(B)	Coefficient (Sig.)	Exp(B)
Constant	0.589 (0.000)	1.803	0.463 (0.000)	1.589
GEND (Male)	0.265 (0.000)	1.304		
DLYWG	-0.059 (0.384)	0.945		
GOVEMP	0.092 (0.219)	1.097		
MRKPRO	0.333 (0.375)	1.395		
PVTEMP	0.075 (0.178)	1.078		
EMPNUM	-0.252 (0.000)	0.777		
ELDPRE	-0.233 (0.000)	0.792		
TWNUM	0.159 (0.000)	1.172		
HHINC			-0.131 (0.000)	0.877
PGSTU			-1.302 (0.000)	0.272
DGSTU			-0.659 (0.000)	0.517
HGSTU			0.333 (0.000)	1.395
HSSTU			0.322 (0.000)	1.380
LPSTU			-0.202 (0.008)	0.817
KGSTU			-0.525 (0.000)	0.592
Model Summary & Goodness-of-fit measures				
-2 Log likelihood	11385.861		8658.007	
Cox & Snell R Square	0.023		0.041	
Nagelkerke R Square	0.031		0.056	
Hosmer and Lemeshow Chi-square (Sig.)	17.5 (0.025)		14.09 (0.079)	
Overall percentage correctly classified	60.1		59.1	

*Note: GEND – Gender (Male=1, Female=0); DLYWG – Daily waged person; GOVEMP – Government employee; MRKPRO – Marketing professional; PVTEMP – Private employee; EMPNUM-Number of employed persons at home; ELDPRE – Presence of elderly persons (>75 years) at home; TWNUM – Number of two-wheelers in the household; HHINC – Monthly household income level; PGSTU – Post graduate student; DGSTU – Degree student; HGSTU – Higher secondary student; HSSTU – High school student; LPSTU – Lower primary student; KGSTU – Kindergarten student

The ownership of two-wheeler facilitates the worker to access the desired location at his/her convenience. Hence, the chance of participation in work increases compared to an employee without two-wheeler.

In comparison with a self employed person, government employees and private employees are more likely (1.097 and 1.078 times respectively) to participate in work. For daily wage workers, the chance of performing work is only 0.945 times when compared with self employed person. Intermittent opportunities for work can be a reason for this. Marketing professionals have the highest probability to participate in work activities daily (1.4 times more in comparison with self employed persons). Their nature of work itself can be a major influencing factor. As they need to travel more as part of their job, non-participation in work even for a single day may necessitate significant adjustments/alternate arrangements in their work schedules. Hence they are observed to be less likely to avoid work activities. The model form of mandatory activity participation of workers is given in Eq.(1) under model application, in section 6.

Binary logit model for student's education activity participation revealed that high school and higher secondary students are more likely to perform education activities on a regular working day. This is in comparison with an upper primary school student. As the education level increases further, i.e., degree and post graduate students, the chance of participating education slightly decreases. At graduation and post graduation level, the students are more likely to perform many extra-curricular activities also, and hence education activity participation probability is less. However in the case of school going students, the chances of outside-school extra-curricular activities may be less. Moreover, the importance given to education activity, particularly among the households in Kerala where literacy rate is 94%, as per Census of India, 2011, may not allow the school students to stay away from regular classes. The overall percentage correctly classified by the models shows a fairly good fit for the models, i.e., around 60%.

5.2. Daily activity-travel pattern for workers

For predicting the day activity travel pattern of workers who chose to participate in work activity, from the previous step, a multinomial logit model is developed. The patterns were broadly categorised into 'HWH', 'HWH+' and 'HWH,T'. These three together constitute majority of travel patterns of workers. HWH+ type of pattern is taken as the reference category. Table 4 gives the model parameters. The model form of worker's daily activity-patterns are given as Eq.(6), Eq.(7) and Eq.(8) in section 6, under the model application.

As evinced by the positive sign of gender, it can be understood that, female workers are more likely to follow HWH and HWH,T patterns rather than HWH+ patterns. Working females are expected to perform HWH pattern for their work travel 3.723 times more than a male worker. Intermediate stops for performing other activities are less probable for them. This may be attributed to female's time constraints due to in-home maintenance responsibilities. Whereas in the case of males, they are more likely to follow complex types of patterns and tend to carry out majority of the out-of-home responsibilities of family. This is in line with the results of Zhong et al. (2012), where women are expected to take more household/family support responsibilities, whereas men are expected to be responsible for more outside-household responsibilities. Bhat (2001) also confirmed the continuing trend of women to shoulder majority of household maintenance responsibilities. Female worker's preference for HWH,T patterns over HWH+ is also evident from the model. They are likely to perform secondary tours (e.g., going for shopping after coming home), rather than perform them during the commute segments. This may be attributed to the reluctance towards additional out-of-home hours after the regular work hours. These secondary tours (e.g. grocery shopping), may be performed in the neighbourhood of their residences. As the number of employed females in the house is more, there are chances for some of them to perform HWH+ travel pattern, than HWH pattern. With increase in number of students, probability for HWH patterns is found to be less. Activities such as dropping the child at educational institution may come into picture and hence, the resulting travel pattern can be HWH+ or HWH,T. Educated persons are also found to follow complex kind of travel pattern compared to simple one, on a regular working day. This may be due to their job and family responsibilities. The percentage correctly predicted by the model is 66%, which indicates fairly good predictive capability of the model.

6. Model application

This section deals with application of the developed models to predict the activity-travel pattern for commuters.

6.1. Activity-travel pattern of workers

For a working person, the utility (V) associated with participating in work activity on a regular day may be written with reference to Table 3, as in Eq.(1). The 'no work' alternative is considered as the reference and hence, its utility is taken as 0 (Eq.(2)).

Table 4. Worker's daily activity-pattern model

Variables	HWH		HWH,T	
	Coefficient (Sig.)	Exp(B)	Coefficient (Sig.)	Exp(B)
Constant	1.417		-0.437	
GEND (Female)	1.314 (0.001)	3.723	0.255 (0.633)	1.29
EDDG	-0.439 (0.383)	0.644	0.233 (0.744)	1.262
EDHG	-0.901 (0.124)	0.406	-1.285 (0.204)	0.277
EDHS	-0.109 (0.831)	0.897	0.450 (0.533)	1.569
FEMPNUM	-0.371 (0.192)	0.69	-0.176 (0.643)	0.838
STUNUM	-0.237 (0.149)	0.789	-0.094 (0.669)	0.91
Goodness of Fit Measures				
Cox & Snell R Square	0.084			
Nagelkerke R Square	0.102			
Overall percentage correctly classified	66.00%			

*Note: GEND – Gender (Male=0, Female=1); EDDG – Education: Degree; EDHG – Education: Higher Secondary; EDHS – Education: High school; FEMPNUM – Number of employed females in the household; STUNUM – Number of students in the household

Each of the dummy variables in the equation will take a value of 0 or 1, depending on the case (Table 2). The code for gender is Female=0 and Male=1. For e.g., the utility for participating in work, for a male worker, who is a private employee, does not own a two-wheeler, having 3 employed household members and no elderly person at home, is calculated, by substituting the corresponding values of independent variables, as given in Eq.(3).

Probability of this person participating in work is calculated as in Eq.(4). 'Probability of not participating in work' will be '1 minus probability of participating in work', as given in Eq.(5).

Since, the probability for 'participating in work' is more than that of 'not participating', the person is predicted to participate in work. A summary of the above calculations are given in Table 5.

In a similar manner, working people's activity-travel pattern is also predicted. With reference to the worker's daily activity-pattern model given in Table 4, the utility (V) associated with a person to perform various travel patterns may be calculated as follows as in Eq.(6), (7) and (8). The categorical variables will take values 0 or 1 depending on the case. The code for gender is Female=1 and Male=0.

The probability associated with the alternatives may be calculated using Eq.(9).

As an example, probability of performing different activity-travel patterns for a male worker, with degree level education, zero employed females and 3 students at home, are estimated and given in Table 6.

Equations:

$$V_{work} = 0.589 + 0.265\times(GEND) - 0.059\times(DLYWG) + 0.092\times(GOVEMP) + 0.333\times(MRKPRO) + 0.075\times(PVTEMP) - 0.252\times(EMPNUM) - 0.233\times(ELDPRE) + 0.159\times(TWNUM) \quad (1)$$

$$V_{no\,work} = 0(Reference\,category) \quad (2)$$

$$V_{work} = 0.589 + 0.265\times(1) - 0.059\times(0) + 0.092\times(0) + 0.333\times(0) + 0.075\times(1) - 0.252\times(3) - 0.233\times(0) + 0.159\times(0) = 0.173; \quad (3)$$

$$and\ Exp(V_{work}) = 1.1889$$

$$P(work) = Exp(V_{work}) / (1 + (Exp(V_{work})) = 0.5431 \quad (4)$$

$$P(no\,work) = 1 - P(work) = 0.4569 \quad (5)$$

$$V_{HWH} = 1.417 + 1.314\times(GEND) - 0.439\times(EDDG) - 0.901\times(EDHG) - 0.109\times(EDHS) - 0.371\times(FEMPNUM) - 0.237\times(STUNUM) \quad (6)$$

$$V_{HWH,T} = -0.437 + 0.255\times(GEND) + 0.233\times(EDDG) - 1.285\times(EDHG) + 0.450\times(EDHS) - 0.176\times(FEMPNUM) - 0.094\times(STUNUM) \quad (7)$$

$$V_{HWH+} = 0(Reference\,category) \quad (8)$$

$$P(V_1) = Exp(V_1) / (Exp(V_1) + Exp(V_2) + Exp(V_3)) \quad (9)$$

where, 1=HWH; 2 = HWH,T ; and 3 = HWH+

Table 5. Mandatory activity participation decision

Gender	No. of emp. Persons at home	Presence of elderly at home	No. of two-wheelers at home	Type of emp.	V_{work}	Exp (V_{work})	P (work)	P (no work)	Prediction
Male	3	0	0	Private	0.173	1.1889	**0.5431**	0.4569	**Work**

Table 6. Activity-travel pattern choice

Gender	Education	No. of emp. females	No. of students	V_1	V_2	V_3	Exp (V_1)	Exp (V_2)	Exp (V_3)	P (1)	P (2)	P (3)
Male	Degree	0	3	0.267	-0.486	0	1.306	0.6151	1	**0.4471**	0.2106	0.3423

Here, the probability of 1st alternative (HWH) is found to be more than other two alternatives. Hence the person is predicted to perform HWH pattern.

If a worker is not participating in work activity, then other out-of-home activities likely to be performed by the person are calculated. Out of the workers who didn't go for work, 82% were not observed to perform any out-of-home activities. The probability values of worker's non-work activity participation are given in Table 7. These probability values are used to determine activity participation of workers with only non-work activity participation, by inverse transformation technique.

Table 7. Probability values of workers' non-work activities

Sl. No.	Activity	Probability
1	No activity	0.8236
2	Other	0.0739
3	Shopping	0.0552
4	Medical	0.0146
5	Escort	0.0136
6	Recreation	0.0117
7	Religious	0.0074

6.2. Activity-travel pattern of students

It is observed from the collected data that 99% of students participating in education activity follow the simple activity pattern HEH (Home – Education – Home). Hence, students who are predicted to participate in education by the mandatory activity participation model (described in section 5.1), are assigned with HEH pattern. For those students, who are not participating in educational activities, their non-educational activity probabilities are as given in Table 8.

Table 8. Probability values for students' other activity

Sl. No.	Activity	Probability
1	No activity	0.9684
2	Other	0.0131
3	Shopping	0.0079
4	Recreation	0.0071
5	Medical	0.0019
6	Religious	0.0013

The developed models are used to generate the activity-travel pattern for the sample used in this study, i.e. 12920 workers and 9684 students. The percentage correctly predicted by the worker's mandatory activity participation model is 61.12 and it is 59.05 for the students. The activity-travel pattern is correctly generated for 66.67% of workers and 95.55 for students. The percentages correctly predicted indicate the reasonably good predictability for the developed models. Hence these models can be used for predicting the mandatory activity participation decision and subsequently the travel pattern of commuters. This study is expected to assist the planning authorities in better understanding commuters' travel characteristics.

7. Summary and conclusions

This study aimed at understanding the travel characteristics of working people and students in terms of their activity participation decisions and travel pattern. Data of 12920 workers and 9684 students from the household activity-travel survey was used for analysis. Different types of simple and complex tours were identified for the study area. As commuters constitute a major share in the population, this work aimed at understanding and modelling workers' and students' travel behaviour.

Modelling mandatory activity participation of working people in binary logit framework revealed that, males are more likely to engage in work activity compared to females, on a regular working day. Presence of elderly persons is negatively influencing the work participation decisions. This may be due to the fact that, work activity may be partially or completely replaced with the medical requirements of the elderly. Number of two-wheelers increases the chances for work activity participation, which can be attributed to the convenience in travel. From the model for student's education activity participation, it was observed that, as the education level increases, the chance of participating education slightly decreases, may be due to extra-curricular activities of students.

In the activity-pattern level analysis, males are tending to perform complex type of tours compared to females. The time restrictions for in-home maintenance responsibilities are likely to restrain female workers from performing more out-of-home activities involving travel. As the number of students at home increases, the chances for complex travel pattern are more for workers. Students are observed to follow simple home-education-home kind of patterns. Using the developed models, the activity participation choice and travel pattern of commuters are predicted.

This study contributes to the current research in activity-based approach in two ways: firstly, by studying the travel characteristics in the context of a developing nation and secondly, by generating the travel patterns of commuters. In order to understand the city's travel behaviour, studies in this line are essential. It is very much important to recognise the travel characteristics of individuals in a developing country like India, where the socio-economic attributes and the transportation problems are quite diverse. Activity-based travel demand modelling is a promising platform which can assist the town planners in formulating efficient demand management strategies to alleviate the transportation problems.

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