Evaluation of Day Pattern Choice of Individuals in the Western Province of Sri Lanka

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ABSTRACT

Traditional considerations of traffic safety focus on the physical environment, and road user's behaviour to ensure sustainable transportation. Road user's driving behaviour and travel patterns play an important role among these. New forms of transportation demand models use an activity-based approach that requires an activity pattern to be assigned to each road user. This research presents the analysis of travel patterns based on a classification procedure in which the set of measurements that define human behaviour is represented by a coding pattern using the outcomes of the dataset of 35,850 households among a total of 124,673 individual daily diaries collected from the CoMTrans study. A total of 1431 activity patterns were observed in the western province. The most common daily pattern is Staying at Home (H), which is around 35.51% of the total population. The 2nd and 3rd most common tour patterns are "H2S3H" (school tour starts at home, leaving home on AM Peak to school and returning to home on Mid-Day) and "H2W4H" (work tour starts at home, leaving home on AM Peak to work and back to home on PM Peak). Each pattern of activity was related to the socioeconomic characteristics of that person. Tour modes were also identified according to each activity. Tour modes were also identified according to each activity. This analysis will form the basis for the development of an activity-based transport model for Sri Lanka in the future, which will help town planners better understand the city's travel behaviour and thus formulate well-organized travel demand management policies to move towards sustainable transportation.

Keywords: *Day pattern; Travel behaviour; Activity-based; Socio-economic characteristics; Western province*.

1. INTRODUCTION

Transportation models have played an important role in predicting transport demands. Transportation models have been evaluated since their origin in the late 1960s. The new systems of transportation demand models use an activity-based tactic, which needs an activity pattern assigned to each individual. The traditional four-step tactic does not provide reliable evaluations of the travel patterns, but the activity-based method, which accounts for the travel behaviour of individual households or persons, seems to be more suitable for estimating trips.

In the context of transportation modelling and social research in general, understanding human behaviour is pivotal to the accuracy of forecasting. Because driver behaviour has a strong relationship with the decisions of the driver, this leads to many accidents on the road (Shaja M.M.M., & Bandara Y.M., 2021). However, considering the complexity of

human behaviour, many have resorted to making simplified assumptions with a reduced temporal resolution, but over the years, there has been a trend to relax these assumptions and consider them at a more disaggregated level.

This research focuses on analysing the activity pattern of each individual in the collected sample data set using coding techniques and finding the relationship between activity patterns and socio-economic characteristics.

2. LITERATURE REVIEW

2.1. Introduction of Transport Modes

The purpose of the transportation models is to forecast the response to transportation demand of changes both in the attributes of the transportation system and the people using it. More specifically, travel demand models are used to predict travel characteristics and usage of transport services under alternative socioeconomic scenarios and land-use configurations (Bhat et al., 2003), such that road capacity programs and traffic management could be based on predicted demand.

2.2. Trip-Based Travel Demand Models

Traditional models are commonly referred to as "four-step models." In this model, individuals are aggregated by traffic zone. There are four sequential decisions that cause traffic:

- Trip generation
- Trip distribution
- Mode split
- Traffic assignment.

These results are modelled separately for succeeding phases. (Stopher et al., 2006) Even though the four-step models have been widely used, a major deficiency of these extensive, aggregate, and supply-oriented models is their absence of behavioural content.

The aggregate approach was gradually replaced by a disaggregated modelling approach. This approach mainly focuses on decision-making and choice processes at the level of individuals. Individual decision-making facilitates the impact of transportation plans on travel patterns. If the impact on an individual's travel behaviour can be predicted, the effects of transport plans can be easily derived by aggregating across individuals.

Because of their intrinsic weaknesses, the trip-based aggregate and disaggregate approaches may be less suitable for predicting the effects of these potential behaviour changes. Later activity-based approaches established some early attention and became a leading modelling technique in recent years. This approach considers travel decisions as derived from activity choices. Travel demand is thus accounted for by explaining and analysing individuals' and households' activity decisions. (Axhausen and Garling, 2002). These choices include where, when, how, for how long, and with whom activities are conducted.

2.3. Literature on day pattern modelling and its role in transport demand modelling

A key element in the activity-based approach is determining the activity schedule for an individual, and Bowman (1998) was the first to use this approach to simultaneously model the key elements of a day-long pattern. He initially considered the purpose and 10 locations of a primary activity for in-home or out-of-home activities of an individual and then considered the number of intermediate stops made when performing the primary activity; additionally, he considered the number and purpose of additional home-based tours to complete a day's schedule of an individual. (De Silva D. 2011)

Many applications have been used with the activity-based approach. Bhat et al. (2004) used activity stop generation to model inter-shopping duration by looking at multi-day activities. Garling et al. (2003) looked into habitual travel behaviour. Kitamura et al.

(2000) went one step further to micro-simulate the daily activity travel patterns using Monte Carlo simulation. Similarly, Kulkarni et al. (2000) used a micro-simulation approach but incorporated geographic information systems to make a more advanced prediction.

2.4. **Example of day pattern**

An example of an activity pattern of an individual, Mr. X is shown below in figure 1. It contains all of the activities that this individual undertakes in a single day.

- 1st Trip-in the morning, Mr. X went to work from home.
- 2nd Trip-in the afternoon, he went for shopping from the workplace.
- 3rd trip-After the Shopping, he returned home.

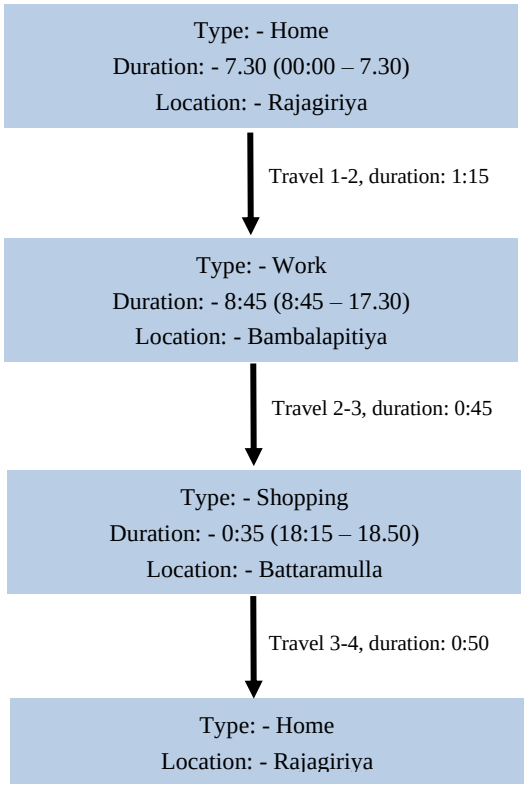

Figure 1: Example of day pattern for one individual

2.5. **Previous works on day pattern interpretation**

Time slices are a method of interpreting individuals' daytime behaviour with a single character representing the activity for that 15-minute interval. For each 15-minute time slice, activities were coded with a location code character over the whole day, which simplifies the day into a single line of characters (De Silva D. 2011)

Coding system is another method of expressing a person's daily behaviour in a well-defined set of characters. An example day pattern is H2W3H, which represents a home activity (H), followed by peak AM travel to a work activity (W), followed by midday travel back to home (H). (Kevin J. Stefan, Alan T. Brownlee, and J. D. Hunt (2016)

3. DATA

The data was not collected as a part of this research but was derived from the data collected for the CoMTrans Study by the Japan International Cooperation Agency (JICA).

3.1. **JICA Household Activity Survey**

The JICA Household Activity Survey (HAS) collected information on both in-home and out-home activities, the number of trips that an individual makes, along with attributes of the trips, for a 24-hour duration on a weekday during November 2012-August 2013. (JICA Technical Report, 2014)

A sample of households selected from the Western Province Region provided 24-hour activity diaries for all household members for 35,850 households, out of a total of 124,673 individual daily diaries available with activity and location for each activity. A range of individual socioeconomic characteristics were also obtained. These included ages, gender, and household characteristics such as income, car ownership, and household size, which are described in detail in the latter part of this chapter.

Each person's record was enlarged to represent the entire population of Western Province by a weight based on income and social status distribution and a measure based on a combination of family size and composition.

3.2. **Validity of the Sample**

To check whether the sample is valid to represent the whole population, the 2020 Census of Population and Housing (Department of Census and Statistics, 2020) is used to compare socioeconomic distribution between the census, sample set, and weighted sample set. Only age and gender distribution were compared, as in Figure 2 and Figure 3.

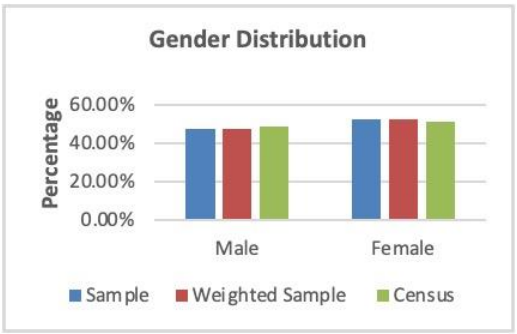

Figure 2: Gender Distribution

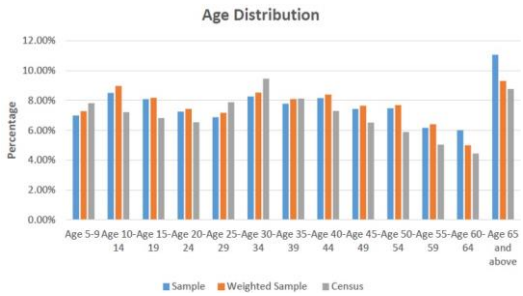

Figure 3: Age Distribution

The weighted sample matches the census data more closely, and the variation between the two is very minimal, suggesting the validity of the weighted sample. In addition, this dataset has been extensively used for modelling work for the Urban Transport System Development Project for the Colombo Metropolitan Region and Suburbs. (JICA Report, 2014)

3.3. **Vehicle Ownership**

Figure 4 shows the household vehicle distribution. 55% of the community does not have a vehicle, with 38% of the community owning one vehicle per household.

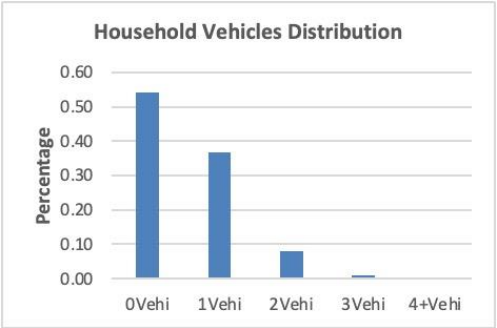

Figure 4: Household Vehicle Distribution

Figure 5 shows the number of vehicles per household by district. Gampaha District shows a relatively high percentage of 0.62 vehicles per household. Kalutara district shows the lowest percentage of 0.45 vehicles per household.

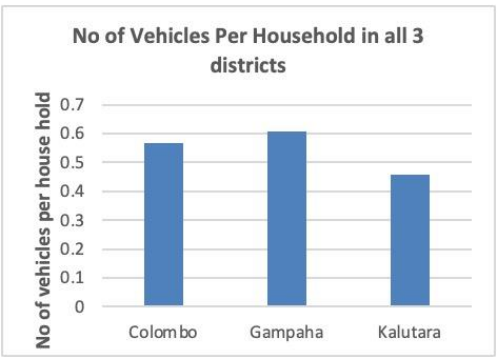

Figure 5: Vehicles per household

3.4. **Income Classification**

Around 70% of the population earns less than Rs. 40,000 per month. On the other hand, very few are in Group A (greater than Rs. 80,000); it is less than 8%.

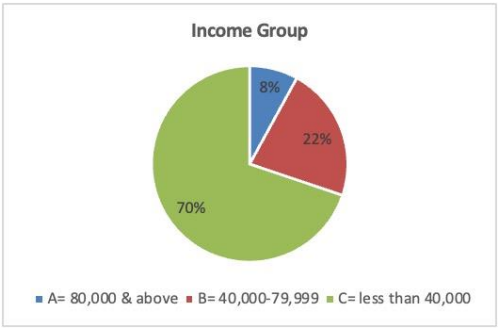

Figure 6: Income Group

4. METHODOLOGY

After considering the methodologies in previous literature, the coding system was adapted for this research. The coding system expresses a person's daily behaviour in a well-defined set of characters. The advantage of this method is that a person's day pattern can be reduced to a set of characters that explain activity plus the time period of travel, which we are more concerned of when we try to understand the trip behaviour. Therefore, it is more convenient compared to time slices.

A tour can be defined as "the movement of a person from an origin to a destination with a purpose." A tour is composed of travel activities and a time period within a day. Both of them have a coding scheme for simple descriptions. (JICA Technical Report, 2014)

It is considered five time periods for modelling and analysis purposes.

Table 1: Time Definition

Code	Time
1	Early Off peak (3AM – 6 AM)
2	AM Peak (6 AM – 10 AM)
3	Midday (10 AM – 3 PM)
4	PM Peak (3 PM – 7 PM)
5	Late Off peak (7 PM – 3 AM)

Table 2: Travel Activity Definition

Code	Activity
H	Home
W	Work
S	School
K	Shop
P	Personal Business
O	Other

To develop the tour and day pattern, the first step is to identify the destination activity and the time of day for each trip. Next, the primary destination for each tour is determined, along with secondary destinations or subtours if present. In the tour development process, the following rules are applied:

1. For work tours, the primary destination is the work location, even if the person stops for another activity on the way to work. The purpose of the tour is home-based work.

2. For school tours without work activity, the primary destination is the school location. The purpose of the tour is to visit a home-based school.

3. The primary destination for non-work, non-school tours is the first stop on the tour.

4. The tour without home at both ends is considered a "non-home-based tour."

Python language, which is used to code the travel diaries of individuals using the definitions above and the JICA data. The tour overview describes the overall nature of the tour. The trip overview "H2W4H" can be described as a work tour that begins from home during the AM. peak from 6 AM to 10 AM and returns home during the PM Peak 3PM-7PM (See Table 1 and Table 2 for code definitions.)

5. DATA ANALYSIS AND RESULTS

5.1. Coding HAS Data

Python language, which is used to code the travel diaries of individuals using the definitions above and the JICA data. Figure 7 shows the code.

Figure 7: Python Coding

5.2. Data Analysis

5.2.1. Tour Purpose

Table 3 below presents absolute number of tours by purpose.

Table 3: Tour Proportions by Purpose

Purpose	Count	Percentage
HBW	1,359,552	39.02%
HBS	1,183,864	33.98%
HBO	932,646	26.7%
None Home Ends	7,856	0.23%
Total	3,483,918	100.0%

5.2.2. Tour Overview

The tour overview describes the overall nature of the tour. The trip overview **"H2W4H"** can be described as **a work tour that begins from home during the AM peak (6AM–10AM) and returns home during the PM peak (3PM–7PM).** (See Table 1 and Table 2 for code definitions.) Other common tour overviews and their proportions are outlined in Tables 4–5 below.

From the analysis, it was observed that there are a total of 1431 activity patterns happening in the western province. Table 4 illustrates the top 10 predominant tour occurrences. The first common tour pattern is "H." Out of the 5,401,716 weighted samples, 1,918,159 samples are staying at home without any trips. The second most common tour pattern is "H2S3H." It starts at home, leaving home on AM Peak (6 AM–10 AM) to go to school and back to home on Midday (10 AM–3 PM).

Table 4: Tour Occurrence Frequency

No	Tour	Weighted Count	Percentages
1	H	1,918,159	35.51%
2	H2S3H	1,006,634	18.63%
3	H2W4H	742,206	13.74%
4	H2W5H	191,441	3.54%
5	H2P3H	158,680	2.94%
6	H2P4H	133,347	2.47%
7	H3P3H	107,714	1.99%
8	H2W3H	95,556	1.77%
9	H1W4H	72,400	1.34%
10	H2P2H3P3H	65,481	1.21%

The time and space behaviour of an individual's activity pattern on a given day (for the Second Most Common Tour Pattern, H2S3H) is shown below.

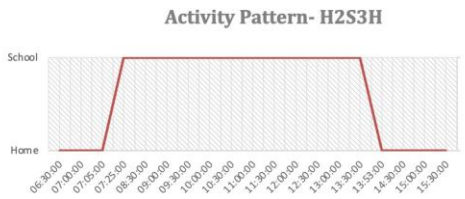

Figure 8: Spatio-temporal behaviour of H2S3H pattern

Below table 5 shows the travel percentages according to the purpose of the trip

Table 5: Proportion of Travel Activities

Purpose	Weighted Count	Percentage
W (Work)	1,365,419	39.19%
S (School)	1,185,473	34.03%

P (Private matters, business)	741,953	21.30%
K (Shopping)	124,960	3.59%
O (Other)	66,112	1.90%
Total	3,483,918	100.00%

5.3. **Distribution of Tour Modes**

Table 6 shows the distribution of tour modes. The most common tour mode is non-A/C bus (private), followed by walking and motorcycles, respectively.

Table 6: Distribution of Tour Modes

Tour Mode Name	Count of Tours	Percentage
Non-A/C bus (private)	1,016,246	29.17%
Walking only	647,741	18.59%
Motorcycle	361,047	10.36%
School bus/van	331,173	9.51%
Three-wheeler (hired)	202,631	5.82%
Non-A/C bus (SLTB)	188,996	5.42%
Car/Jeep/Van	169,845	4.88%
Three-wheeler (private use)	160,137	4.60%
Bicycle	156,872	4.50%
Railway	124,835	3.58%
Staff service	43,686	1.25%
Employee transport	40,332	1.16%
Others	20,210	0.57%
A/C bus	7,016	0.20%
Taxi (car/van)	6,795	0.20%
Pickup	5,251	0.15%
Taxi (nano)	1,324	0.04%

Table 7 illustrates the top 9 tour modes by tour purpose. This table will help to construct the tour mode choice model for each purpose.

Table 7: Percentage Share of Tour Mode by Tour Purpose

Tour purpose	Tour Mode	Count of Tours	Percentage
Work	Non-A/C bus (private)	453,948	33.25%
	Motorcycle	219,285	16.06%
	Walking only	174,007	12.74%
	Car/Jeep/Van	90,690	6.64%
	Railway	88,745	6.50%
	Three-wheeler (private use)	72,145	5.28%
	Non-A/C bus (SLTB)	71,647	5.25%
	Bicycle	70,381	5.15%
	Staff service	44,191	3.24%
School	School bus/van	330,731	27.90%
	Walking only	281,561	23.75%
	Non-A/C bus (private)	269,234	22.71%
	Three-wheeler (hired)	96,844	8.17%
	Non-A/C bus (SLTB)	56,738	4.79%
	Motorcycle	42,825	3.61%
	Three-wheeler (private use)	34,668	2.92%
	Bicycle	27,961	2.36%
	Car/Jeep/Van	21,299	1.80%
Other	Non-A/C bus (private)	291,060	31.20%
	Walking	190,559	20.42%
	Motorcycle	98,561	10.56%
	Three-wheeler (hired)	83,991	9.00%
	Non-A/C bus (SLTB)	59,723	6.40%
	Bicycle	57,040	6.11%
	Car/Jeep/Van	56,710	6.08%
	Three-wheeler (private use)	52,376	5.61%

5.4. **Summary of results**

Socio-economic characteristics for each day pattern (for predominant 10-day patterns) were analysed and the majority of items are shown with their percentages in Table 8 below.

Day Pattern	Socio-economic Characteristic	Majority	Percentage
H	Gender	Female	70.00%
	Age	More than 65 years	19.51%
	Social Status	Housewife	46.79%
H2S3H	Gender	Male	50.5%
	Age	05-14 yrs	74.82%
	Social Status	Student (grade 1-5)	38.87%
H2W4H	Gender	Male	62.8%
	Social Status	Working (Full Time)	89.82%
	Occupation	Office clerks customer service clerks	15.43%
H2W5H	Gender	Male	82.9%
	Social Status	Working (Full Time)	86.58%
	Occupation	Sales persons at shop, stall, and market	18.34%
H2P3H	Gender	Female	53.2%
	Social Status	Housewife	35.32%
H2P4H	Gender	Male	84.20%
	Social Status	Working (Part Time)	47.51%
H3P3H	Gender	Female	63.83%
	Social Status	Housewife	49.68%
H2W3H	Gender	Female	68.98%
	Social Status	Working (Fu Time)	85.06%
	Occupation	Professors, Lectures, Teachers	60.36%
H1W4H	Gender	Male	78.92%
	Social Status	Working (Full Time)	88.83%
	Occupation	Labours	17.22%
	Gender	Female	71.03%
H2P2H3P3H	Social Status	Housewife	65.47%

6. CONCLUSION

There are different ways of interpreting the behaviour of a person. The present study found that the coding system is more suitable since a person's daily pattern can be compressed into a set of characters that explain activity and time period of travel, with which we are more concerned when we try to understand the trip behaviour.

There are a total of 1431 day patterns observed in the western province from this analysis. "H," "H2S3H," "H2W4H," "H2W5H," "H2P3H," "H2P4H," "H3P3H," "H2W3H," "H1W4H," and "H2P2H3P3H" are the top 10 activity patterns happening in the western province. The results of this study show that 35% of the total population is not making any trips. Among them, 70% of the population is female. In terms of social status, around 47% of the population are housewives, 14% are unemployed, and 13% are retired people. Under an age-wise categorization, around 20% of people who stay at home are over 65 years old, either because they are retired from work, ill, or too old to travel.

The remaining 65% are making trips on a particular day, of which 39.19% are work trips, 34.03% are school trips, 21.30% are personal business trips, 3.6% are shopping trips, and 1.9% are other types of trips. Moreover, the most common mode of transportation is non-A/C buses (private), which account for 29.17% of all trips, followed by walking and motorcycles as the 2nd and 3rd most common modes, respectively.

In conclusion, the key findings from the present studies are that when we consider the activity patterns of traveling people, the most common activity is "H2S3H", which is 18.63% of the total population. All the people are students. Around 75% of the trip makers are between 5 and 14 years old. The next common activity pattern is "H2W4H," which is 13.74%

of the total population. It was observed that government employees, clerks, and senior officers are returning home in the PM peak. Meanwhile, the next common activity pattern is "H2W5H," which is 3.54% of the total population. This group consists of salespeople, workers in construction, and drivers and operators of vehicles who return home in the late off-peak. The next common activity is "H2P3H," which includes housewives and retired people as the majority. Since they are not working, they do activities such as visiting relatives' houses, meeting friends, and other personal activities in the morning and return home by lunchtime.

These findings of the research will help to develop an activity-based model in the future.

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