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TIME EXPENDITURE DIFFERENCES AMONG WEEKDAYS, WEEKENDS, AND FRIDAYS FOR RESIDENTS OF MAKKAH, KINGDON OF SAUDI ARABIA

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ABSTRACT

Many researchers have studied the differences in travel behaviours during the weekdays and the weekends for building travel demand in Makkah, Saudi Arabia, any travel demand framework should recognize the differences in residents' travel behaviour not only between the weekdays and the weekends, but also on Fridays. During the weekends (i.e., Thursday and Friday), most residents spend time with their families and friends on Thursdays, whereas some go to work. On Fridays, there is the Friday prayer, which takes place around noon, and most of the stores are closed until late afternoon. This paper presents modelling of the activity duration for residents of the city of Makkah for weekdays and weekends. The municipality of Makkah collected a full-day travel diary for the residents of Makkah in 2010 for all days of the week. The data were categorized as either weekdays or weekends. Then the multiple discrete continuous extreme value (MDCEV) model was used to estimate the activity duration for 3 separate groups of days (i.e., weekdays, Thursdays, and Fridays), and a fourth model was estimated for all days of the week. This paper will highlight the differences in travel behaviour for the residents of Makkah between the weekdays and the weekends time periods. The outcomes of this paper could be expanded for use in Muslim communities and for all other religions that perform religious rituals during the weekends.

1. INTRODUCTION

A travel demand framework is the first step for planning a city. Several frameworks are used to model travel demand, such as the conventional four-step demand model, agent-based model, and activity-based model. One of the most advanced modelling techniques is the activity-based travel demand model, specifically, the econometric modelling framework. It consists of multiple connected models forming an individual day plan, including information such as activity start time, duration, location, and mode of transportation.

Makkah, which is located in western Saudi Arabia, is considered the capital city for all Muslims. The city attracts millions of worshippers every year from around the globe. As a result of the high demand, the Al-Haram mosque, which is the main attraction of the city, is under expansion so that it will hold up to 1.2 million pilgrims. In the city of Makkah, the calendar year is divided into four seasons by the type of religious observance conducted during each time period. The seasons are Hajj, Ramadan, Friday, and Umrah. Hajj is conducted only once a year, on the last month of the lunar calendar. Ramadan is also an annual event, but it lasts for a whole month, which is the ninth month of the lunar calendar. Fridays are considered a special religious season that happens weekly, with big gatherings in mosques to perform Friday prayer. Finally, Umrah is an all-year season during which pilgrims and residents conduct a special religious ritual in Al-Haram. In Makkah, a large number of residents and visitors make religious trips to Al-Haram on Fridays to perform Friday prayer. In 2001, the total daily travel demand in Makkah for all modes of transportation was around 4.37 million trips (Kaysi et al. 2010).

Beyond special seasonal events, transportation planning agencies require information on travel demand during both weekdays and weekends to plan for the city better. Starting on June 29, 2013, the weekends in Saudi Arabia has officially become on Friday and Saturday. During weekends in Makkah in 2010 (i.e., Thursday and Friday), most residents spend time with family and friends on Thursdays, whereas others have to work or catch up on weekly chores and grocery shopping. However, Fridays are mainly for religious activities; the stores will not operate until late afternoon or remain closed for the day. In addition, religious activities have received limited attention in the literature when modelling travel demand. This raises the need to study whether the travel demand framework should distinguish Fridays from weekends in Makkah. The focus of this paper is to evaluate the behavioural effects on time usage for weekdays and weekends in Makkah using an activity duration model. Researchers have studied the differences in travel behaviour between weekdays and weekends for different reasons. Ashish (2004) highlighted the spatiotemporal constraint differences during weekdays and weekends as an important cause to distinguish between the two time frames. Another cause is that total work trips decline and travel volume during weekends exceeds peak-hour congestion (Rongfang, 2009).

The objectives of this paper are to study the daily time expenditure behaviour for the residents of Makkah during weekdays and weekends and to examine whether the travel demand framework in Makkah should distinguish Fridays from weekends. In 2010, the municipality of Makkah collected a full-day travel diary for the residents of Makkah during the third and the fourth months of the lunar calendar for the whole week. The data were categorized based on three groups: weekdays, weekends, and Fridays. Then the multiple discrete continuous extreme value (MDCEV) models was used to estimate activity duration. A separate model was estimated for each of the three groups, and a fourth model was estimated for all days of the week together.

2. ACTIVITY DURATION STUDIES FOR WEEKDAYS AND WEEKENDS

Zhong et al. (2007) acknowledge that activities during weekdays are different from those on weekends in participation rates and start times. The literature has further studied the differences between weekdays and weekends based on participation rates, start time, duration, and location using statistics, the Wilcoxon log-rank test, and the best-fit duration model. Studies have suggested looking at weekdays differently from weekends when modelling travel demand. Rachel and Chandra (2007) conducted a descriptive study on activity participation during weekdays and weekends for school-aged children. They indicated that the highest number of trips during weekends are to church. Children and their families make trips to church with an average duration of 2.5 hours of activity. Retail stores are a relatively frequent activity location from noon to 4:00 p.m. during weekends. Kids spend more time in sport practices, kids' clubs, and other meetings during weekends compared to weekdays. They also spend more time on passive activities, such as watching TV, than on sport activities during both weekdays and weekends. The study noted that age is a key factor for specifying the type of activities.

The literature in general concluded that activity duration during weekdays is substantially different from those of activities performed during weekends. Ashish (2004) modelled activity duration using a structural equation model (SEM). Sociodemographic characteristics of households and individuals were used to estimate the model and to show the differences in activity duration between weekdays and weekends. Based on Chandra et al. (2012) and Werner and Engel (2009), as dimensionality of the problem increases, the SEM becomes computationally demanding. In addition, as the number of dependent variables increases, the SEM suffers from identification problems. As a result, the MDCEV model will be used to estimate the models. Residents' time expenditure behaviour by itself is important in modelling travel demand when using an activity-based modelling framework. It helps in understanding the residents' overall time-use patterns and their mode of choice patterns.

3. HOUSEHOLD TRAVEL SURVEY OF MAKKAH

The municipality of Makkah collected a household travel survey during the third and fourth months of the lunar calendar 1331 AH (2010 AD). The data were collected through personal interviews with family members aged 8 years and older, except for women. The householder of the family or the driver answered the questions directed to women for cultural reasons. The survey included only the residents of Makkah. Family members needed to be staying a minimum of 3 nights at home to be eligible for the survey. The survey started by giving a description of the survey and obtaining permission from the householder to conduct the survey. Then the interviewer verified the household address and asked the questions in a specific order. Finally, the answers' completeness and clarity were approved. The survey contained three parts: (a) household information, (b) individuals' information, and (c) trip information. The household part included relative information such as the number of household members, the number of owned cars, and the household income. The individuals' questionnaire contained personal household socio-economic information such as age, occupation, place of work, and driver's license status. The trips part covered trip chains made the day before the interview for each individual in the household. For illustration, the destination of the first trip in the trip chain is the origin of the second trip in the trip chain. Each trip part included trip start and end time, origin and destination zones, mode of transportation used, occupancy of the mode of transportation, and trip purpose. After organizing the data set, a total of 22,000 individual cases was selected for the model estimation. The participants for eight out-of-home activities are as follows:

1. Single-stop work activity (ACT 1).
2. Single-stop school activity (ACT 2).
3. Single-stop shopping activity (ACT 3).
4. Single-stop recreation activity (ACT 4).
5. Single-stop other activity (e.g., hospital, clinic; ACT 5).
6. Multiple recreational activity stops (e.g., trip from gym to restaurant; ACT 6).
7. Multiple shopping activity stops (ACT 7).
8. Religious activity (ACT 8).

4. METHODOLOGY

One of the advanced modelling techniques in modelling activity duration is the MDCEV model proposed by Chandra (2005). It has a micro-economics framework base that uses the random utility maximization (RUM) theory such that a person tries to maximize his or her utility, which is constrained by the time budget. The model contains three parameters to capture the trade-off in time consumed between in-home and out-of-home activities, such as the pure satiation parameter, translating parameter, and baseline utility parameter [see Chandra (2005) for the model formulation and derivations]. The three parameters combined form the total utility function (see Equation 3). The specifications implemented by Habib et al. (2008) and their software code are used in this paper.

The pure satiation parameter (μ) represents the satiation effect of out-of-home activity duration expenditure and is given by

[1] $$\mu = 1 - \exp(-\beta_z X_z)$$

where X_z = in-home activity variables for the pure satiation parameter and β_z = coefficient of variable X_z. This parameter is a function of in-home activity variables, and it shows the effect of the increase or decrease in in-home utility on the out-of-home activity duration. The increase in the coefficient β_z increases μ and decreases the time spent out-of-home, as shown in Equation 1.

The translating parameter (Ω) represents the trade-off between out-of-home activities, such as a person's spending all day on one type of activity, and is given by

[2] $$\Omega = \exp(\beta_o X_o)$$

where X_o = out-of-home activity variables for the translating parameter and β_o = coefficients of variable X_o. As noted, the higher the coefficient β_o, the higher the Ω value and the lower the out-of-home activity duration (see Equations 2 and 3). Ω also includes the satiation effect of out-of-home activity (Kim et al. 2002).

The total individual utility for spending time in-home and out-of-home is the summation of the subutilities of each individual activity, as follows:

[3] $$Total\ Utility = \sum_{a=1}^{No.of\ Activities} (\Omega_a/\mu)\ \exp((\beta_v X_v)_a + \varepsilon_a)\left(\frac{Y_a}{\Omega_a} + 1\right)^{\mu} - 1) + \frac{1}{\rho}\exp(\varepsilon_z)(z)^{\mu}$$

where ε = error term (type I extreme value distribution) and z = total time spent on all in-home activities. The total individual utility contains the pure satiation parameter, the translating parameter, and the baseline utility parameter (B_a). The total utility function is used to estimate the model parameters and drive the likelihood function.

The baseline utility parameter of specific activity a (B_a) is the marginal utility at the zero time expenditure point:

[4] $$B_a = (\beta_v X_v)_a$$

where X_v = out-of-home activity variables for the baseline utility parameter and β_v = coefficients of variable X_v. The higher the coefficient β_v, the higher the B_a value and the higher the out-of-home activity duration (see Equations 3 and 4). The in-home utility is considered the base for the out-of-home utility, such as when the in-home utility is set to zero.

The total activity duration of a specific activity a is the average time spent on the activity multiplied by the frequency of the activity, which is given by

[5] $$T_a = AVG_a\, Frq_a$$

where T_a = total time spent on activity a, AVG_a = average time spent on activity type a, and Frq_a = frequency of activity type a.

The model is constrained with a total time budget of 16 hours for out-of-home activities. Individuals with more than 960 minutes (i.e., 16 hours) of out-of-home activities are excluded from the data. It is assumed that a person should spend at least 8 hours at home for sleeping and other in-home activities.

The Kuhn-Tucker optimality conditions are applied to the utility function (Equation 3) to transform it to a deterministic utility part of a specific activity (V_L) and a deterministic utility part of the total in-home activities (V_i) as follows:

[6] $$V_L = (B_a + (\mu - 1)\ln(T_a / \Omega a + 1) - \ln(\mathrm{AVGa}))$$

[7] $$V_i = (\mu - 1)\ln(i)$$

Then the transformation variable theorem and the error term are used to drive the likelihood function. The final shape of the likelihood function used to estimate activity duration is given by

[8] $$p(T_1, T_2, T_3 \ldots, 0,0,0, T_a) = Ln\left(\prod_{a=1}^{M}(M-1)\left(\prod_{a=1}^{M}\frac{1-\mu}{T_a+\Omega_a}\right)\left(\sum_{a=1}^{M}\frac{T_a+\Omega_a}{1-\mu}\ AVG\ FRQ\right)\left(\frac{\prod_{a=1}^{M}\exp(V_L)}{\sum_{L=1}^{L}\exp(V_L)^M}\right)\right)$$

where M = frequency of activities conducted more than once and L = total number of in-home and out-of-home activities.

The variables' coefficients were estimated using the GAUSS 15.0 software with the Broyden–Fletcher–Goldfarb–Shanno gradient (BFGS) search algorithm.

5. RESULTS AND DISCUSSION

Four empirical models were estimated (i.e., weekdays, Thursdays, Fridays, and all days) to model the differences in time consumption among the residents of Makkah during the specified day groups. Each model comprises eight out-of-home activity durations with a time budget constraint of 16 hours. The mean log-likelihood and goodness of fit vary between the four models. The goodness of fit for the Friday model is the highest, which shows the importance of including Friday as a separate category. Rho-square is the index used to measure the goodness of fit of this model (see Equation 9). It ranges between 0 and 1. The best-fit model is 1. However, values between 0.1 and 0.3 are considered reasonable for such a complex model. Rho-square values in this paper show extraordinarily high values of 0.69. Figure 1 and Table 1 show the details of the goodness of fit of each of the four models.

[9] $$Rho\text{-}Square = 1 - \frac{\text{Full model mean LogLikelihood}}{\text{Null Model mean LogLikelihood}}$$

The full model mean log-likelihood increases in the following order: the Thursday model, the all-days model, the weekday model, the Friday model. This means the Friday model has the highest mean log-likelihood. However, the null model follows a different order that results in the goodness of fit of the Thursday model being the lowest, then the all-days model, then the weekday model; the highest is the Friday model. The variability in travel plans seems to be the lowest in the Friday model because it has the highest goodness of fit. This is a reasonable output because most people spend their mornings at home because there are no working or shopping activities until the afternoon. In other words, the residents have a half-day of out-of-home activity to use and a limited number of out-of-home activities to do. The number of parameters' coefficients varies from 54 to 65 based on the model. The weekdays model has the highest number of parameters (see Table 1 and Figure 1).

Table 1:Summary of the number of parameters and number of cases

Goodness of fit model components\the models	All days	Weekdays	Thursdays	Fridays
Total number of cases	18,434	18,434	2,700	928
Number of parameters of the full model	59	65	54	61
Number of parameters of the null model	3	3	3	3

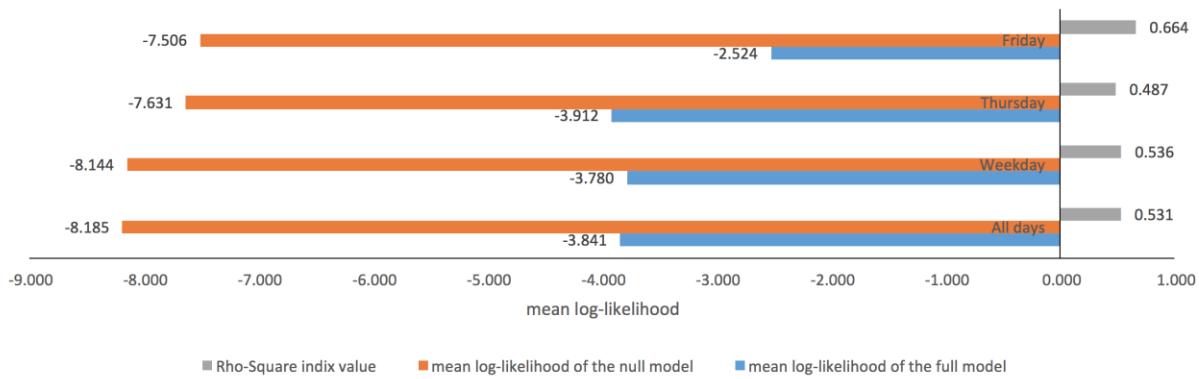

Figure 1: Goodness of fit model components.

A 90% confidence interval is used to test the significance of the parameters and to decide whether to keep or omit the variables' coefficients. The model has three parameters, as discussed earlier: translating satiation, pure satiation, and baseline utility. The interpretation of the model parameters and its variables' coefficients follows.

6. PURE SATIATION AND TRANSLATING SATIATION PARAMETERS

The pure satiation parameter (μ) defines the marginal rate of utility. An increase in the μ value or β_i value reduces the out-of-home activity time. Household information is used to model μ. μ contains a constant and the number of people per household. The constant and the variable coefficient are the same across all in-home and out-of-home activity types. The constant values are negative and almost the same in all four models. In the all-days and weekday models, the number of people per household coefficient is negative, which indicates that the number of people per household affects activity duration during weekdays and not the weekends (see Table 2).

Table 2: Purely satiation parameters components for the four models.

Purely satiation components	All days	Weekdays	Thursdays	Fridays
Constant	–2.146	–2.158	–2.075	–2.474
# people/household	–0.003	–0.003	0	0

The translating satiation parameter Ω ensures the corner solution, such as when a person can spend all of his or her activity duration on one activity type, and includes the satiation effect. The increase in the Ω_a variable coefficient β_o decreases the time spent out-of-home for a specific activity of type a. Trip information is used to model the translating satiation effect. The constant, the number of people combined in the activity, and the mode of transportation are the variables that define Ω_a. Both coefficients of the constant and people combined in the activity variable are the same across each activity type for the Friday model. For the three other models, the constant varies from one activity type to another, and the occupancy coefficients are the same across all activity types. In the Friday model, the constant and occupancy coefficients are positive. This constant is the highest constant coefficient of the models. This reflects the residents' preference for spending time at home more on Friday than the rest of the week. The occupancy coefficients are positive for all the models. The highest occupancy coefficient is for Thursday, which indicates that the residents prefer not to spend time out-of-home when the travel group is high. More household members have more needs and consequently less time to spend out-of-home per person need. The next highest occupancy coefficient is for the Friday model, followed by the weekday model, then the all-days model. The low coefficient value during weekdays (around 0.48) reflects the lower effect of the trip party on activity duration compared to Thursday (Table 3).

Table 3: Constants and occupancy coefficients for the four models.

Translating satiation components	All days	Weekdays	Thursdays	Fridays
Constant ACT1	5.496	0.630	2.738	3.631
Constant ACT2	5.496	0.630	2.738	3.631
Constant ACT3	–0.568	–1.44	–1.542	3.631
Constant ACT4	2.068	0.840	–1.980	3.631
Constant ACT5	0.748	–1.260	–6.069	3.631
Constant ACT6	2.146	0.985	2.738	3.631
Constant ACT7	1.681	0.841	–0.967	3.631
Constant ACT8	1.852	1.914	2.880	3.631
Occupancy	0.353	0.483	2.839	1.415

Dummy variables for each mode of transportation are used to model the effect of mode choice on activity time consumption. Private auto with a chauffeur, private auto, company-owned taxi, individually owned taxi, private school bus, private company bus, walking, and motorcycle are considered. Taxi services owned by individuals are not registered in the Ministry of Transportation in Saudi Arabia, and it is hard to keep records of them. These are the equivalent of Uber in Canada. In addition, they are competing with taxis owned by companies because they offer competitive fares. However, these taxis are accounted for in this data set. None of the modes were significant for the all-days model.

However, during weekdays, coefficients for all modes of transportation are positive except for private company buses, which indicates that residents who use private company buses spend more time in out-of-home activities such as work compared to residents who use private autos or motorcycles (the highest coefficient value). On Thursday, the only negative coefficient is for taxis owned by companies, which shows that this is the residents' mode of transportation of preference when spending more out-of-home time. On Fridays, all mode of transportation coefficients are negative. The lowest values are for taxis owned by companies and by individuals, which results in spending more out-of-home time compared to the other modes. Parking fares in the central area where Al-Haram is located are high, which makes taxis an attractive mode of transportation (see Table 4).

Table 4: Mode of transportation coefficients for the four models.

Mode of transportation	Weekdays	Thursdays	Fridays
Private auto (chauffeur)	0.503	0	–0.948
Private auto	2.559	1.81	–1.460
Taxi (owned by company)	0	–1.156	–3.293
Taxi (owned by individual)	1.095	0	–2.637
Private school bus	0	3.845	–1.407
Private company bus	–1.059	0	–1.013
Walking	0.438	0	0
Motorcycle	2.461	6.908	0

Baseline Utility Parameter

The baseline utility is the zero-time expenditure point. The baseline utility functions of specific activities are estimated with respect to the total in-home activities. For illustration, the parameters of the baseline utility function of the total in-home activities are assumed to be zero. The baseline utility for out-of-home activities uses individuals' information such as constant, gender, and age for all the models. Travel time to activities and acquisition of driver's license are included in the Friday model only because they are statistically significant. In the Friday model, the constant values are negatives with slight variations across activity types. For the other three models, all activities have one constant, and they are negative in value (i.e., they range from –27.6 to –30.3). The highest constant value is for the Thursday model. In other words, the residents prefer to spend more out-of-home time on Thursdays than on the rest of the week (Table 5).

Table 5: Baseline utility constants for the four models.

Baseline utility components	All days	Weekdays	Thursdays	Fridays
Constant ACT1	–30.312	–30.638	–27.630	–41.346
Constant ACT2	–30.312	–30.638	–27.630	–34.057
Constant ACT3	–30.312	–30.638	–27.630	–39.790
Constant ACT4	–30.312	–30.638	–27.630	–38.107
Constant ACT5	–30.312	–30.638	–27.630	–37.929
Constant ACT6	–30.312	–30.638	–27.630	–44.329
Constant ACT7	–30.312	–30.638	–27.630	–41.346
Constant ACT8	–30.312	–30.638	–27.630	–41.782

A gender-specific dummy variable is included in the model to capture the differences between males and females in spending time on specific activities out-of-home relative to in-home. The positive parameter values indicate that males spend more time in out-of-home activities than females. Each activity has its own parameter except for in the Friday model, which contains a general gender-specific positive coefficient. This indicates that males spend more time in all activity types than females. For the other three models, the highest parameter value for males among the three models is for school activities, then work activities, which indicates that these are the major activities for males. Males spend more time than females on school activities, work activities, single-stop shopping activities, and single-stop recreational activities in all three models.

The highest parameter values for females in the three models are for multiple shopping stops (ACT 7), which indicates that females spend more time in these activities than males. ACT 7 is the most important activity for females. Females spend more time in Al-Haram during weekdays than on weekends. They might be trying to avoid the visitors' congestion in Al-Haram during the weekends, or they might have other plans during the weekends. Commonly, females make more hospital visits, Al-Haram visits, and multiple recreational and shopping stops than males in the three models (Table 6).

Travel time and driver's license were found significant in the Friday model. Each activity contains its specific coefficient. All travel time coefficients are positive, which indicates that the increase in travel time increases the utility for out-of-home activity. Multiple recreational and social activities contain the highest coefficient values; thus, residents spend more time on these specific activities. Only males of 18 years and older are allowed to drive. Males prefer to drive to work, school, and single shopping destinations. Because the rest of the activity was conducted the most by females, who are not allowed to drive, the coefficients have negative signs (see Table 7).

Table 6: Gender-specific dummy variable for the four models.

Gender-specific dummy variable (male)	All days	Weekdays	Thursdays	Fridays
ACT1	4.208	4.136	3.896	0.693
ACT2	6.306	6.297	6.155	0.693
ACT3	2.936	2.866	2.952	0.693
ACT4	3.053	3.069	3.670	0.693
ACT5	–0.468	–0.480	0	0.693
ACT6	–1.173	–1.115	–1.182	0.693
ACT7	–2.324	–2.472	–1.933	0.693
ACT8	–1.375	–1.393	–1.066	0.693

Table 7: Travel time and driver's license coefficients for Friday model.

Baseline utility components	Travel time	Driver's license
ACT1	0.155	1.344
ACT2	0.120	0.420
ACT3	0.159	1.789
ACT4	0.229	–0.009
ACT5	0.169	–0.009
ACT6	0.497	–0.009
ACT7	0.497	–0.009
ACT8	0.328	–0.009

The individual's age is a key variable when explaining time-consuming behaviour with a variability of high significant variable coefficients. To capture the nonlinear effect of the age, the variable was set as a dummy variable for the seven age categories (see Figure 2). The base of these age categories is age less than 20 years old, which is set to zero. Age coefficients were not consistent across the four models. Not surprisingly, religious activities' (ACT 8) variable coefficients for all ages are positive at different values depending on age, except for age category > 70 on Friday. This shows that Al-Haram activity is a quite important to residents of all ages in Makkah. The highest parameter values are for weekdays, which indicates that the city residents visit Al-Haram on weekdays more than on weekends. It appears that the city residents try to avoid Friday prayer in Al-Haram due to the high demand resulting from pilgrims and merchants from the hotels and shopping centers in the surrounding areas.

For work activities (ACT 1), most of the coefficients are positive. In general, people aged 21–60 are willing to go to work more than people aged 61 and older. As shown in Figure 2 for the general case of the all-days model, as the age increases, the residents' willingness to go to school decreases. For a single shopping activity (ACT 3), from the average model (i.e., the all-days model), younger age groups are willing to do more shopping trips than older age groups. Only those 21–30 years old hold a positive coefficient in multiple shopping stops (ACT 7). On average (i.e., the all-days model), young residents 21–30 years old are willing to spend more time in single and multiple recreational activities (ACT 4 and ACT6) than other age groups. In the all-days model, hospital visits' and other activities' (ACT 5) coefficients are positive for all ages except for ages > 70. That shows that these groups are willing to go on hospital visits more than the older age groups. Variations in parameters' coefficients values and signs are visible across the models, which supports the fact that time expenditure behaviors during weekdays, Thursdays, and Fridays are different. Otherwise stated, this is related to the fact that the study considered weekdays and weekends (i.e., Thursday and Friday) and a specific event (e.g., Friday prayer) that affected all activities.

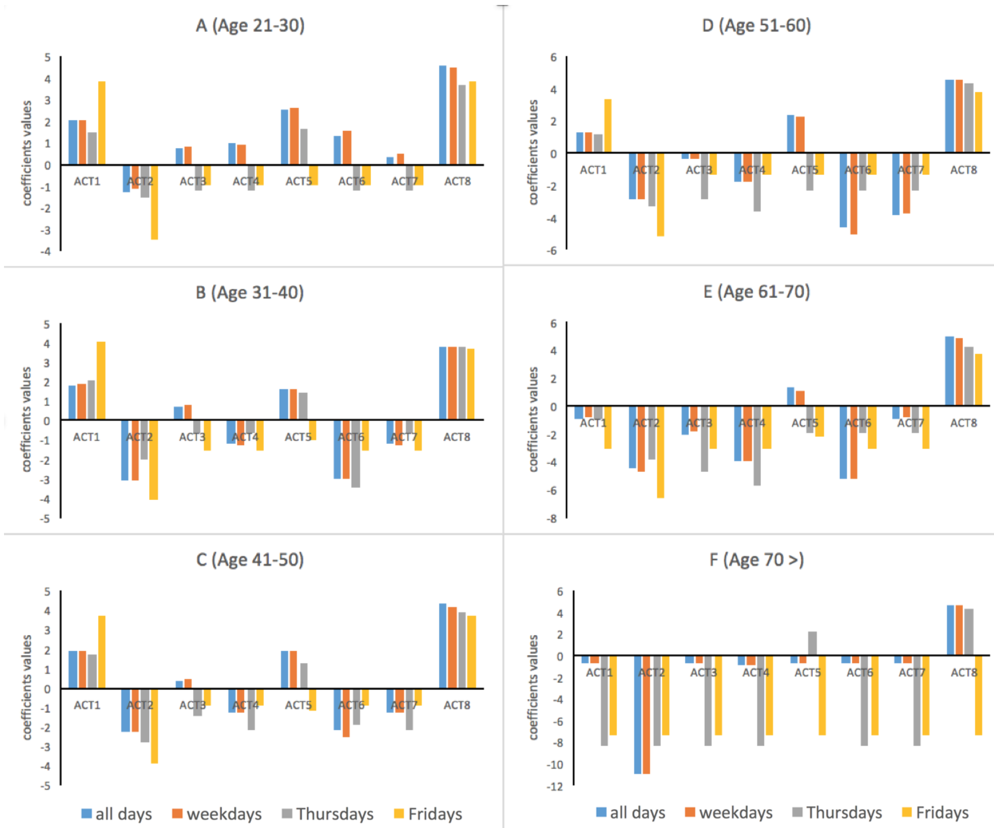

Figure 2: Age variable coefficients for different age categories.

7. CONCLUSIONS

In this paper, the MDCEV model was used to analyse the trade-off between in-home and out-of-home activity duration for weekdays and weekends. Out-of-home activities were divided into eight activity types with a time budget constraint of 16 hours. A travel diary was collected by the Municipality of Makkah for 2 months of the lunar calendar year during the Umrah season in 2010. The data were categorized based on three groups: weekdays, Thursdays, and Fridays. Then an activity duration model was developed using the Kuhn-Tucker demand system approach for the city of Makkah. A separate model was estimated for each of the three groups, and a fourth model was estimated for all days of the week together. As of June 29, 2013, weekend days has been changed. Thursday and Friday were the weekend days before June 29, 2013, and it has changed to be on Friday and Saturday. Considering the new change, modifications need to be done for future analysis. It is expected that the time expenditure behavior for the current Friday from morning until the late afternoon will remain the same since the city follow the same pattern. However, after late afternoon, Friday time expenditure behavior will be swapped with the first day of the weekend before June 29, 2013. For the last day of the current weekend (i.e. Saturday), time expenditure behavior is expected to be similar to the first day of the old weekend from morning until late afternoon. Beyond the late afternoon, the time expenditure behavior is expected to follow the second day of the old weekend because the residents will be preparing for school and work.

The key factors that affected the activity duration for various trip purposes were considered, and included gender, occupancy, age, mode of transportation, number of people per household, travel time, and driver's license. From the results, it appears that these models capture the trade-off between in-home and out-of-home time expenditures with high Rho-squared values ranging from 0.48 to 0.69. The Friday model resulted in the highest goodness of fit. Categorization of the data based on the days provided a meaningful insight into different time expenditure behaviour during these days and revealed the differences among the four day groups.

Residents of Makkah are willing to spend more time in Al-Haram during weekdays than during weekends. Because the residents of Makkah do not visit Al-Haram more on Fridays, studying pilgrims' activities in the city of Makkah might provide a reasonable answer to the congestion on Fridays. In addition, the residents might try to avoid the high-congestion areas and the hot weather by performing Friday prayers in mosques close to their homes. This model could be applied to Medina city, which is similar to Makkah. The only two cities in Saudi Arabia that have a holy mosque at the center of the city, which attracts millions of pilgrims and visitors, are Makkah and Al-Medina. The high number of visitors affect the residents time expenditure behavior. Other cities in Saudi Arabia, which have smaller scale mosques spread all around the city, are expected to have different travel behavior compared to Makkah because of the low number of mosques visitors. Consequently, this model could be applied to other cities in Saudi Arabia but with considering the crowd factor and with appropriate data.

From the analysis of these models, other religious communities outside Makkah that perform rituals during the weekends might use these estimated models because Makkah is a multinational. In addition, Friday in Makkah and Saturday in most of the countries are the last day of the weekend. In case there is a main prayer area and high visitor volumes, the residents are expected to avoid the main area and leave a chance for the visitors to pray. All Muslim communities perform Friday prayer every Friday afternoon all around the globe. However, they might not spend most of the time at home on Friday when Friday is considered a weekday. This approach also could be useful in other applications such as modeling regular public events (e.g., farmer's markets), which take place during the weekends in non-peak hour period. Appropriate data collection is needed for this regard.

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