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Using The Activity-Based Models to Study the Effect of Increasing Fuel Prices on the Individuals' Daily Movement Patterns (Case study: Egyptian Obour city)

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Abstract: The present study Provides a tool to overcome the problem of the lack of accurate models to study many policies affecting the transport system in Egypt, especially the policies of raising fuel prices and their impact on the daily movement patterns of individuals. It also aims to create a model to study the policies of raising fuel prices using activity-based transport demand models because they are the most accurate and realistic methods of modeling transport demand. Egyptian Obour City was chosen as the study area. A total of 934 representative samples of individuals within the study area were collected through questionnaires containing questions specific to the characteristics of households, characteristics of individuals and characteristics of daily tours of individuals. The SPSS program was used to build five models of movement patterns within the study area, where it was found that these models are the most widespread within the study area. The study showed that the cost of day tours has an impact on the individual's choice of daily patterns, as it turned out that a 1% increase in the price of gasoline leads to an average increase in the public transport fare by 0.123%, and this increase leads to a decrease in the odd ratio for Home-based work primary tours pattern by -0.036%, for Home-based education primary tours pattern by -0.155%, and for Home-based education primary tour and secondary work tour pattern by -1.954%. It seems that this effect is small, but when applied to the census of the entire Egyptian society, the effect will be significant. The study also showed that car ownership is the most influential factor in individuals ' decisions in choosing their daily patterns.

Keywords: activity-based models, Daily Movement Patterns, Binary logistic regression models, and odd ratio.

1. INTRODUCTION

There are many difficult questions facing decision-makers in the transportation field, and they must make appropriate and informed decisions. Decision-makers are no longer confronted only with questions about how and where to expand transportation system capacity, but they also must consider the questions about how to best manage the existing transportation system. Such as studying the impact of increasing fuel prices on the movement patterns of individuals and their daily activities and the impact on the country's economy. Over the past decades, several methods for modeling transport demand have developed. The traditional model is considered as one of the oldest methods used to predict the demand for transport. This is for ease of application and use anywhere, as well as the acceptable accuracy of its results, and in life, it is called the sequential model and four-step model, because the model consists of four consecutive steps that are implemented to reach the volume of future demand for Transport. In this study, activity-based models were used to build a more accurate model of demand for transport and used in the study of the impact of increasing fuel prices on the daily activities of individuals, which can be used to study the impact of other administrative policies on the transport system to help decision-makers.

2. LITERATURE REVIEW

Transport demand models have evolved through three main stages based on the basic unit on which the model is built. Traditional models relied on the trip as a building unit of the model. Various attempts have begun to develop traditional transport models by choosing a building unit for the model that is more accurate modulation of reality [1]. With the huge advances in technology and data collection techniques, new models have emerged to estimate future transport demand, and activity-based transport demand models have come on top of these new models. Activity-based transport demand models provide a realistic representation of the movement of individuals and simulate the realistic constraints of time, space, and connections between activities [2].

2.1 Types of Travel Demand Models

Sketch-Planning Models are considered the simplest types of transportation models and are used in deducing approximate estimates of the demand for travel. These types of models require little data, so they are easy and fast to implement, and they need commonly used and widely used programs such as spreadsheets and geographic information systems (GISs) [3]. Strategic-Planning Models are narrow in scope but carry appropriate details for some analytical studies in specific areas. These models are used when desired to quickly obtain an analysis of different scenarios. This type of model has the advantage of being inexpensive in terms of its development and application. Strategic planning models are a very appropriate model for testing a wide range of broad-based policies, but they may be less appropriate for detailed analysis of project alternatives [3]. Trip-based travel models have evolved over the past decades and have become the most used to date. The individual trip is the main unit of analysis in the trip-based models and involves movement from a single origin to a single destination [4]. These models were named after the trip-based models. The trip-based model is called the four-step model because this model is based on four basic steps models: trip generation model, trip distribution model, mode choice model, and trip assignment model [5].

Tour-based models can be considered a sophisticated extension of trip-based models [1]. A tour approach is a powerful tool for explaining travel behavior, as shorter trips can be considered as one longer tour. The collection of separate trips into one tour depends on the fact that all trips start from and end at home [6].The most important characteristic of tour-based models is the explicit representation of the temporal and spatial constraints of the activities .However, tour-based models do not link tours on the same day [1]. Activity-based models assume that the demand for travel is caused by the need of people to meet their daily needs and participate in various activities. Activity-based models share some similarities to traditional 4-step models: activities are generated, destinations for the activities are identified, travel modes are determined, and the specific network facilities or routes used for each trip are predicted [3]. FIGURE 1 Clarifies the difference between trip-based, tour-based, and activity-based models' units.

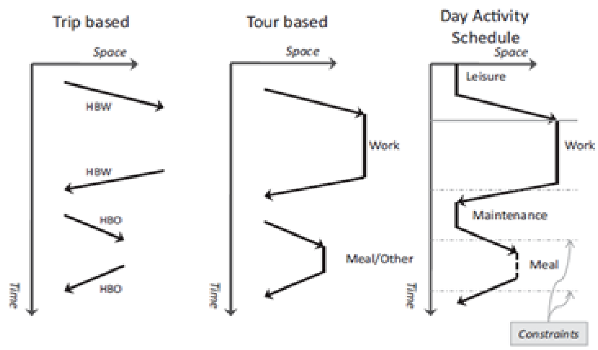

Fig 1. Trip-based, Tour-based, and Activity-Based Demand Models

There are many elements that distinguish activity-based models from trip-based models, and they are as follows: Activity-based travel models represent the movements and activities of everyone separately throughout the day, considering the types of daily activities that they perform and setting the priorities of activities. Activity-based models more closely replicate actual traveler decisions and thus may provide better forecasts of future travel patterns [3]. The Portland model is considered the first activity-based transport demand model created based on the theories of Ben Akiva and Hagerstrand. The model contains five main models that make up the Portland activity-based model. TABLE 1 shows the five main models that make up the Portland activity-based model, as well as the variables and influencing elements in each model [6].

TABLE 1. Main Models in Portland Activity-Based Model as well as the Variables and Influences Elements in Each Model

Model / variable types	Lifestyle	Mobility	Destination	Travel	Conditional
Day Activity Pattern	√	√			√
Home-based Tour	√	√			√
Home-based Tour	√	√	√	√	
Work-based Sub-tour	√		√	√	
Intermediate Stop	√	√	√	√	

TABLE 2. Travel Questions and Answers

Key Travel Questions	Trip–Based Model Components	Activity–Based Model Components
What activities do people want to participate in?	Trip generation	Activity generation and scheduling
Where are these activities?	Trip distribution	Tour and trip destination choice
When are these activities?	None	Tour and trip time of day
What travel mode is used?	Trip mode choice	Tour and trip mode choice
What route is used?	Network assignment	Network assignment

Activity-based models are often like tour-based models, as the tour-based models do not link the one-day tours to each other, so every activity-based model is a tour-based model and vice versa, i.e., no tour-based model is an activity-based model [7]. TABLE 2 displays answers to transportation questions in terms of Trip-based models and activity-based models [3].

22.1 Theory Of Activity-Based Travel Demand Models

Activity-based travel theory provides detailed guidance for modeling individual and household decisions in urban areas. Hagerstrand laid the theoretical basis for activity-based demand models by explaining the temporal and spatial constraints in which all human beings live. These Hypotheses put by Hagerstrand are now known as activity-based travel theory. First, the demand for travel is derived from the demand for activities that require travel. Second, Human behavior is subject to the constraints of time and space. Third, the household has a very large influence on the travel decisions of individuals and their daily activities. Humans generally work in the household context and household resources are usually shared with their members. Finally, Travel decisions occur dynamically. Decisions made at some points are influenced by future expectations and events of the past. Habits and moods determine an individual's behavior and behavior in response to a change in behavior and asymmetry [8].

2.2.2 Approaches of Activity-Based Models

Regional and local transport planning institutions usually follow one of the paths for developing the following Activity-Based models: Upfront Development Approach, Incremental Development Process, and Transfer and Refinement.

For the Upfront Development Approach, the agency creates a new activity-based model that is largely independent of any other trip-based model. This model can be designed and implemented as a single effort without relying on any data taken from previous models and this leads to great accuracy of the model, but it requires a lot of effort, which increases its construction cost. While The Incremental Development Process includes developing components of previous models that rely on trips and using them to create activity-based models. The gradual transformation from traditional models to activity-based models leads to save cost. But it may increase the timetable. Finally, Transfer and Refinement implementation strategies have been pursued recently. This type of approach involves taking an activity-based model designed and implemented for a specific area and developing it for another area under study so the activity-based model can be implemented in a very simple period [3].

3. DATA COLLECTION AND ANALYSIS

One of the basic steps in the process of building demand models for transportation is defining the study area. In this research, Egyptian Obour City was selected as a study area. Al-Obour City is one of the cities of the second generation of new cities and is considered a population and industrial attraction area to get out of the narrow valley and to reconstruct and reconstruct the desert [9]. The study sample involved 934 participants representing different genders, ages, educational levels, and jobs. The aim of this study is to evaluate the potential variables that affect participants' choice of a certain full-day pattern from the following five patterns. It was found that these patterns are the most widespread in the study area as shown in the following:

1. Home-based work primary tours.
2. Home-based education primary tours.
3. Home-based other primary tours.
4. Home-based primary tours and secondary tours.
5. Home-based education primary tour and secondary work tour.

The SPSS program (Statistical Package for Social Sciences) was used to study the relationship between the odd ratio of an individual choosing a certain daily pattern and the economic and social variables affecting the choice.

The Binary Logistic Regression Model was used as it includes two types of variables (categorical variables and numerical variables). The researcher created a logistic model for each of the five types of daily movement patterns using the odds ratio that is defined as the ratio between the probability of an event occurring to the probability that it will not occur as shown in Equation (1). It is known that the right-hand side of the normal linear regression takes values between (-∞, ∞). But when we have a binary dependent variable (Binary), the linear regression is not applicable because the value of the right-hand side for binary logistic regression will be limited between (0, 1), and therefore one way to solve this problem is to introduce an appropriate mathematical form on the dependent variable (y) as shown in Equation (2). The logistic regression equation must be rearranged in terms of the odds ratio so that we can interpret the coefficient in a good way as shown in Equation (3) [10].

$$\text{Odds} = \frac{p}{1-p} \qquad (1)$$

$$P = Y = \frac{1}{1+e^{-(ax+b)}} \qquad (2)$$

$$\text{Ln (Odd)} = ax + b \qquad (3)$$

In general

$$\text{LN(Odd)} = B0 + B1(X1) + B2(X2) + B3(X3) + B4(X4) + B5(X5) + B6(X6) \ldots\ldots$$

According to the SPSS program output, the value of Exp (B) is the ratio of the change in the value of the odds ratio represented by the change in the value of the independent variable by one unit. The value of (B) represents the logarithm of the odd ratio and therefore:

- If B> 0, then Exp (B) is greater than the correct one and the result is an increase in the odds ratio.
- If B< 0, then Exp (B) is smaller than the correct one and the result is a decrease in the odds ratio.
- If B = 0, then Exp (B) it equals the correct one and the result is no change in the odds ratio [10].

3.1 Binary Logistic Regression for Full-Day Patterns

Five models were made for five daily movement patterns of individuals. Tables (3 to 7) show these models. These models can be used and from them the probability of choosing each style can be obtained when sufficient information is available on the characteristics of the area under study. The emphasis in these models is on studying the impact of the average cost of tours and car ownership variables using odd rario concept, as they are the most important variables influencing the choice of patterns and are directly related to fuel prices.

3.1.1 Binary Logistic Regression for Home-Based Work Primary Tours

TABLE 3 clarifies the model of binary logistic regression output, in which we can determine how the main independent variables can affect the dependent variable (the choice of "Home-Based Work Primary Tours" pattern). The model shows only the variables that have an impact on the choice of this pattern and that contain a significant value of less than 0.05

TABLE 3 : Binary Logistic Model for Home-Based Work Primary Tours" Pattern

Model Summary						
	-2 Log likelihood		Cox & Snell R Square		Nagelkerke R Square	
	563.046[a]		0.512		0.683	
Variables in the Equation						
	B	S.E.	Wald	D.F	Sig.	Exp(B)
Gender (Female)	0.231	0.304	0.578	1	0.0447	1.259
Education (Illiterate)			13.085	4	0.011	
Education (Pre-secondary)	2.689	1.122	5.743	1	0.017	14.710
Education (Secondary)	1.825	0.614	8.823	1	0.003	6.204
Residence building type (Family home)	-0.726	0.308	5.572	1	0.018	0.484
Household income	-0.300	0.095	9.957	1	0.002	0.741
Age	0.114	0.014	64.115	1	0.000	1.120
Average cost of tours	-0.003	0.002	5.212	1	0.022	0.997
Household residents	-0.151	0.081	3.500	1	0.031	0.860
Vehicles owned by household	-0.637	0.277	5.290	1	0.021	0.529
Household drivers	0.382	0.165	5.341	1	0.021	1.466
Constant	-0.713	0.721	0.978	1	0.323	0.490

TABLE 4: Binary Logistic Model for Home-Based Education Primary Tour ”Pattern

Model Summary						
	-2 Log likelihood		Cox & Snell R Square		Nagelkerke R Square	
	629.675a		0.402		0.559	
Variables in the Equation						
	B	S.E.	Wald	D.F	Sig.	Exp(B)
Gender (Female)	-1.063	0.217	24.048	1	0.000	0.345
Education (Illiterate)			11.896	4	0.018	
Residence building type (Rented apartment)	0.598	0.274	4.754	1	0.029	1.818
Age	-0.220	0.027	66.287	1	0.000	0.803
Average cost of tours	-0.013	0.005	6.030	1	0.014	0.987
Household residents	0.191	0.073	6.806	1	0.009	1.211
Vehicles owned by household	0.636	0.262	9.327	1	0.002	1.890
Household drivers	-0.360	0.177	4.152	1	0.042	0.698
Constant	3.158	1.020	9.591	1	0.002	23.524

TABLE 5. Binary Logistic Regression for the “Home-Based Other Tours” Pattern

Model Summary						
	-2 Log likelihood		Cox & Snell R Square		Nagelkerke R Square	
	297.949a		0.104		0.278	
Variables in the Equation						
	B	S.E.	Wald	D.F	Sig.	Exp(B)
Gender (Female)	2.156	0.752	8.216	1	0.004	8.640
Education (Illiterate)			10.165	4	0.038	
Education (Secondary)	-2.191	0.789	7.715	1	0.005	0.112
Education (Postgraduate (Master/PHD))	-1.232	0.491	6.293	1	0.012	0.292
Residence building type (Ownership Apartment)			7.841	3	0.049	
Residence building type (Rented apartment)	-0.969	0.382	6.426	1	0.011	0.379
Household income	0.245	0.131	3.478	1	0.042	1.277
Age	0.053	0.013	15.510	1	0.000	1.054
Household residents	0.094	0.111	0.717	1	0.048	1.098
Household adults	0.281	0.140	4.007	1	0.045	1.325
Vehicles owned by household	1.104	0.072	1.060	1	0.003	3.015
Constant	-6.281	1.214	26.779	1	0.000	0.002

TABLE 6. Binary Logistic Regression for the “Home-Based Primary Tour and Secondary Tour” Pattern

Model Summary						
	-2 Log likelihood		Cox & Snell R Square		Nagelkerke R Square	
	458.630a		0.151		0.297	
Variables in the Equation						
	B	S.E.	Wald	D.F	Sig.	Exp(B)
Residence building type (Ownership Apartment)			10.291	3	0.016	
Residence building type (Rented apartment)	-0.955	0.299	10.170	1	0.001	0.385
Household income	0.170	0.098	3.017	1	0.042	1.185
Age	-0.259	0.050	27.024	1	0.000	0.772

Household residents	-0.171	0.088	3.738	1	0.05	0.843
Household adults	0.293	0.114	6.632	1	0.010	1.340
Vehicles owned by household	0.832	0.312	2.011	1	0.015	2.300
Constant	2.528	1.639	2.381	1	0.123	12.534

TABLE 7. Binary Logistic Regression for the Home-Based Education Primary Tour and Secondary Work Tour." Pattern

Model Summary						
	-2 Log likelihood		Cox & Snell R Square		Nagelkerke R Square	
	127.386a		0.054		0.287	
Variables in the Equation						
	B	S.E.	Wald	D.F	Sig.	Exp(B)
Gender (Female)	1.426	0.802	3.160	1	0.045	4.160
Age	-0.051	0.041	1.550	1	0.0213	0.950
Average cost of tours	-0.178	0.054	10.767	1	0.001	0.837
Household adults	-0.481	0.246	3.841	1	0.050	0.618
Vehicles owned by household	-0.223	0.270	1.487	1	0.045	0.799
Constant	1.451	2.012	0.520	1	0.471	4.267

According to the previous model, it turns out that the average cost of tours is playing a significant role in individuals' choice for "Home-Based Work Primary Tours". The odd ratio of choosing this pattern, versus not choosing it, decreases by 0.3% when the average cost of tours increases by 1%. The number of Vehicles owned by household, is a significant determinant of the choice of the "Home-based work primary tours" pattern. As for one increase in the number of Vehicles, the odd ratio of choosing this pattern, versus not choosing it, decreases by 47%.

3.1.2 Binary Logistic Regression for Home-Based Education Primary Tours

TABLE 4 clarifies the model of binary logistic regression output, in which we can determine how the main independent variables can affect the dependent variable (the choice of "Home-Based Education Primary Tours" pattern). The model shows only the variables that have an impact on the choice of this pattern and that contain a significant value of less than 0.05.

According to the previous model, it turns out that the average cost of tours is playing a significant role in individuals' choice for "Home-Based Education Primary Tours". The odd ratio of choosing this pattern, versus not choosing it, decreases by 1.3 % when the average cost of tours increases by 1%. The number of Vehicles owned by household, is a significant determinant of the choice of the "Home-Based Education Primary Tours" pattern. As for one increase in the number of Vehicles, the odd ratio of choosing this pattern, versus not choosing it, increases by 89%.

3.1.3 Binary Logistic Regression for Home-Based Other Tours

TABLE 5 clarifies the model of binary logistic regression output, in which we can determine how the main independent variables can affect the dependent variable (the choice of "Home-Based Other Tours" pattern). The model shows only the variables that have an impact on the choice of this pattern and that contain a significant value of less than 0.05.

According to the previous model, it turns out that the average cost of tours is not playing a significant role in individuals' choice for "Home-based other primary tours". The number of vehicles owned by households, is a significant determinant of the choice of the "Home-Based Other Primary Tour" pattern. As for one increase in the number of Vehicles, the odd ratio of choosing this pattern, versus not choosing it, increases by 201.5%.

3.1.4 Binary Logistic Regression for Home-Based Primary Tour and Secondary Tour

TABLE 6 clarifies the model of binary logistic regression output, in which we can determine how the main independent variables can affect the dependent variable (the choice of the "Home-Based Primary Tour and Secondary Tour" pattern). The model shows only the variables that have an impact on the choice of this pattern and that contain a significant value of less than 0.05.

According to the previous model, it turns out that the average cost of tours is not playing a significant role in individuals' choice for the "Home-Based Primary Tour and

Secondary Tour". The number of vehicles owned by households, is a significant determinant of the choice of the "Home-Based Primary Tour and Secondary Tour" pattern. As for one increase in number of Vehicles, the odd ratio of choosing this pattern, versus not choosing it, increases by 130%.

3.1.5 Binary Logistic Regression for Home-Based Education Primary Tour and Secondary Work Tour

TABLE 7 clarifies the model of binary logistic regression output, in which we can determine how the main independent variables can affect the dependent variable (the choice of the "Home-Based Education Primary Tour and Secondary Work Tour" pattern). The model shows only the variables that have an impact on the choice of this pattern and that contain a significant value of less than 0.05.

According to the previous model, it turns out that the average cost of tours is playing a significant role in individuals' choice for the "Home-Based Education Primary Tour and Secondary Work Tour". The odd ratio of choosing this pattern, versus not choosing it, decreases by 16.3 % when these average cost of tours increases by 1%. The number of Vehicles owned by households, is a significant determinant of the choice of the "Home-Based Education Primary Tour and Secondary Work Tour" pattern. As for one increase in the number of Vehicles, the odd ratio of choosing this pattern, versus not choosing it, decreases by 20.1%.

4. TESTING OF THE SENSITIVITY OF FUEL PRICES CHANGES INTO THE INDIVIDUAL'S MOVEMENT PATTERNS

Fuel prices have witnessed a steady rise in their prices over the past seven years, because of the state's orientation towards economic reform and the reform of the fuel subsidy system. This comes in accordance with the Egyptian government's plan, which aims to completely lift subsidies on various types of hydrocarbons to the global price. [11].

4.1 The Impact of the Increase in Gasoline and Diesel Prices on the Ride Fare

The increase in fuel prices leads to an increase in the fare of the ride and this increase affects the decisions of individuals, their movements, and daily activities, which leads to dispensing with some non-essential activities and sufficing with mandatory activities. The daily movement patterns models of individuals showed that a 1% increase in the average cost of tours reduces the odd ratio for Home-Based Work Primary Tours by 0.3%, for Home-Based Education Primary Tours by 1.3%, and for Home-Based Education Tours With Work Tours by 16.3%. The central agency for mobilization and statistics released its latest study In June 2017 on the impact of fuel prices on the cost of transportation inside and outside cities. This study was conducted in conjunction with the announcement by the Egyptian government to increase gasoline prices again as part of the plan to lift fuel subsidies, to become:

Gasoline 80: 3.65 pounds per liter instead of 2.35 pounds, an increase of 55%.

Gasoline 92: 5 pounds per liter instead of 3.50 pounds, an increase of 43%.

TABLE 9 shows the impact of the increase in gasoline in June 2017 on the ride far for some public transport vehicles and the impact of these increases on the odd ratio of movement patterns for individuals. The table shows that the effect of the increase in fuel prices decreases the more the trend is towards the use of public transport, as the more passengers in the vehicle, the more the percentage of the increase is distributed to them.

TABLE 9: The Effect of Increasing the Ride Far for Different Modes on the Odd Ratio of the Modes

Vehicle capacity	passenger's share percent	Change in odd ratio for patterns due to an increase in fuel price on 29 June 2017 for an average distance of 10 km				
		Home-based work primary tours.	Home-based education primary tours.	Home-based other primary tours.	Home-based primary tours and secondary tours.	Home-based education primary tour and secondary work tour.
11 passengers	%8.73	-2.6%	-11.3%	-	-	-142%
14 passengers	%6.86	-2.06%	-8.9%	-	-	-111.8%
25 passengers	%2.5	-0.75%	-3.25%	-	-	-40.75%

4.2 The Impact of Car Ownership on Daily Movement Patterns

The data of the central agency for public mobilization and statistics revealed the development of the volume of licensed vehicles until the end of December 2020, as the total number of licensed vehicles in the governorates of the Republic decreased to 10.8 million vehicles compared to 11.5 million vehicles at the end of December 2019, a decrease of 6.1%. The number of public transport buses has increased in conjunction with the increase in gasoline prices, and this indicates the tendency of individuals to use public transport with an increase in gasoline prices, which leads to a rise in the cost of private transport [12].

Using the model of movement patterns of individuals, it is possible to deduce the effect of reducing car ownership by 6.1% in 2020 compared to 2019, as this reduction in car ownership led to an increase in Home-based work primary tours by 287%, a decrease for Home-based education primary tours by 543%, for Home-based other primary tours by 1230%, for home-based primary tours and secondary tour by 793%, and increase for Home-based education primary tour and secondary work tour by 122%.

5. CONCLUSION AND RECOMMENDATION

In this study, questionnaires were conducted targeting the study area to create a model of daily movement patterns of individuals, where the model of movement patterns is an essential and initial step for building an Activity-Based Model. This model was used to study the impact of gasoline prices on the daily movement patterns of individuals. The study clarified the main factors influencing individuals ' choices of their daily movement patterns. Since the car ownership factor and the average cost of tours are the most affected factors by the price of gasoline, it was necessary to study the impact of these two factors on daily movement patterns.

Finally, the study showed that the increase in fuel prices leads to an increase in the fare of the ride and this increase affects the decisions of individuals, their movements, and daily activities, The study showed that the effect of increasing fuel prices decreases as the number of passengers in the vehicle increases, as the percentage of the increase is distributed to them. Therefore, public transport is the least affected by the increase in gasoline prices. The study showed that the car ownership factor has a great influence on the choice of daily movement patterns.

The research recommends following some procedures regarding gasoline pricing, which boil down to the following:

- Using activity-based demand models instead of traditional models in the study of transport management policies.
- The need to create an activity-based transport demand model to study the policies of raising fuel prices and the impact of these increases on various activities to support decision-making on gasoline prices.
- Completing the rest of the activity-based model building parts as it is in the Portland model to see the impact of the increase on individuals' choices of destinations, modes, and tours time of day.
- The need to expand public transport, as it is less affected by increasing fuel prices, unlike private transport.
- The need to link the rise in gasoline prices to the development of public transport and its infrastructure so that the impact is not significant on the movement of individuals and their daily movements and the transformation of individuals from using private to public transport is a smooth transition without crises.

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