Implementation of Energy Parameters as Socioeconomic Data in Travel Demand Planning

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***Abstract*—Energy parameters (fuel & energy consumption) in the transportation sector could be defined as the result of applying different policies in comprehensive sustainable management of the public and private transportation system. Validity assessment of stated and revealed preference survey in transportation planning can be often complicated task for planners, so using of a real preference survey has been proposed in this study. For preventing the current flaws in analysis of travel demand models provided by an activity-based approach or household travel behavior, fuel and energy consumption modeling has been proposed in this study. Presence of strong correlations between vehicle fuel usage and trip's quantity by exogenous and endogenous variables has been proven in this study by monitoring refueling data for almost 15 years in Shiraz city of Iran. Models with specific emphasizing on fuel consumption and energy matters can be recognized as a suitable substitute for previous conventional models. Author's new model was proposed using of energy parameters, which is part of socioeconomic data for increasing accuracy and accessibility. With modelling based on energy consumption if the amount of trip rate and car ownership level in Iran reaches those of in developed countries, the crisis of fuel consumption and transportation demand will happen. Therefor based on the concluded results applying strategies with substituting energy supply management to energy demand management would be wise action to improve overall performance of transportation sectors.**

***Index Terms*—fuel consumption, transportation and traffic demand modeling, trip generation, trip attraction, trip quantity, tazs**

I. Introduction

World oil demand is projected to increase more than 40% by 2030, where transportation industries are rapidly expanding. Transportation accounts for almost 20% of the world's energy consumption and more than 50% of the consumption of liquid fuels. In the year 2030, the transportation sector alone will consume the same amount of liquid fuel as that consumed by all sectors in 2003; this fact necessitates the development of the new modelling based on fuel and energy consumption [1].

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"Reference [2]-[10]" considered the various nations, different financial, technological and transportation policies adopted to significantly reduce the enormous amount of gasoline consumption, which can be seen in Fig. 1.

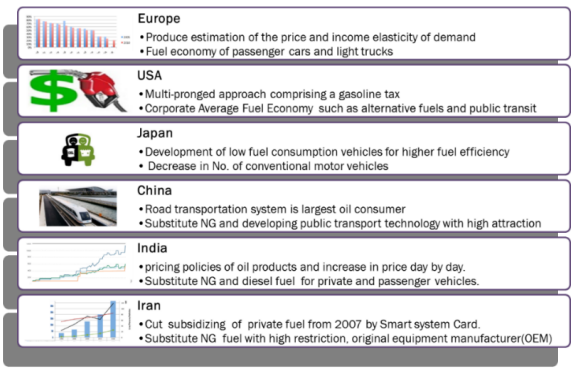

Figure 1. Policies for control of fuel consumption

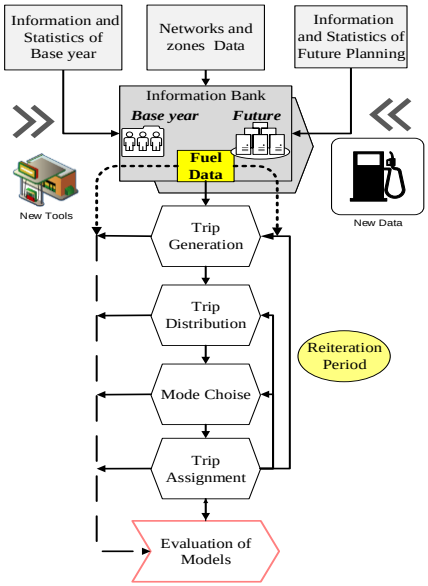

Figure 2. Modified version of conventional model

A. Innovative Data for Planning

By recording the fuel consumption data and implementing other variables, the attempts have been

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made to estimate more valuable functions in different travel demand procedure. Introducing and utilizing of the fuel data cell to a bank of information for travel demand modelling which can be seen in Fig. 2 is one of the key activities to achieve reliable model with emphasizing of sustainable development significance. The conventional procedure of analysis and planning in transport practice, commonly referred to as the Four-Step Model (FSM), is shown in Fig. 2.

Using refueling records in initial stage will help the planner to minimize mistakes, and fit data by realistic situation. Most of the present methodologies in traffic modelling are based on census and statistics of urban population, available facilities and would be evaluated by pollutant standard factors; however, in this study attempts have been done to monitor energy consumption and convert it to vehicle movement.

Four-steps are trip generation, trip distribution, modal split, and assignment. The four-step model starts with estimation of the total number of trips generated by each zone based on the data of socioeconomic activity's level in each particular zone, which means having stronger relation to consumption of fuel. The next stage is to distribute trips from their origins to particular destinations and consumption quantity of each station can be a reasonable indicator of that. The following stage, modal split, is an estimation of the choice of transport modes, via car, underground train, or bus trips can be identified in structure of refueling. The final stage, assignment, is to estimate how the trips travel through the network; the traffic flows generated, the resulting traffic conditions, and the cost for a traveler to each origin-destination pair, which is the result of location and frequent of refueling data. The best of travel demand models should start with valuable and accurate data. Any mistake or error in the input data of generating trips can cause serious deviation in Travel Demand Model Forecasting (TDMF).

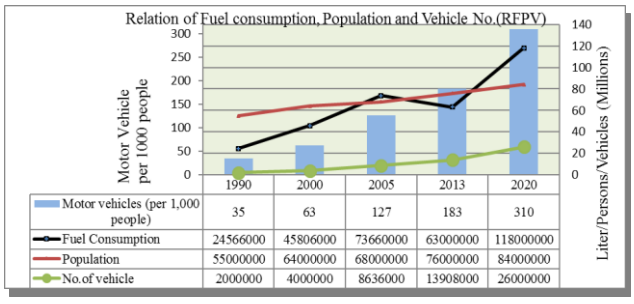

Figure 3. Daily fuel consumption relation in Iran

B. *Need for Study*

The number of vehicles has risen considerably over the time period of 1990 to 2020 from approximately two to twenty six million vehicles in Iran [11]. On the other hand, population of people climbed similar to the Fig. 3 for number of the vehicle from 55 to 84 million people in the period of 1990 to 2020. The blue color bar graph shows number of motor vehicles per 1000 people in the years 1990 to 2020. Various trends can be observed from Fig. 3. To sum up, there has been an almost equal trend of an increase in the number of vehicle and population from 1990 to 2020, while figures pattern for fuel consumption per day in all over Iran has not followed the same trend. A dip of roughly one-third the total number of fuel consumption from 2005 to 2013, then the previous trend of growth can be predicted for 2013 to 2020 which can mainly be justified by predicted increases of the number of vehicle in this period [12].

As can be seen in Fig. 4 measuring fuel consumption is a managerial and technical policy to achieve general and specific overlapping goals related to sustainability.

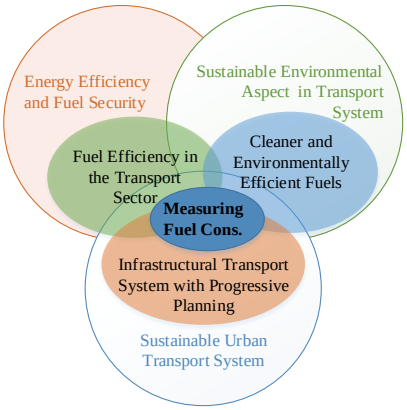

Figure 4. Fuel consumption and sustainability.

Fuel Scantling Distribution (FSD) system motivates people to use their allotted subsidized rations in private vehicles and encourage people to consume fuel. It can create pressure on existing demand of fuel. Fuel Smart Card System (FSCS) could change society travel behavior or complicate trip structure as well as reducing fuel consumption. So strong comprehensive study should be performed to understand and hence solve the above question. The International Monetary Fund (IMF) reported that the typical Iranian family gets about $4,000 a year in subsidies on oil and natural gas alone, more than average middle-class family's income.

With change of modern to postmodern social lifestyle after world war (1950s) and its ascendancy in next decades, parameters like mass society, demographic pattern, urban life, mass literacy, land use and communication have been totally altered. With prolonging of technological enhancement in post-modern (21st) century, socioeconomic status of people in all over the world has been changed. The majority of these alterations have been already happened especially in developed countries; however, they are still undergoing in developing countries with a high urbanization ratio. Considering the fact that monitoring and evaluating of these changes is significantly complicated task, post-socioeconomic data (socioeconomic data related to modern and post-modern age) can be an effective solution for that rather than convectional data.

Some of these post-socioeconomic parameters have been enlisted in Fig. 5

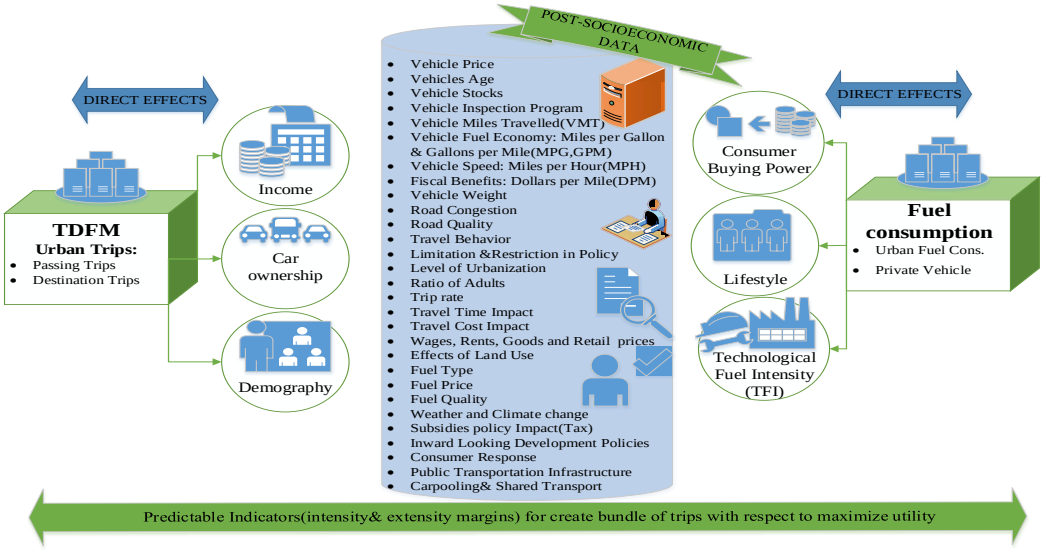

Figure 5. Compounds of urban travel demand vs. fuel consumption with highlighted parameters.

II. Preliminary Analysis of Fuel Data

For the preliminary analysis from fuel data collected in 10 days period in 2012, which can be seen by details in following figures, more than 2 million liters fuel sold per day has been recorded with about 120 thousand transactions in 64 different fuel stations.

Considering the fact that Thursday is a governmental and Friday is public holiday, detailed proportional week days fuel sold can be seen in Fig. 6. Thursday with 17% of fuel sold is the greatest figure following by Wednesday with 16% and Sunday and Tuesday and Monday by 15 %. Surprisingly the first day of week, Saturday, is the minimum figure in the presented graph. The importance of these figures can be understood when it would be considered that each percent can be numerically described as 140,000 liters fuel consumption or 8500 kilometers distance.

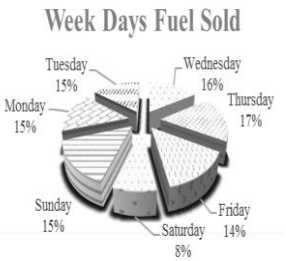

Figure 6. Daily petrol sale for week days

In addition to above mentioned, the author made this decision to study the relationships between total sold fuel price vs. number of refueling and the total amount of fuel. The results can be seen in the following graphs.

In Fig. 7 horizontal axis represents number of refueling vs. vertical axis unit fuel price for each station; furthermore, the bubble size represents petrol volume quantity for 64 stations in 10 days of preliminary analysis. A linear function can be assigned to define the relation between the number of refueling and fuel price unit.

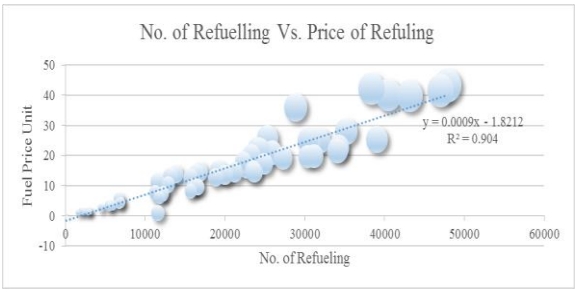

Figure 7. Daily petrol price unit vs. No. of refuelling station with volume of each station.

In Fig. 8 horizontal axis represents a number of refueling verses vertical axis 1000 liter fuel consumption for each station and moreover, petrol stations have been categorized in four clusters based on range of petrol volume consumption, which can be seen by various colors.

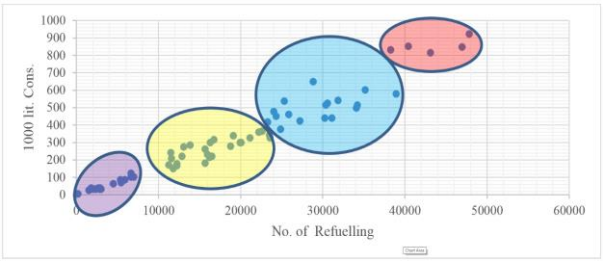

Figure 8. Daily fuel consumption vs. No. of refuelling category for 64 petrol stations

After completing TDMF for Shiraz city based on the home interview survey (1999 Sharif University) for horizon year of 2012 and developing final car loading for 167 TAZs with cube software, according to aforementioned categorized location of each station has been detected. The presence of red, blue and yellow color stations in certain districts of city can be a function of demographic data, car ownership, public transportation availability, income level, trip production and attraction variables and traffic management policies.

Fig. 9 indicates fuel consuming ratio based on square size in which; big squares illustrate top five high consumption stations; Medium-size squares represent 18 average consuming stations and small one's show low consuming refueling point.

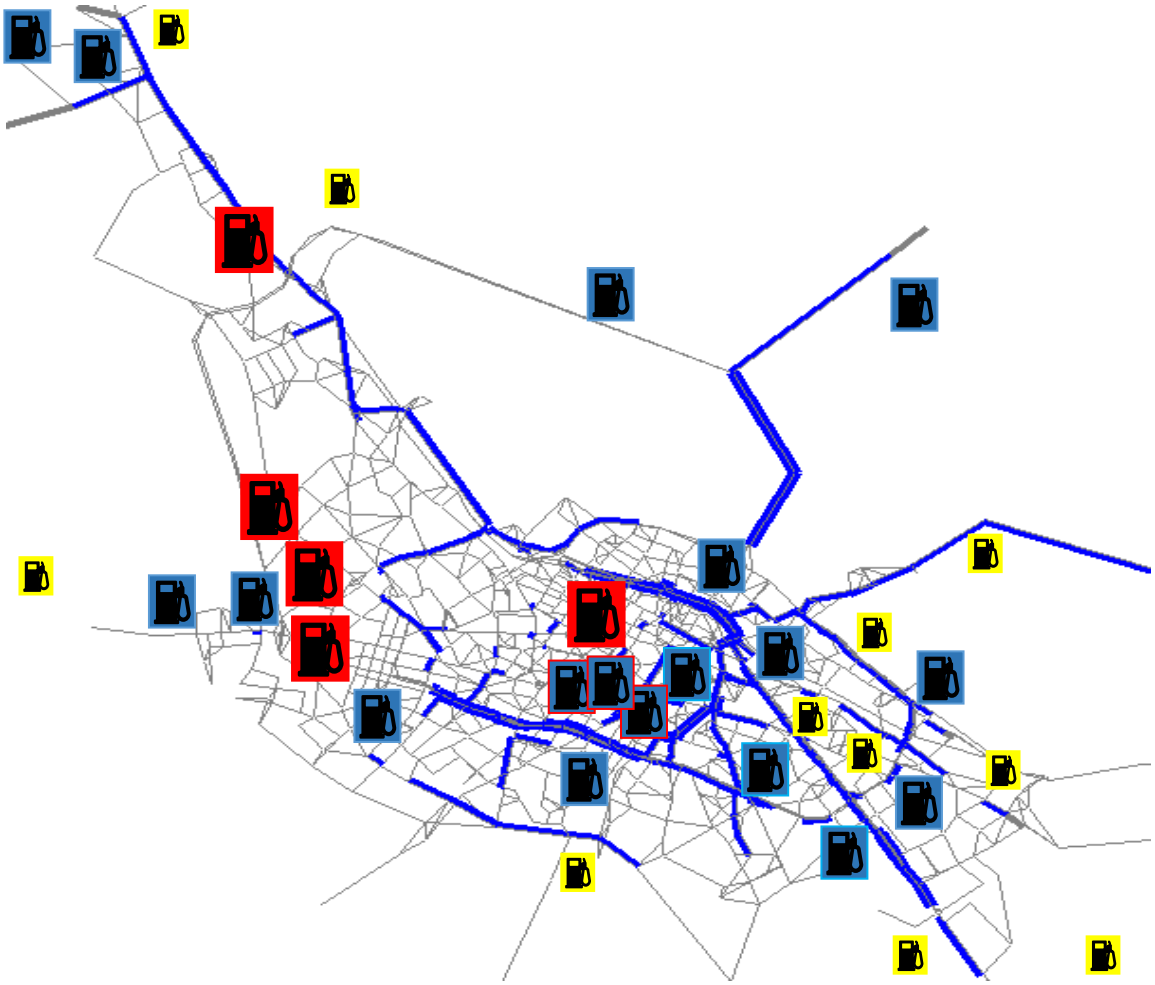

Figure 9. Final car loading for TADs with CUBE software and categorized petrol stations

TABLE I. INFORMATION FOR TRIPS QUANTITY PREDICTION

Parameters/Years	1999	2009	2012	2023
Annual Petrol consumption (lit.)	508,027,803	730,435,000	755,960,000	
Daily Petrol Consumption (lit.)	1,391,857	2,001,192	2,071,123	
Daily CNG consumption(m^3)	50,000	400,000	622,180	
Daily Energy consumption (lit.)	1,441,857	2,401,192	2,693,303	3,101,733
Avg. of Fuel Consumption Rate (Fuel Economy) (lit./100Km)	16.3	16.3	16.3	16.3
Vehicle Distanced Travel (VKT) (Km)	8,845,748	14,731,239	16,523,331	19,029,037
Avg. Trip Length	8.75	8.75	8.75	8.75
No. of Vehicular Trip = VKT/Avg. Trip length	1,010,943	1,683,570	1,888,381	3,171,507
Car Occupancy Rate	1.9	1.7	1.6	1.5
No. of Total Trip (Production& Attraction)	1,920,791	2,862,069	3,021,409	4,122,958
Population	1,142,282	1,455,073	1,531,714	1,649,183
Trip Rate	1.68	1.97	1.97	2.00

III. Analysis of Results

Based on heat value specification for various fuels each cubic meter of CNG was considered as one liters of petrol. The total number of trips was estimated approximately 2 million trips, and 1.5 million liters petrol consumption has was observed per day in Shiraz city in 1999 based on HIS of Sharif University. Reviewing other studies, including 323 types of vehicle study regarding consumption and emission test in Iran, 2001, average of fuel consumption was estimated 16.3(lit/100km) for city trips. Consequently, vehicle distance travelled (VDT) can be calculated about 8.8 million kilometers per day, with average trip length of 8.75 km (as observed in base year TDMF). Furthermore, car occupancy rate of 1.9 was observed by HIS 1999, therefore the total number of 2 million trips was calculated. According to careful analysis, it can be clearly concluded that the strong and tangible correlation can be observed between fuel consumption and travel supply and demand chain. Studying of this topic can lead us to find the possible way to reduce any fuel consumption abuse related travel demand modelling. The same procedure has been considered for 2009; 2012 and calculated figures can be seen in Table I.

Fuel economy was assumed 16.3 lit. /100 Km and Trip length value was observed 8.75 Km based on HIS (conducted in 1999) during this study. It is noteworthy that car occupancy rate has been predicted to decline from 1.9 to 1.5 because of increasing car ownership rate.

Finally for horizon year (2023) quantity of trips and fuel requirement can be predicted by inverse analysis.

IV. Conclusions

TDMF was developed for TAZs (167 zones) plans, which should be calibrated by sensitivity analysis in planning. In current TDMF made in 2010, important parameters for horizon year of 2012 were calculated, with updating independent variables related to trip production and attraction, which lead to trip's quantity.

Daily fuel consumption data related to 1999 approves total number of trips as production or attraction which is equal to HIS OD matrix.

Presence of strong correlations between vehicle fuel usage and trips quantity by exogenous (independent) and endogenous (dependent) variables have been proven in this study by monitoring refueling data for almost 15 years in Shiraz city of Iran. Furthermore, assuming of energy consumption and other variables, two separate margins were examined through which energy consumptions are affected: the extensive margin (vehicle choice) as exogenous and the intensive margin (driving / vehicle usage) as the endogenous variable. These margin's parameters should be classified as exogenous and endogenous variables.

Three outcomes can be used to examine consumer's behavior: gasoline consumption, Vehicle Miles Travelled (VMT/VKT/VDT) as endogenous and vehicles fuel economy (MPG) as exogenous parameter and also type of fuel are exogenous to the transportation demand models. An exogenous variable is used for setting arbitrary external conditions, and not in achieving a more realistic model behavior.

As a result of this study quantity of trips and trip rate has been calculated for 1999; 2009 and 2012 with the same model have been forecasted for 2023 as the horizon year.

Based on concluded results and transportation policies, existing lifestyle expectation of Iranian people, the crisis in energy consumption makes a comprehensive evaluation appears more evident. If this excessive amount of trip rate and car ownership level in Iran reaches those of in developed countries, the crisis of fuel consumption and transportation demand will happen.

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