DEVELOPING AN INTEGRATED LAND USE-TRANSPORTATION MODEL (ILUTM) FOR ANALYSIS AND PREDICTION OF ENERGY CONSUMPTION THROUGH ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM (ANFIS)

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ABSTRACT

For control and reduction of energy consumption in urban environments, planners need an efficient model for prediction and analysis the energy consumption in relation to the interaction of transportation and land use systems. Therefore, existent ILUTMs were developed based on different modeling techniques. These models need data which are not available especially in developing countries. In addition, calibration of these models takes a lot of time and cost. Moreover, land use and transportation systems are parallel systems which interact simultaneously, but the existent models are sequential models. Owing to these facts, the complexity and uncertainty of urban systems, in this paper, a model were developed based on ANFIS which is parallel, flexible, adaptable with various data aggregation, compatible with different geographic analysis levels, more complex than previous models and represents the uncertainty of the real conditions.

INTRODUCTION

The energy crisis and increasing trend of energy consumption have made energy optimization a compulsory duty around the world (Soltani et al., 2012). The transportation energy consumption is rooted in the interaction of land use and transportation systems (Hickman and Banister, 2007). For these reasons, the prediction and analysis of energy consumption in relation to the interaction of land use and transportation systems attracted the attention of researchers in various disciplines (Mohammadi et al., 2013). The chorological study of land use-transportation models show that the recent researches focused on developing ILUTMs for solving the urban problems such as traffic congestion and prediction of energy consumption and gas emissions (Barechman and Small, 1988; Dobes, 1998; Beimborn, 2002; Timmermans, 2003; Wegener, 2003; Southworth, 2005; Araghi, 2008; Iacono et al., 2008; Shahi, 2009; Mohammadi et al., 2013). Mohammadi et al. (2013), prioritized existent ILUTMs through application of fuzzy analytic hierarchy process and study the first and second priorities more accurately. They imply that the existent ILUTMs are not compatible with the data which are available in developing countries and their adaptation takes a lot of time and cost. Moreover, although land use and transportation systems interact simultaneously in uncertain conditions, the structure of existent models is sequential (Rodrique, 1997). Thus, in this paper, an integrated model based on ANFIS which is parallel, flexible, adaptable with various data aggregation, compatible with different geographic analysis levels and more complex than previous models is developed for removing the restrictions of existent models.

MATERIALS AND METHODS

Urban system includes eight subsystems (network, landuse, workplaces, housing, employment, population, goods, transport and travel) which are intricately linked to each other (Clement, 1996). Another classification of urban systems is shown in Figure 1. Besides, interaction of transportation and land use systems represent the other subsystems (Pfaffenbichler, 2003). Due to these facts the state of urban system in time t in relation to the energy consumption could be describe as a set of elements: $US_t=\{T_i^{jk}, L_i^{jk}, T_j^{i'k'n}\}$ where $US_t$ is the urban state at time t, $T_i^{jk}$ is the value of variable $i_jk$ in row n in the type of $i_j$ in the subsystem of transportation system i, $L_i^{jk}$ is the value of variable $i_jk$ in row n in the type of $i_j$ in the subsystem of transportation system i and $i, i', j, j', k, k', n$ could be adopted values from 1 to $\infty$. For representation of urban system in this manner, the subsystems of land use and transportation systems which should be considered in modeling process is determined at first (i.e. transportation system comprised of network, travel, etc subsystems). Then, each subsystem is divided in types (i.e. network subsystem divide in arterial and local network). Finally, the variables of each type are determined (i.e. the variables of arterial network are length of network, terrific volume, etc) (table 1).

All of these steps are according to the purpose of study, aim of modeling and data which are available or could be collected. It must also be noted that the table 1 is considered as the input of ANFIS. Since the urban system and the interaction of its subsystems is complex (Junfeng, 2003), most of the decisions are taken under uncertainty conditions (Riberio, 1996), and
The ANFIS is a fuzzy Sugeno model which is developed based on adaptive systems to facilitate learning and adaptation (Guler and Ubeyli, 2005). ANFIS includes five layers in which the first hidden layer is for fuzzification of input variables. T-norm operators are deployed to calculate the rules in the previous part in second layer. The rule strengths normalize in the third hidden layer and the consequent parameters of the rule are determined in fourth layer. Overall input is calculated as the summation of incoming signals in the last layer (Figure 2) (Abraham, 2001).

Back propagation learning algorithm is applied in the ANFIS for calculation of premise parameters.

The output of fourth layer which is called adaptive layer is given by $O^4_i = \bar{w}_i f_i = \bar{w}_i (p_i x + q_i y + r_i), \ i = 1,2$. In the final layer, there is a single fixed node labeled with S. This node calculates the sum of all incoming signals. Therefore the summation output of the model is represented by $O^5 = \sum_{i=1}^{2} \bar{w}_i f_i = \frac{\sum_{i=1}^{2} \bar{w}_i f_i}{w_1^2 + w_2^2}$.

As indicated before urban systems are depending on each other. Therefore, the relationship between land use and transportation could be represented by equations such as $T_t = f(L_{pt})$ and $L_t = f(T_{pt})$ (where $T_{pt}$ is interaction of transportation system with other systems and subsystems at time $t$, $L_{pt}$ is interaction of land use system with other systems and subsystems at time $t$ and $f$ is the function that represents the relationships between urban systems and must be solved by the ANFIS; $p$ is in the range of 1 to $\infty$) in various analysis levels (local, regional, etc). Thus, the proposed model follows the steps which are shown in Figure 3.
CONCLUSIONS

Transportation-land use system is a complex spatial system composed of several elements representing the level of spatial accumulation (Rodrique, 1997). The recognition and prediction of the land use-transportation system is necessary for optimization of energy consumption which requires the application of ILUTMs. Due to the complexities of urban systems, developing progressive and complex models for modeling urban phenomenon which are compatible with the modeler goals and existent data become more necessary. Thus, in this paper an integrated model based on ANFIS which is one the new modeling methods is developed for analysis and prediction of energy consumption in relation to the interaction of land use and transportation. The designated model is more accurate and complex than the conventional models. In spite of existent integrated models, the proposed model derives a benefit from parallel and flexible structure. It is adaptable with different level of data aggregation, and capable of adding the extra variables. Above all, this modeling approach could be considered besides the other integrated modeling techniques at least.

References