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Spatial distribution of urban trips in recently expanded Surat city through Fuzzy Logic with various clustering Techniques: A case study of typical metropolitan city in India

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Abstract

Trip distribution finds prime place after trip generation in sequential modelling of travel demand to cover the spatial dimensions in a geographical area, to reflect on trip length and frequency. It provides the basis for strategic land use and transport infrastructure development both at local and regional levels. Trip distribution problems in the real world are quite complex with association of uncertainty in the decision making and therefore calls for an unorthodox approach to deal with the concerned issue. Soft computing technique - Fuzzy Logic (FL) is believed to be capable of addressing the uncertainty lying in the travellers' behaviour and has been sought to develop realistic behavioural models in the recent years. FL takes into account linguistic variables and is based on simple and logical "IF-THEN" rules which closely resemble human thought process. Fuzzy Logic based trip distribution models are developed employing Fuzzy C-mean (FCM) clustering, and are compared for their performance with the *Genfis* based approach, where a Sugeno-type Fuzzy Inference System (FIS) is generated using Subtractive clustering. Surat, a fast growing metropolitan city in India is considered to realize the study. The models developed here, find applications in strategic land-use and transport planning for developing Indian cities.

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Keywords: Travel demand estimation, Trip distribution, Fuzzy Logic, Fuzzy C mean clustering, Subtractive clustering, Genfis

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1. Introduction

Four stage modelling process is the commonly employed method for forecasting travel demand, involving phases such as trip generation, trip distribution, mode choice and traffic assignment. Trip distribution analysis plays vital role as it deals with the destination choice phase. Conventional trip distribution models which has major limitation that the input variables need to have crisp values and hence should be measured accurately, which consumes lot of time and resources. Moreover, decision of trip maker for choosing a destination involves human approximations which are not precisely captured by these conventional models. This can be overcome by using artificial intelligence techniques like fuzzy logic for modeling trip distribution. Fuzzy logic try to harness the human knowledge which is often guided by approximations by accepting input values in linguistic terms. The fuzzy rule base comprises of several IF-THEN rules which closely resemble human knowledge and decision-making. Thus to overcome limitation of traditional model, application of fuzzy logic seems to be most appropriate to consider ambiguity, imprecision and vagueness in influencing variables. Fuzzy logic model in contrast to the conventional model takes into account highly non-linear relationship between input and output variables.

Clustering is the effective tool for natural grouping of data from a large data set, and allows concise representation of characteristics of the data. Given a data set, the aim of clustering is to partition it into different groups (clusters) so that the members in the same group are of similar nature, whereas members of different groups are dissimilar. While clustering, various similarity measures can be considered, one of the most commonly used is distance between data samples. The Fuzzy Inference System (FIS) is a simple way to construct systems models without using complex analytical equations. The Fuzzy C-mean algorithm and Subtractive clustering algorithm are implemented to find the number and the position of clusters for a set of highly non-linear data. In the present study, different FIS are created using Fuzzy C mean clustering as well as Subtractive clustering. Fuzzy C-mean clustering provides a method that shows how to group data points that populate some multidimensional space into a specific number of different clusters. As for subtractive clustering, the radii parameter is changed to obtain different number of clusters. Generally, increasing the number of generated cluster yields an improvement in result. For subtractive clustering the radii parameters are tuned. This automatically generates the number of clusters. The fuzzy models developed with the help of these two clustering techniques are compared here to find out the efficiency of the clustering systems and thereby arriving at realistic trip distribution models.

2. Literature Review

Fuzzy Logic (FL) concept was introduced by Zadeh [1]. A method of generating fuzzy rules from the numerical data was demonstrated, which facilitated the combination of numerical as well as linguistic information into a common assembly – fuzzy rule base [2]. A pioneering fuzzy logic approach to trip distribution modeling was put forward by estimation of air passenger flows among selected major industrial cities and tourist resorts using known productions and attractions as inputs [3]. Later, another study by the same research group showed improved performance with a hybrid Genetic Fuzzy Rule Based System (GFRBS) design [4]. Trip generation and distribution modelling using fuzzy logic was further attempted, considering trip generation at country level, whereas trip distribution between origin country and destination countries (country-pair level) and provided empirical evidence relating to successful use of fuzzy logic as a non-traditional technique [5]. Discretionary trips being flexible than compulsory trips, are characterized by uncertainty in decision making, modelling the behavior towards such trips is observed to be addressed well by fuzzy logic based approach [6]. Several studies advocated the use of Fuzzy Logic as a tool to address the uncertainty in the people's expressions and imprecision in their perception towards travel attributes [7]. Also, Fuzzy logic systems could be treated as universal approximators, which mean that a fuzzy logic system can uniformly approximate any real continuous non-linear function to an arbitrary degree of accuracy [8, 9]. Fuzzy Inference System (FIS) can be of two types, viz. Mamdani and Sugeno FIS. Mamdani fuzzy inference system finds application in wide variety of disciplines due to intuitive and interpretable nature of its fuzzy rule base [10, 11].In Mamdani-type the consequent of each rule is a fuzzy set, whereas in Sugeno-type the consequent is a function of input variables. Due to this difference, the inference mechanism of determining the output of the system in both the categories varies to some extent. The basis of selection of optimum Membership Functions (MFs) for fuzzifying the input variables has always