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Fuzzy Logic Based Route Choice Behaviour Modelling

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Abstract - *Travelling is one of the most important activities people engage in to serve various purposes of everyday life. Route choice modelling is essential in terms of transportation planning which requires predicting future traffic conditions on transportation networks and understanding travellers response and adaptation to sources of information. The main objectives of the study is to predict the route choices for the thrissur city and to determine the significant factors. These perceptions and preferences based on route characteristics are then tied to travellers personal attributes such as income, age, gender, and other socio-economic characteristics. Household survey is carried out in Thrissur city for collecting travellers information. Survey is carried out in the 52 corporation ward of Thrissur City. The collected data is analysed and the highest number of trip attraction (destination) and production (origin) zones are identified and the origins and destination is fixed. Fuzzy Logic concept is used to model the uncertain route choice behaviour.From the Fuzzy Inference System, the result obtained are for Punkunnam the mostly choosen routes are Thrissur Kuttipuram Road and Kodungallur Shornur Road, for Nedupuzha the mostly choosen routes are Kodungallur Shornur/SWaraj round and Kodungallur Shornur Road,for Mannuthy the mostly choosen routes are Thrissur Palakkad Road and Thrissur Mannamangalam Road, for Kuttumuck the mostly choosen route.In this study factors affecting route choice between alternate routes were identified using Surface Plots.They are Travel Cost, Distance, travel time between Origin and Destination and Type of Employment.*

Key Words: **Predicting; Socio-economic;Fuzzy Logic; Fuzzy Inference System**

1.INTRODUCTION

The process of allocating given set of trip interchanges to the specifed transportation system is usually referred to as traffic assignment. The fundamental aim of the traffic assignment process is to reproduce on the transportation system, the pattern of vehicular movements which would be observed when the travel demand represented by the trip matrix, or matrices, to be assigned is satisfied. The traffic assignment or route assignment problem is one of the critical steps in travel demand forecasting process. It is used to forecast traffic flow of links in a network, given the traffic volumes between the origin destination nodes and the characteristics of the links.

The study of travel behaviour is a broad topic that provides insights into the choices that individuals and households make about their travel needs. Within this broadarea lie various sub-categories like study of mode choice, destination choice, route choice, and so forth. The interplay of these different choice dimensions is what makes the analysis of travel behaviour so complex and yet interesting. Over the years, travel behaviour researchers have worked towards the development of increasingly sophisticated quantitative models, often used in conjunction with qualitative approaches, which could offer us powerful tools for helping us to understand those complexities. Although, understanding route choice behaviour is only a dimension to overall travel behaviour analysis, it does provide very useful insights into travellers decision making process which can eventually be tied back to broad travel behavior assessment. Route choice prediction is also essential in terms of transportation planning which requires predicting future traffic conditions on transportation networks and understanding travellers response and adaptation to sources of information.

It involves evaluating travellers perception of route characteristics that include travel time, cost, distance, safety, reliability and so. These perceptions and preferences based on route characteristics are then tied to travellers personal attributes such as income, age, gender, and other socio-economic characteristics. Route choice prediction or development depends on human behaviour, travellers imperfect knowledge about the transportation network composition, and the uncertainty and heterogeneity associated with travellers perceptions about route characteristics.

Travellers decision to take particular routes depends on the utilities associated with these routes. In Thrissur City , the nature of transportation system as well as availability of mode, comfort of the mode, road surface conditions etc. are different. No study has been done by using Fuzzy Logic to address this issue of how people choose their route in Thrissur, more precisely in Thrissur city. In this thesis efforts will be given to predict the route choices using Fuzzy Logic for one origin and one destination point in the context of Thrissur City.

2. LITERATURE REVIEW

Carlo Giocomo[1] Trip generation is the first step in the conventional four-step transportation forecasting process (followed by trip distribution, mode choice, and route assignment),widely used for forecasting travel demands. It

predicts the number of trips originating in or destined for a particular traffic analysis zone. Typically, trip generation analysis focuses on residences, and residential trip generation is thought of as a function of the social and economic attributes of households. At the level of the traffic analysis zone, residential land uses "produce" or generate trips. Traffic analysis zones are also destinations of trips, trip attractors.The analysis of attractors focuses on nonresidential land uses.

Modeling of human choice mechanism has been a topic of intense discussion in the transportation community for many years. In most choice situations, the decisionmaker (traveler) also experiences uncertainty because of the lack of complete information on the choices. In the traditional modeling framework, the uncertainty of the analyst and that of the decision-maker are both embedded in the same random term and not clearly separated (Mauro et.al.)[2], travellers behavioural characteristics in the day-to-day route choice are considered by forgetting previous travel times, risk attitude, habit effect, travellers amount of attention on the route choice being made, perception of actual travel time, etc. Zhengbing [3].

Route choice behavior depends on travel cost. Travel time, traffic safety, comfort, habits and socioeconomic and demographic characteristics of which travel time is generally the key factor of all. Overall approach for the route choice is to evaluate costs of each route and to choose the route with lowest travel cost(Chaun et.al.)[4]. Primary paramaters while making a choice between an origin and destination are travel time, traffic safety, cost (fuel), traffic signs, jam and queing, road type, landscape, road construction and habitual effects. Cost is generally proportional with travel time. Traffic safety, travel time, congestion and environmental effects were the main variables considered in the study (Yetis sazi et.al.,)[5]. The choice of a particular route is dynamic in character and depends on many factors. In fact, a driver chooses a route by considering inputs from different set of information. For example, a drivers decision to select a particular route depends on the characteristics of the trips (e.g. purpose, time, origin, destination, and mode) to be made, the attributes of the alternative routes available and the characteristics of the driver (Agata et.al.,)[6] and (Eran et.al.)[7].

The questionnaire was designed to extract information regarding the particular route one user was using at the time of conducting the survey and the reasons behind choosing the particular route. The reasons or variables which significantly influence the individuals route choice behavior were selected based on the literature review. Since bus routes were considered for this study, only bus users socio economic characteristics and travel attributes (both route attributes and bus attributes) were considered as the influential indicators for route choice. The factors considered are Age, Gender, Monthly Income, Distance, Travel Cost, Travel Time, Waiting Time, Comfort level, Safety Level, Security Level and Regularity Level (Nandita Basu et.al.)[8].

3. STUDY OBJECTIVES

The objectives of the project are : To Predict the Route choices for Thrissur City using Fuzzy Logic and to identify the significant parameters.

4. STUDY METHODOLOGY

The steps involved in the methodology of the study are presented in Figure 1 and each step is explained as below.

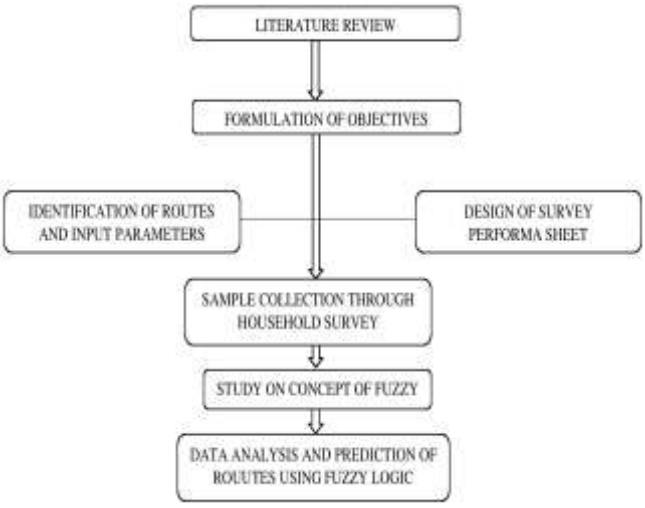

Fig – 1: Methodology

4.1 Formulation of Objectives

First the aim and objectives are identified to set the goals and scope of the study. The objectives have been set by recognizing the problems of the current practice in route choice. Ideas regarding existing problems of the research area are referred by studying different literature and journal papers.

4.2 Study Area Selection

The study area is the Thrissur corporation area which include 52 wards. The total number of trip attractions and trip production zones are identified and highest number of trip attraction zones and trip production zones are identified and fixed as origin and destinations. Thekkinkadu is fixed as the destination zone whereas Punkunnam, Kuttumuck, Mannuthy and Nedupuzha is fixed as origins. Routes from each origin to destinations are identified. Fig 2 show the Thrissur Corrporation map.

Fig – 2: Thrissur Corporation

Punkunnam to Thekkinkadu is the first OD pair considered which is shown in fig 4. which consist of 3 routes they are R1, R2 and R3 respectively. R1 is Thrissur Kuttipuram Road, R2 is Kodungallur Shornur Road and R3 is Kottapuram Road. Kuttumuck to Thekkinkadu is the second OD pair considered which is shown in fig 5. It mainly consists of 3 Routes which are named as R1, R2 and R3 respectively. R1 is Cherumukku Viyyur Thanikkudam Road, R2 is Kuttumuck Villadam Road and R3 is Viyyur Thanikkudam Road.

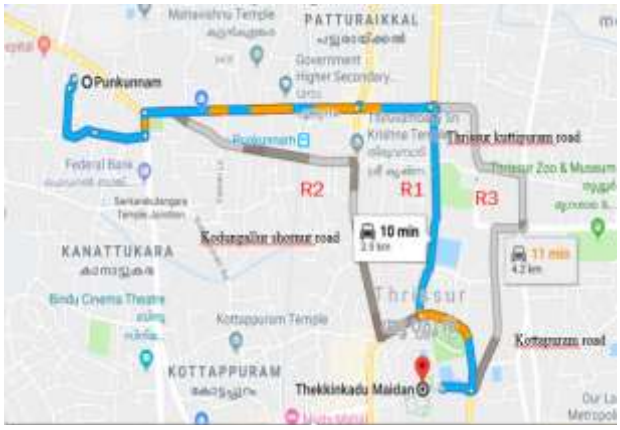

Fig – 3: Punkunnam to Thekkinkadu(OD1)

Mannuthy to Thekkinkadu is the third OD pair considered which is shown in fig 4. It mainly consists of 3 Routes which are named as R1, R2 and R3 respectively. R1 is Thrissur Palakkad Road, R2 is Moorkanikkara Thrissur Road and R3 is Thrissur Mannamangalam Road. Nedupuzha to Thekkinkadu is the fourth OD pair considered which is shown in fig 5. It mainly consists of 3 Routes which are named as R1, R2 and R3 respectively. R1 is Kodungallur Shornur Road via Swaraj Round, R2 is Kodungallur Shornur Road and R3 is Nedupuzha Road

Fig – 4: Kuttumuck to Thekkinkadu (OD2)

Fig – 5: Nedupuzha to Thekkinkadu (OD3)

Fig – 6: Mannuthy to Thekkinkadu (OD3)

4.3 Identification of Variables

Selecting criteria of a route are evaluated based on some factors. At first, the factors or variables are selected based on the literature review and then a preliminary survey has been conducted to set the final variables based on how one user perceives the factors for choosing a route. A list of variables are mentioned in Chapter 2 (literature review) shows that many factors or variables are related to drivers or travellers route choice. The choice may vary for different

characteristics of the driver, different attributes of route, road, traffic characteristics, and environment and in different circumstances. The selected variables are presented in Table 1.

Table -1: List of Variables

Variable Number	Variable Name
1	Age
2	Gender
3	Monthly Income
4	Mode Used
5	Typeof Employment
6	Travel Time
7	Travel Cost
8	Distance
9	Congestion
10	Type of Activity

4.4 DESIGN OF SURVEY PERFORMA SHEET

The heart of any survey research project is a survey questionnaire itself. Although it is easy to think of interesting questions to ask people, constructing a good survey questionnaire is not easy at all. The problem is that the answers people give can be influenced in unintended ways by the wording of the items, the response option provided, and many other factors.

A questionnaire was designed for a home interview survey for surveying road users. The questionnaire consists of three parts. Part A consist of socioeconomic information, part B consists of personal information, part C consist of travel information on the private road users. The model of the questionnaire is shown in Appendix A. Name of the household head, type of dwelling, number of members etc are the factors included in the socio-economic information. Gender, age, income, occupation, Vehicle Ownership are the major factors in personal information. Route selected,Purpose of Trip, Frequency of trip, Mode used for Trip, Travel time, Travel cost, Traffic congestion on the selected route, road condition of the selected route habituation of route, are the factors included in the travel information part of the
questionnaire form.

4.5 CONCEPT OF FUZZY LOGIC

MATLAB fuzzy logic toolbox facilitates the development of fuzzy-logic systems using graphical user interface (GUI) tools command line functionality. The tool can be used for building Fuzzy Expert Systems Adaptive Neuro-Fuzzy Inference Systems(ANFIS). There are five primary GUI tools for building, editing, and observing fuzzy inference systems in the Fuzzy Logic Toolbox :

- Fuzzy Inference System (FIS) Editor
- Membership Function Editor
- Rule Editor
- Rule Viewer
- Surface Viewer

5. DATA COLLECTION

For this study, data is one of the major factors. Data collection was done by a home interview survey using the predefined questionnaire.

5.1 Sample Size Selection Criteria

Estimation of sample size in research using Krejcie and Morgan is a commonly employed method. Sample size estimated by Krejcie and Morgan (1970) with help of the equation .

$$S = \frac{\chi^2 * NP(1-p)}{e^2(N-1) + \chi^2 * p(1-p)}$$

Where,
s = required sample size.
N = population size.
p = population proportion (assumed to be 0.50 since this would provide maximum sample size)
e = degree of accuracy expressed as a proportion (0.05)

To get data from every wards, 48 individuals (or 12 houses) will be selected in random from all the 52 wards. Hence, a total sample of 2496 individuals will be obtained as sample for the survey.After surveying, the highest number of attraction zone is identified as Thekkinkadu and the highest number of production zones are identified as Punkunnam, Kuttumuck, Nedupuzha and Mannuthy. The household survey is again conducted in these zones about a sample size of 200.

6. DATA ANALYSIS

Stratification of the collected samples is discussed in the following sections. The collected data is entered in the Microsoft Excel and the preliminary analysis is done.Fuzzy Toolbox in MATLAB is used for the remaining analysis and to obtain the result.

6.1 Preliminary Analysis

Percentage of population grouped under different level of attributes is discussed in this section. The attributes selected are gender, age group, monthly income, vehicle ownership, frequency of trip, Mode used etc.

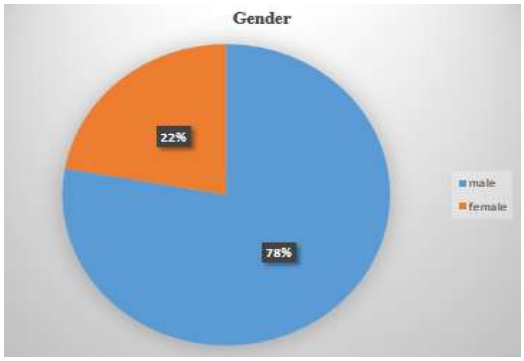

Fig – 7: Distribution Based on Gender

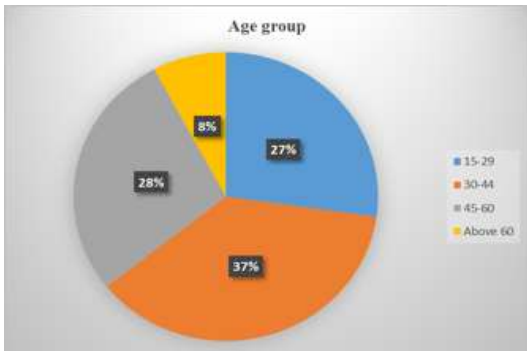

Fig – 8: Distribution Based on Age Group

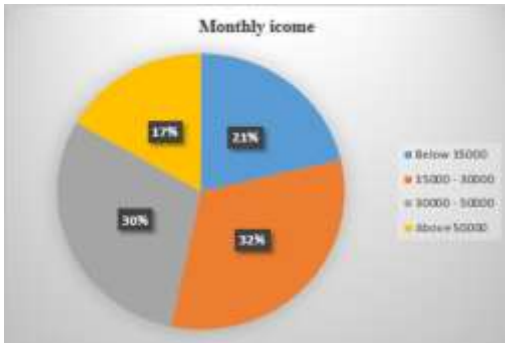

Fig – 9: Distribution Based on Monthly Income

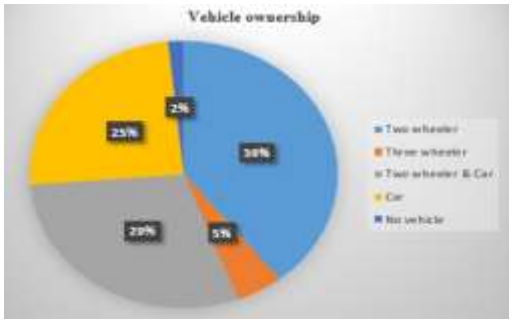

Fig – 10: Distribution Based on Vehicle Ownership

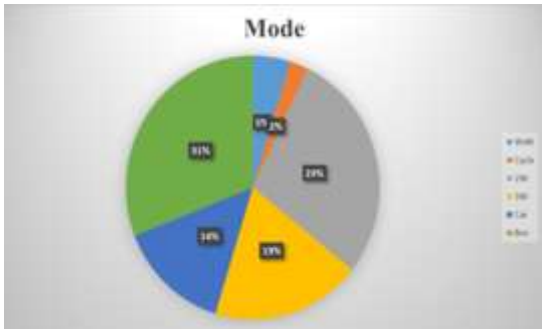

Fig – 11: Distribution Based on Mode Used

6.2 Development of Fuzzy Logic Model

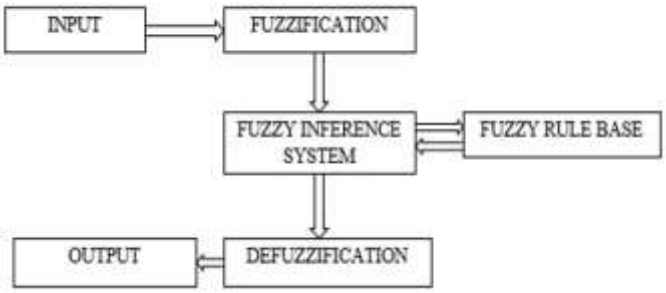

Fig – 12: Flowchart of Fuzzy Inference System

6.3 Fuzzification

There are several shapes which can be adapted to frame membership functions such as Triangular, Trapezoidal, Gaussian, etc. Here, the shapes of the membership functions are Triangular for the input variables, viz. Age, Gender, Income, Type of employment, Mode, Travel time, Travel cost, Type of activity and congestion and output variable route choice. All the input and output variables are divided into fuzzy sets.

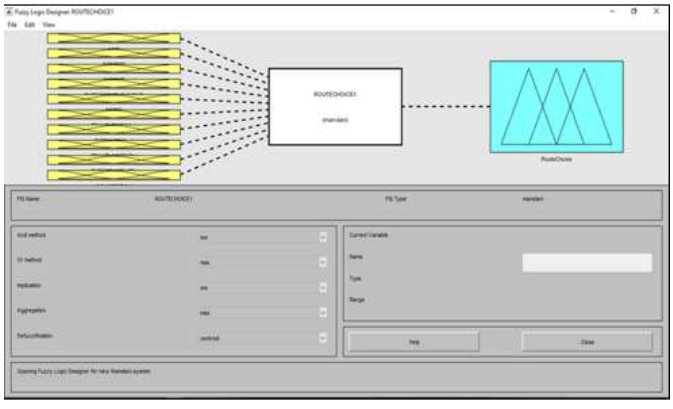

Fig – 13: Basic Fuzzy Structure

Membership function for the input parameter Age is divided into five categories ie Child (C), Young (Y), Middle Age Adult (MAA), Senior Adult (SA) and Old Adult (OA) respectively. Membership Function for Gender. Since gender is a categorical one it only has 2 categories either Male or Female. Membership Function for MONTHLY INCOME is a numerical one. It is divided into five categories they are 0 - 10000 (Others), 10000 - 20000 (VL), 30000 - 55000 (L), 55000 - 75000 (M) and Above 75000 (H).

Membership Function for TYPE OF EMPLOYMENT(TOE) is a categorical one. It is divided into seven categories they are Others, Student (S), Homemaker (M), Government Employee (GE), Private Employee (PE), Self Employee (SE) and Retired (R). Membership Functions for MODE is divided into six categories they are Walk (W), Cycle (CY), Two Wheeler (2W), Three Wheeler (3W), Car (C) and Bus (B) respectively. Membership Functions for TRAVEL TIME is mentioned in Minutes and it is divided into four categories they are 5 - 6 (VL), 6 - 7.5 (L), 7.5 - 8.5 (H) and 8.5 - 10 (H).

Membership Functions for DISTANCE is mentioned in Km and it is divided into four categories, they are 3 - 3.15 (VL), 3.15 - 3.3 (L), 3.3 - 3.4 (M) and 3.4 - 3.4 (H). Membership Functions of TRAVEL COST is divided into three and they are 0 - 10 (L), 10 - 30 (M) and 30 - 50 (H). Membership Functions of TYPE OF ACTIVITY is divided into five, they are Others, Work (W), Education (E), Shopping (S) and Religious (RL). Membership Function for CONGESTION is divided into three categories they are Low (L) , Medium (M) and High (H). Membership Function for the output variable ROUTE CHOICE and it is divided in to R1 ,R2 and R3.

Table – 2: Details of MFs of variables used

Variable	No. of MFs	Linguistic variable	Type of MF	MF Parameters
Age	5	Child Young MAA SA OA	Triangular Triangular Triangular Triangular Triangular	[0 0 15] [16 23 30] [30 42.5 55] [56 62 70] [71 100 100]
Gender	2	Male Female	Triangular Triangular	[0 1 2] [1 2 3]
TOE	7	Others S M GE PE SE R	Triangular Triangular Triangular Triangular Triangular Triangular Triangular	[-1 0 1] [0 1 2] [1 2 3] [2 3 4] [3 4 5] [4 5 6] [5 6 7
Mode	6	W CY TW 3W C B	Triangular Triangular Triangular Triangular Triangular Triangular	[-1 0 1] [0 1 2] [1 2 3] [2 3 4] [3 4 5] [4 5 6]
Travel Time	4	VL L M H	Triangular Triangular Triangular Triangular	[5 5 6] [66.75 7.5] [7.5 8 8.5] [8.5 10 10]
Distance	4	VL L M H	Triangular Triangular Triangular Triangular	[3 3 3.15] [3.15 3.22 3.3] [3.3 3.33 3.4] [3.4 3.5 3.5]
Travel cost	4	VL L M H	Triangular Triangular Triangular Triangular	[-10 0 10] [10 20 30] [30 50 50]
TOA	5	O W E S RL	Triangular Triangular Triangular Triangular Triangular	[-1 0 1] [0 1 2] [1 2 3] [2 3 4] [3 4 5]
Congestion	3	L M H	Triangular Triangular Triangular	[-1 0 1] [0 1 2] [1 2 3]

Similiarly, the analysis for the remaining zones (Kuttumuck, Nedupuzha & Mannuthy) is done.

6.4 Fuzzy Rule-Base Formulation

Fuzzy rule base generation is a very important phase in the Fuzzy Inference System. A fuzzy rule base consists of a number of If-Then rules. Intersection Rule Configuration (IRC) method was adopted for rule generation. In this method, every possible combination of rules are explored and are used to determine the outcome. Fuzzy inference mechanism works on the principle of simple and logical If-then rules. Total 160 numbers of IF-THEN rules are formulated here based on the logical thinking and general experience. One example of the rule is shown below:

If Age is MAA AND Gender is MALE AND Income is LOW AND Mode is 2W AND Type of Employment is PE AND Travel Time is LOW AND Distance is LOW AND Travel Cost is LOW AND Type Of Activity is W AND Congestion is MEDIUM THEN Route choice is R1.

6.5 Defuzzification Process

The fuzzy output of the fuzzy inference system cannot be used directly for application purpose and hence the defuzzification of the aggregated output fuzzy sets is carried by using Centroid method, to convert the linguistic output into crisp format**.** The fuzzy output of the fuzzy inference system cannot be used directly for application purpose and hence the defuzzification of the aggregated output fuzzy sets is carried by using Centroid method, to convert the linguistic output into a crisp format. The rule viewer can be used as diagnostic to see, the rules which are getting fired for particular input values and how individual membership function shapes influence the results.

And the output for Punkunnam is If Age = 42, G = 1 , Income = 30000 , Type of Employment = 4 , Mode=3, Travel time = 9.2 , Distance =3.3 , Travel Cost =20 , Type of Activity=2 , Congestion = 2 then the Crisp Output = 0.374 and the Choosen routes are R1 and R2 (Fig 14). And the output for kuttummuck is If Age = 50, G = 2, Income = 65000 , Type of Employment = 3 , Mode=3, Travel time = 16.6 , Distance =7.68, Travel Cost =45 , Type of Activity=2 , Congestion =2 then the Crisp Output =0.488 the Choosen route is R2.(Fig 15)

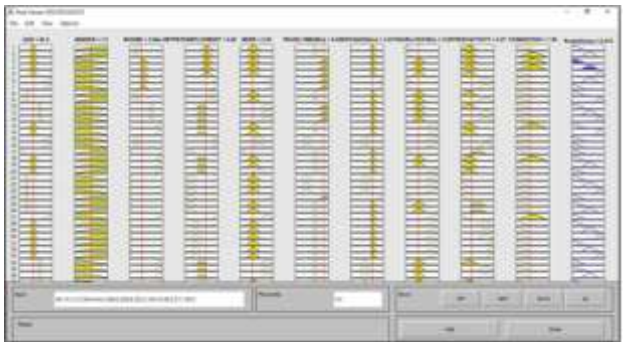

Fig – 14: Rule Viewer – Punkunnam

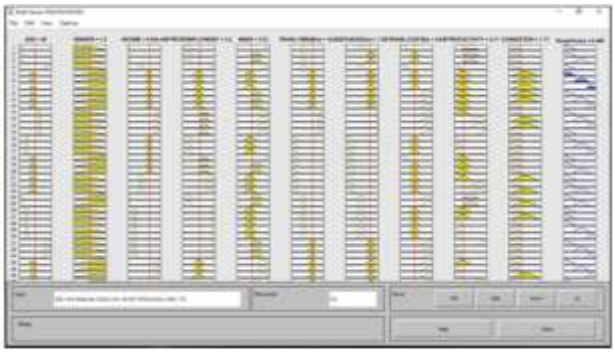

Fig – 15: Rule Viewer- Kuttumuck

And the output for Nedupuzha and Mannuthy are If Age = 38, G = 1 , Income = 38000 , Type of Employment = 4 , Mode=3.5, Travel time = 17.5 , Distance = 8.11, Travel Cost =80 , Type of Activity=2 ,Congestion = 1.5 then the Crisp Output = 0.342 the Choosen routes are R1 R2 (Fig 16) If Age = 49 , G = 1.5, Income = 25000, Type of Employment = 3, Mode=3.5 , Travel time = 21.7 , Distance =7.73 , Travel Cost =60 , Type of Activity=2 , Congestion = 1.5 then the Crisp Output = 0.378 the Choosen routes are R1 R2.(Fig 17)

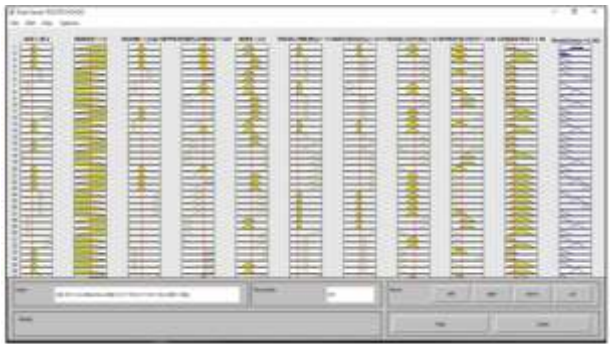

Fig – 16: Rule Viewer- Nedupuzha

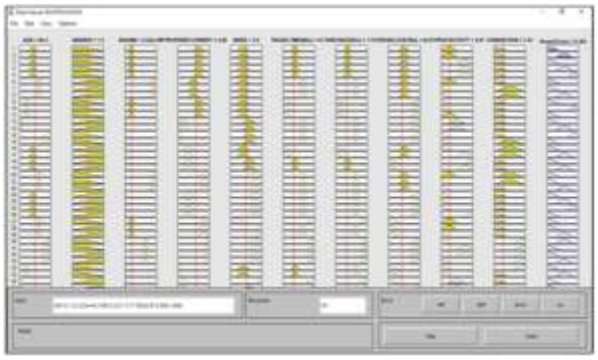

Fig – 17: Rule Viewer- Mannuthy

6.6 Surface Plots

The surface viewer involved using surfview is a tool that examine the output surface an Fuzzy Inference System stored in a file for any one or two inputs.

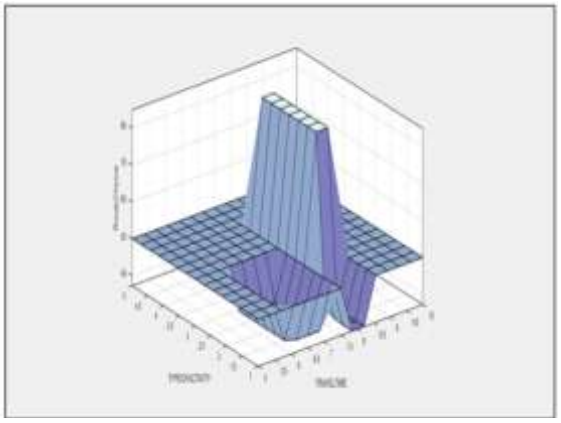

Fig – 18: Surface Viewer- Type of Activity and Travel Time

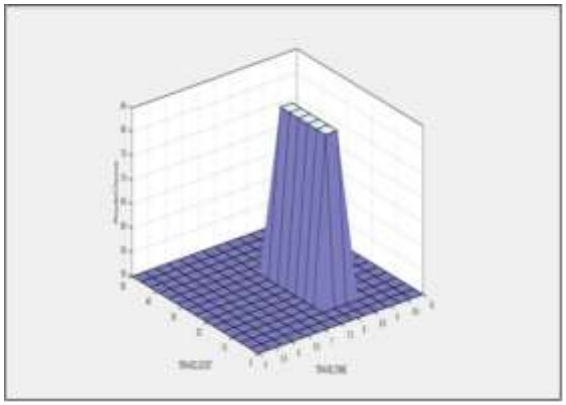

Fig – 19: Surface Viewer- Travel Cost and Travel Time

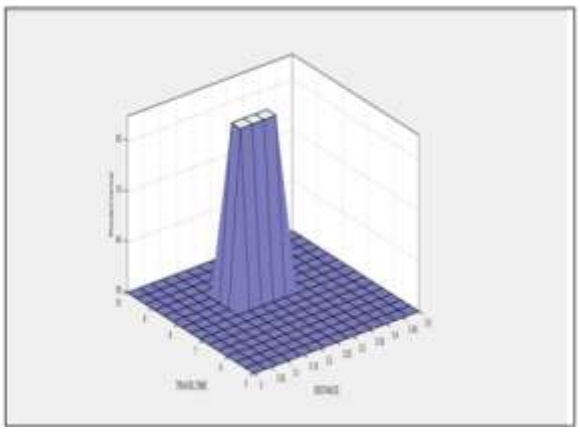

Fig – 20: Surface Viewer- Distance and Trvael Time

7. CONCLUSIONS

Route choice behaviour is one of main components of Transport System. In this study Fuzzy Logic Models is used to predict the route choice behaviour of a user. In this study factors affecting route choice between alternate routes were identified using Surface Plots.They are Travel Cost, Distance, travel time between origin and destination and Type of Employment**.** The result shows that for Punkunnam the mostly choosen routes are Thrissur Kuttippuram Road (R1) and Kodungallur Shornur Road (R2).For Nedupuzha the mostly choosen routes are Kodungallur Shornur Road/Swaraj round (R1) and Kodungallur Shornur Road (R2). For Mannuthy the mostly choosen routes are Thrissur Palakkad Road (R1) and Thrissur Mannamangalam Road (R2) and for Kuttumuck the mostly choosen route is Kuttumuck Villadam Road (R2).

In this study, route choice model with fuzzy logic is provided. It is found from the study that the human psychology in making daily route choice decision can be represented more efficiently by using the linguistic variable.The results obtained in this study shows that the created model could represent the reality well. It could beconcluded that fuzzy logic based model provides precise estimation of urban traffic along with a description of human perception.

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