Mode Choice Modeling for Work Trips by Analytical Hierarchy Process : Case studies in Asian Cities, Singapore and Calcutta.

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1. Introduction

Though the Utility Maximization as well as the Economic Psychological Theory are the two most commonly followed approaches for Mode Choice Analysis. The Analytical Hierarchy Process, a tool coined by Saaty in 1977, was primarily aimed towards determining the relative importance of a set of activities or phenomena based on the subjective comparative judgments of the respondents. Complex decision making processes consisting of intricate network of factors, which otherwise are not identified are broken down into less complicated, exclusively independent component parts, arranged in a hierarchical order. The subjective judgments trade-off are then quantified and the judgments are synthesized to determine the best decision.

2. Use of AHP for Travel Demand Estimation

The advantage obtained from the structured hierarchy of the AHP model is that it can encompass several variables which otherwise would have been difficult to be tracked down. In this case the responses of the commuters for work-trips have been gathered From both the cities: Calcutta and Singapore. The number of samples collected from the cities are 147 and 607 respectively.

3. Structure of the Model

The Model designed to analyze the Modal Choice consists of three levels. The goal of the structure is "Selection of the Mode for Work Trip". The second level in the choice hierarchy consists of the *criteria of selection* of the mode. Six factors considered in the second level are the associated factors of the mode those influence the selection of a mode, viz. *cost, time saving ability, comfortability, safety, accessibility, reliability.* The third level, *alternatives* , consists of the primary modes which are available to the commuters while going to the office in the particular city. These alternatives are different for different cities and are chosen based on the ridership of the modes. Their number has been restricted to four only considering the huge amount of comparison involved for every increased number of mode at the third level. Hence for Singapore the four modes are : *bus, car, MRT, motorcycle*; where as for Calcutta, minibus being one of the prime modes, replaces motorcycle to make the combination : *bus, minibus, car and MRT.*

The followings are the steps followed during the analysis:

1. The responses have been analyzed individually to get the individual scores. Only the consistent results (CR< 10%) have been accepted.

2. The individual responses have been regressed with the personal variables like income, sex, family size, average income, age, etc. The results obtained from those are tabulated in Table 1.

3. The results i.e. the weights obtained from the AHP are grouped in three categories based on the income of the respondent, viz. poor, middle and high.

4. The estimated share of the model obtained from the AHP are then compared with the actual modal share.

4. Results

The results obtained from the AHP analysis have been analyzed from different angles. The scores of the different criteria in the second levels indicate the relative importance as well as the magnitude of influence of the corresponding factor on the mode choice decision. Upon regressing the results obtained from the AHP analysis with respect to the personal variables, it has been found that different personal variables like: *income, average income, family size, age, sex, etc.* are quite strongly related with the weightages on the six chosen criteria. Amongst all, income has been found to be the most prominent factor influencing the preferential weightages.

Similar mathematical operations on different modal preferences according to different selection criteria yielded the following results. Those tabulated personal traits helped us to have an insight into the reason of variability among the respondents based on their personal traits.

The observations made from the following tables have been discussed as follows:

In Calcutta, the preference on *cost* has been found to be dependent on the *Average Income and Family Size* whereas it is negatively influenced by *Vehicle Ownership and Income* in Singapore. Calcuttans belonging to higher income bracket prefer *MRT* more than other users and voted against *bus and minibus.* So far as the costwise preference of the mode is concerned,

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Table: 1 **Personal Characteristics and Their Influence on the AHP Results**

	COST	*TIME SAVING*	*COMFORT*	*RELIABILITY*	*SAFETY*	*ACCESSIBILITY*
Calcutta	1. Age +	1.Age- 2.Vehown-	1. Time + 2. Vehown+ 3. Fmly-		1. Avginc+	1. Vehown+ 2. Age+ 3. Inc-
Singapore	1. Vehown- 2. Income-	1. Age-		1. Age-	1. Vehown-	1. Income+

Note: (+) indicates that the factor is positively correlated with the personal variables.
(-) means that the factor is negatively correlated

where:

Age : Age of the Respondent
Time : Time spent by the respondent in the work -trip.
Vehown : Vehicle Ownership of the respondent
Avginc : Average Income
Fmly : Size of the family of the respondent
Sex : Sex of the respondent

Table: 2 **Variables Influencing Different Factors Behind the Choice of Modes in Calcutta**

	COST	TIME SAVING	COMFORT	RELIABILITY	SAFETY	ACCESSIBILITY
MRT	Avginc + Fmly +	Age - Inc +	Sex -	Sex - Inc +	Avginc + Sex - Fmly + Inc +	Vehown -
BUS	Avginc - Fmly -	Time - Inc - Vehown - Age +	Avginc + Inc - Fmly + Time -	Fmly + Time +	Vehown - Fmly - Age -	Time + Age - Vehown -
MINI	Avginc - Vehown - Fmly -	Time - Age + Inc -	Avginc - Age + Time - Vehown +	Age + Avginc - Inc - Time - Sex +	Vehown - Sex + Fmly - Inc - Avginc -	Vehown - Time +
CAR		Time +	Time + Age -	Sex + Vehown +	Vehown + Fmly- Sex + Inc - Avginc - Age +	Vehown +

Table: 3 Variables Influencing Different Factors Behind the Choice of Modes in Singapore

	COST	*TIME SAVING*	*COMFORT*	*RELIABILITY*	*SAFETY*	*ACCESSIBILITY*
MRT	Income - Age + Vehown + Time +	Vehown -	Age +	Time + Age + Vehown -		
BUS	Income - Time +	Vehown - Age -	Age -	Vehown +	Vehown - Income -	Time +
MCYCLE			Inc -	Age -	Age -	
CAR	Income + Time - Vehown -	Vehown - Age -		Age - Time -	Income +	Income + Vehown +

in Singapore, income is negatively related to *bus* & positively related to *car*.

In both the cities *age* is negatively related to the preference on time saving ability of the mode. Young trip makers are more concerned about *time saving* whereas with increased age, commuters become more concerned about *comfort, accessibility and reliability* of the mode.

In Calcutta, people making longer trips and owning vehicles are more concerned about *comfort* obtained from the mode they ride. In Singapore, higher age group people are more concerned about *reliability* i.e. regularity, frequency etc of a mode.

In both the cities the concern for safety is higher for the vehicle owners. In Calcutta, concern for safety is related to the *average income* of the respondent as well.

The preference on accessibility in Calcutta depends on the *vehicle ownership* of the respondent. Car owners are found to be more concerned about accessibility of the mode. In Singapore *income* is found to influence the accessibility. *Income* has a negative effect on the accessibility of all the modes except *car*, the accessibility of which is very strongly related to it.

5. Comparison of the Weights on the Modes between the cities:

When the modes *MRT, bus & car* are compared in the light of the factors in the level-1 of the AHP hierarchy, i.e. the factors like *Cost, Time Saving, Comfort, Reliability* etc., the results varied a lot between the two cities.

If carefully noted it can be made out that the most preferred mode of conveyance in Singapore is the *car*, whereas that is *MRT* in Calcutta. In both the cities, comparatively, *bus* seems to be the least preferred mode, except when compared in the light of the factor *cost & accessibility*. This discrepancy amongst the two cities indicates that commuters in Calcutta do not travel a distance as long as a Singaporean do. The absence of good transportation facilities and infrastructural support in Calcutta is the reason why *MRT* has been given the highest preference here. So far as the *accessibility* is concerned the preferential weight of *MRT* is lower than that of *bus* in Singapore which indicates that the *MRT* is not as well accessible as *bus* is. This is a generic

Table: 4 Comparison of Preferential Weights on the Modes Based on Different Criteria

FACTORS		MRT	BUS	CAR
COST	CALCUTTA	0.449	0.314	0.237
	S'PORE	0.342	0.235	0.423
TIME SAVING	CALCUTTA	0.482	0.159	0.359
	S'PORE	0.268	0.178	0.554
COMFORT	CALCUTTA	0.419	0.145	0.436
	S'PORE	0.323	0.152	0.524
RELIABILITY	CALCUTTA	0.448	0.148	0.403
	S'PORE	0.355	0.190	0.455
SAFETY	CALCUTTA	0.492	0.147	0.361
	S'PORE	0.471	0.234	0.295
ACCESSIBILITY	CALCUTTA	0.310	0.321	0.369
	S'PORE	0.265	0.320	0.415

6. Comparison of the Results of AHP and Actual Mode Shares

The comparison has been drawn for different respondents belonging to different income levels and the observations have been discussed in the following paragraphs.

Though the magnitude of preference varies, the AHP model results are in favor of *MRT and car*. But the reality is completely different. In Calcutta *minibus and bus* are mostly used modes followed by *car and MRT* respectively. In Singapore the mostly used modes are again *bus & MRT* followed by *car and motorcycle*. Qualitatively the data obtained from Singapore is better and hence it has given rise to a better result. The *MRT* ridership could be predicted quite satisfactorily. Nevertheless a difference exists between the predicted and the actual modal share for *bus and motorcycle*.

When compared with income it has been found that in Calcutta the preferential weight of *MRT* increase with income range. This has been correctly reflected in the AHP results. The actual modal shares of Calcutta when compared across *income* shows opposite trends for *bus and car*. When income increases the ridership of *bus* reduces whereas that of *car* increases. Unlike Calcutta, in Singapore, the popularity of *MRT* reduces with income. Here the public transit modes, *bus* as well as *MRT* has got the same characteristics i.e. the ridership reduces with income.

The AHP model results of Singapore is much more realistic than that in Calcutta and hence is more reliable. The predicted shares of the car ridership increases with income. The weight of *MRT* also has decreased with income - since with the rise of income, the preferential weights regarding *safety* on *MRT* reduces and that of *car* increases.

7. Conclusion

The most noteworthy finding in the research is the amazing similarity in the basis of mode selection , which seems to be same, irrespective of the location, income and the exiting transportation facilities of the concerned city. This approves of the fact that the behavioral dynamics of the commuters is practically consistent and does not vary depending on the location . Amongst the six criteria , *safety* has been found to be the most prominent factor in both the places where as *cost* is the least influencing of all . The modal shares predicted by the models are based on the ideal situation and are successful only when the services offered by the corresponding mode reaches the level of expectation of the commuters. The well planned MRT in Singapore is one of the most thriving public transportation mode and hence its share of the commuters could be successfully predicted by the AHP model. This model can be a good tool in the study of passenger psychological dynamics. It is felt that the failure of the AHP model in predicting the actual mode share may be the result of its inability of inclusion of several important personal variables like, income, sex, age, car ownership, etc. as well as the other trip related variables viz. time spent, distance of the trip , etc. Future development of this model is possible with these aforesaid changes such that it can be used as a model to study the passenger behavior under both ideal as well as the present situation.