INCORPORATING NON-MOTORISED MODES IN URBAN TRANSPORTATION PLANNING

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abstract: Traditionally urban transportation planning has not included walking, cycling and other non-motorised modes of travel in modelling and plan development. Trip generation and modal split models have included motorised modes only. With renewed interest in non-motorised transportation, it is imperative that cycling must be introduced in urban transportation planning process. This will result in engineering development of bicycle infrastructure facilities and an integrated transport system with its due share for non-motorised modes. In addition to the time and cost characteristics of competing modes used in conventional utility function in modal split models, scores of each mode on sustainability, health impacts and special features will have to be considered. Preliminary attempts have been made to develop the disutility function for cycling with a view to determining the share of commuter trips for this mode. The topic is of special interest in developing countries where non-motorised modes play a significant role in passenger and freight travel but are not considered in an integrated transport planning.

1. INTRODUCTION

1.1 Background

Non-motorised transportation is being recognised as an earnest mode of travel especially for commuting to work and school/university. Although, the precise number of regular commuters using bicycle may not be known, there appears to be overwhelming evidence that its patronage is increasing. The commonly cited motivational factor is the improvement and maintenance of the health of bike-user although economic and environmental reasons are also considered important.

In order to incorporate bicycle as a competing mode for travel in modal choice modelling, it is imperative that the characteristics of the modes which influence choice must be identified. The relative attributes of competing modes must be assessed for use in modal choice models.

1.2 Statement of the Problem

Surveys in the U.S., Europe, and Australia have clearly shown that interest in cycling has been on the increase. Although cycling has been a prominant mode for commuting in developing countries like China and India, it has been used mainly for recreation and fun in the western countries. However, there is an increasing trend towards using bicycle as a commuter mode even in the developed world.

With such increasing interest in cycling and other non-motorised transportation modes, travellers, city councils, transport operators and planners consider cycling as a viable alternative to motorised modes. The greatest impetus has come from the consideration of global sustainability. It is imperative that cycling must be introduced in urban transportation planning process. This will result in engineering development of bicycle infrastructure facilities and an integrated transport system with its due share for NMT.

This paper is a preliminary attempt to formulate the modal choice model for motorised and non-motorised modes. Although the disutility concept is retained in this study, the characteristics of modes have been expanded to incorporate the special motivating characteristics of non-motorised modes. For the first time, the disutility is reduced by considering the positive effects of cycling. In addition to the time and cost characteristics of competing modes used in conventional utility function in modal split models, scores of each mode on sustainability and health impacts has been considered.

1.3 Aims and Scope

The main objective of this study is to examine the appropriateness of the contemporary modal choice modelling techniques in incorporating non-motorised modes. Usually, the modal choice models have only considered car driver, car passenger and public transport modes. Non-motorised modes are used for considerations other than the travel time or cost which are usually ignored in traditional modelling. For the first time, the concept of positive utility is incorporated in the disutility functions to account for the motivational factors.

The scope of this research is limited to investigating the feasibility of incorporating cycling as a competing mode in modal choice modelling. This includes the development of positive utility components and prescription for the framework for formulating the revised disutility functions for the competing modes. The estimation of coefficients of disutility functions will be described in another paper.

2. THEORETICAL CONSIDERATIONS

2.1 Travel Demand

Travel demand is considered as a derived function. People travel because they wish to do something at their destination - work, education, business, shopping or even a social engagement. However, when cycling is done purely for the sake of "fun", it does not meet the normal criteria used in travel demand forecasting in that such demand is not a derived function. With the exception of "fun" journeys, transportation is usually a means to an end. Commuting is an excellent example of derived demand and modal choice modelling is limited to commuter travel in this study.

2.2 Disutility Functions

Travel involves sacrifices. These include monetary cost, travel time, and negative qualitative aspects such as discomfort, inconvenience, safety risk, walking, and frustration associated with waiting, in-vehicle standing, unreliability etc. These sacrifices are represented by the level of disutility. Higher the level of disutility associated with a travel mode, lower will be the propensity to use that mode. The disutility functions are built from the characteristics of the mode and the traveller.

2.3 Modal Attributes and Shares

The most commonly used attributes of travel modes have been the trip cost and travel time. Several models use a generalised cost which converts time into monetary units and adds the two together. These models are generally formulated not by using data aggregated to zones totals but by summarising trips for specific type of travellers.

The division of choice riders among the competing modes is based on trip-maker characteristics, trip purpose, and the friction between pairs of zones encountered when using each mode. Friction is a composite of travel time, out-of-pocket costs, and inconveniences associated with walking, waiting, and transferring. The proportion of total choice riders expected to use one of the modes is computed and used to predict future choices in the light of proposed changes in the networks of one or more modes.

Other models use utility functions. The utility of a mode is usually modelled as a linear function of the variables describing the alternative. The variables are transportation system characteristics as well as the socio-economic characteristics of the trip-maker, possibly stratified by trip purpose. Examples for home to work trips are travel cost, travel time, comfort and household income. The coefficients are most commonly estimated by the method of maximum likelihood.

Separate choice models may be developed for each income group.

3. BICYCLE MODE CHARACTERISTICS

The catalogue of modal characteristics included in this study has been expanded from the traditional list to account for the special characteristics of the cycling mode. The expanded list includes

- Cost (fuel, registration and insurance cost, amortisation, maintenance, parking etc. in case of car; and fare in case of public transport)
- Travel time (door-to-door)

- Safety risk
- Comfort (seat, weather protection)
- Convenience
- Health improvement / maintenance
- Environmental and ecological impacts (sustainability)
- Travel distance (to account for distance propensity of NMT and motorised modes)
- Other effects (flexibility, load factor, load carrying capacity)

There is scope to design and produce bicycles which can alleviate several shortcomings of the present day bicycles and increase the utility function of cycling mode further.

4. INCORPORATING CYCLING IN MODAL CHOICE MODELLING

4.1 Mode Switching

Traditionally, all aspects of travel by any mode are negative - cost, time, and other qualitative aspects - or are so modelled. However, cycling offers definite positive aspects, the most significant of which is health/fitness. Almost all cyclists have reported positive health aspect of cycling as the main motivating factor for cycling.

The majority of cycling commuters have shifted from motor car. Obviously, they have realised that the disutility of travelling by car is more than that by bicycle. The majority of commuters who switched to bicycle are male, professional, and in higher household income bracket. Their age distribution and car ownership levels are not dissimilar to rest of the population.

The modal choice modelling incorporating non-motorised modes should be able to demonstrate that certain group of people will find bicycle offering less disutility compared to car and switch to cycling.

4.2 Factors used in Disutility Functions

As stated earlier, the most commonly used quantitative factors in mode choice modelling are travel time and travel cost (out-of-pocket expenses). Other qualitative factors such as comfort and convenience have also been generally considered through the use of walking and waiting/transfer times. This has resulted in their incorporation as a negative utility reflecting these as sacrifices.

However, aspects of cycling which motivate people to switch their commuting mode from car or public transport to cycling should be considered as reducing the disutility of cycling mode. These qualitative factors are listed as positive utility factors, as shown in Table 1. This Table shows the factors deemed to be taken into account in making mode choice decisions, and their relative magnitude in case of three principal modes of travel being considered in this study.

Table 1: Factors Affecting Modal Disutility

FACTORS	CAR	PUBLIC TRANSPORT	BICYCLE
Quantitative			
Travel cost	High	Medium	Low
Travel time	Low	Medium	High
Qualitative - Negative			
Discomfort	Low	Medium; variable	Medium to High
Inconvenience	Low	High	Very low
Safety risk	Medium	Low	Medium to High
Qualitative - Positive			
Health Effect	Poor	Poor	Very positive
Environmental	Poor	Poor to medium	Very positive

In Table 2, the quantitative factors are shown as symbols where usually $C_c > C_p > C_b$ i.e. cycling is the cheapest mode followed by public transit while car is the most expensive mode. The relationship between travel time by different modes is generally of the form $T_c < T_p < T_b$ which states that car travel is the fastest while cycling is the slowest of the three commuter modes. In actual situations, however, these relationships may not be valid. Car drivers may perceive the out-of-pocket costs for travel to be less than the fare on public transport mode, especially if the car driver is provided with free or subsidised parking at destination. Similarly, a cyclist may be able to continue and reach the destination quicker than a car driver who may be held up in acute congested conditions for substantial periods. Obviously, these factors are specific between origin and destination locations and time of day. In any case, these factors are unambiguously quantifiable and measurable. The perception about actual and real cost of driving can, however, be contentious.

Table 2: Modal Characteristics

FACTORS	CAR	PUBLIC TRANSPORT	BICYCLE
Quantitative			
Travel cost	C_c	C_p	C_b
Travel time	T_c	T_p	T_b
Qualitative - Negative			
Discomfort	1	2	3
Inconvenience	1	3	1
Safety risk	2	1	3
Qualitative - Positive			
Health Effect	0	0	3
Environmental	0	0	3

The qualitative factors have been ranked as 0 (no effect), 1 (low), 2 (medium), and 3 (high). The car mode has low discomfort level and medium level of inconvenience (not finding parking space), the public transport has less risk of accident/injury but is less convenient, while the bicycle is very convenient though has low level of comfort and a high risk of accident/injury. The qualitative factors commonly included in modal choice models have been limited to walking and waiting time which represent inconvenience. Discomfort has been represented by Pienaar (1996) by the time for which a public transport passenger is unable to get a seat. This pseudo measure of comfort is a poor approximation but at least some attempt has been made to quantify discomfort. Safety risk has not generally been used in the disutility functions.

Finally, the factors which motivate people to use bicycle in preference to car are introduced in this approach to modal choice modelling. Most cyclist were found to have access to car. Ninety percent of those who did not own a car said in a survey that this was by their choice (Moritz, 1997). Furthermore, a majority of respondents were professionals with medium to high levels of income. This leads to the inference that factors motivating cyclists are important determinants of the modal choice.

Two factors are proposed for inclusion. These are improved health effects and the perception of contributing to environmental sustainability as a result of cycling in lieu of using motorised modes. These factors are additional to others considered in the conventional modal choice models such as the inexpensiveness of the bicycle mode which is covered in travel cost.

4.3 Trip Length and Disutility of Cycling Mode

It must be recognised that cycling is a serious competing mode for commuting for trips of up to 15 km or shorter. Two approaches to accommodating this particular attribute are suggested. The simpler approach is to develop modal choice models for trips which are shorter than the threshold level. The choice of modes is modelled for those trips where competition is real. The other is to incorporate a decay function in determining the utility of cycling mode. In other words, the disutility of cycling mode should increase with the trip distance and should be incorporated in determining propensity to cycling which reduces with increasing distances. In this approach, models can be developed for trips of any length.

4.4 Relative Weights for Qualitative Attributes

It is common to assign weights to qualitative factors based on their relative importance in choice decisions. For example inconvenience could be assigned a weight of 2 compared to discomfort if the travellers perceived inconvenience to be twice as undesirable as discomfort. The choice of weights should be established by determining the relative importance which the commuters give to various qualitative attributes of travel modes. This could be arrived at through commuter surveys which could also be used to ascertain which factors are considered by the commuters in making decisions about modal choice.

5. MODE CHOICE ESTIMATION

5.1 Mode Choice Model

The common mathematical formulation used in modal choice modelling is that of the logit function. The probability of choosing alternative m , P_m, is given by

$$P_m = e^{DU_m} / \sum_n e^{DU_m}$$

where n is the set of available alternatives.

The disutility function for mode m, DU_m, is given by

$$DU_m = \sum_i \theta_{im} X_{im}$$

where θ_{im}'s are the coefficients estimated by the method of maximum likelihood, and X_{im}'s are independent variables which are the transportation system characteristics as well as socioeconomic characteristics of tripmaker.

In the present modelling formulation, X_{im} are as follows:
X_{1m} = travel cost for mode m
X_{2m} = travel time for mode m
X_{3m} = ordinal value of negative qualitative factors (discomfort, inconvenience, etc.)
X_{4m} = ordinal value of positive qualitative factors (health, environment, etc.)
$X_{5m} = X_5$ = transformed income variable

Note that θ_{3m} and θ_{4m} will be opposite in sign.

5.2 An Application

A hypothetical situation of modal choice between origin A and destination B is presented. The trip distance is an average of 10 km. During the morning peak, 1000 trips are made between A and B. Three competing modes are car, public transport and cycling. Table 3 shows the travel time and travel cost by each of the modes.

Table 3: Travel Time and Cost

FACTORS	CAR	PUBLIC TRANSPORT	BICYCLE
Travel cost, ¢	500	200	10
Travel time, min.	15	20	30

From Table 3, it is obvious that

$X_{1m} = C_m$ where m takes on the symbol c for car, p for public transport and b for bicycle.

$X_{1c} = C_c = 500$
$X_{1p} = C_p = 200$
$X_{1b} = C_b = 10$

$X_{2m} = T_m$ where m takes on the symbol c for car, p for public transport and b for bicycle.

$X_{2c} = T_c = 15$
$X_{2p} = T_p = 20$
$X_{2b} = T_b = 30$

$X_{3c} = 4$ for car,
$X_{3p} = 6$ for public transport and
$X_{3b} = 7$ for bicycle
(assuming unit weight for each attribute)

$X_{4c} = 0$ for car
$X_{4p} = 0$ for public transport and
$X_{4b} = 6$ for bicycle
(assuming unit weight for each attribute)

The disutility functions for the three modes are

$$DU_c = \theta_c + \theta_{1c} X_{1c} + \theta_{2c} X_{1c} + \theta_{3c} X_{1c} + \theta_{4c} X_{1c} + \theta_{5c} X_5$$
$$DU_p = \theta_p + \theta_{1p} X_{1p} + \theta_{2p} X_{1p} + \theta_{3p} X_{1p} + \theta_{4p} X_{1p} + \theta_{5p} X_5$$
$$DU_b = \theta_b + \theta_{1b} X_{1b} + \theta_{2b} X_{1b} + \theta_{3b} X_{1b} + \theta_{4b} X_{1b} + \theta_{5b} X_5$$

Using the method of maximum likelihood, the coefficients, θ's are estimated and values of disutility functions are computed. These are plugged in the logit model to obtain the probability of using each mode. Given that 1,000 trips are made between A and B during the morning peak period, the number of trips made by each mode can be obtained.

6. CONCLUSIONS

Traditionally urban transportation planning has not included walking, cycling and other non-motorised modes of travel in modelling and plan development. However, with renewed interest in non-motorised transportation, it is imperative that cycling is destined to be introduced in urban transportation planning process. This will result in engineering development of bicycle infrastructure facilities and an integrated transport system with its due share for non-motorised modes.

In addition to the time and cost characteristics of competing modes used in conventional utility function in modal split models, scores of each mode on sustainability, health impacts and special features have been considered in this paper. Preliminary attempts have been made to develop the disutility function for cycling with a view to determining the share of commuter trips for this mode. The modelling framework presented in this paper can be used to systematically incorporate cycling as a genuine and earnest mode for commuting in making mode choices, to estimate the effects of improving operational attributes of bicycles, and provides a rational basis for the development of bicycle networks in urban areas.

The topic is of special interest in developing countries where non-motorised modes play a significant role in passenger and freight travel but are not considered in an integrated transport planning.

7. REFERENCES

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