AN APPLICATION OF AHP IN THE TRAFFIC PLANNING

He Xianci   Liu Haihua

ABSTRACT

It's always difficult to determine a feasible traffic structure in triffic planning. On the basis of the 'Traffic Behaviour Theory', this problem has solved by AHP. It's considered that the traffic structures depend on the traffic behaviours of millions of passengers and cargo-owners and the support capabilities of a government. With investigation data of O-D flow, an optimal ording for the traffic structure, correspond to tour (or transportation) distance D and national income per capita R, be determined by AHP. As a part of National Traffic Planning approved by the Ministry of Communications, the method presented in this paper is provided with feasibility.

It is necessary for a feasible traffic planning to take account of not only the demands of passengers and cargo-owners on traffic but also the support capabilities of a government. On the basis of the 'Traffic Behaviour Theory', an optimal structure of traffic, correspond to various income levels and various traffic manners in planning terms, is determined by AHP in this paper.

1. An Optimal Structure of Traffic Manners

According to the basic views of the 'Traffic Behaviour Theory', the choices of traffic manners depends on individual preferences as well as income levels of millions of passengers and cargo-owners. The traffic policymakers must pay attention to these preferences. Generally speaking, the traffic behaviours of the passengers are affected by many factors, such as income, tour distances, tour purposes, ages, sexes, etc, in which the former two are the main ones. With investigation data of O-D flow, an optimal structure of traffic manners be shown as Fig 1.

We divide the tour distances D into m sectors. Lut D_i $(i=1,\cdots,m)$ is tour distances for the ith sector, A_i $(i=1,\cdots,m)$ is an optimal traffic manner for the ith sector. The proportions of passenger capacity d_i $(i=1,\cdots,m)$ are obtained by the investigation data of dynamic O-D flow.

We have

$$\Sigma^{m}{}_{1}d_i=1.$$

So $\{d_i|i=1,\cdots,m\}$ is single ordering for second level.

Furtherly, lut the planning period be 1 to n, R_i $(i=1,\cdots,n)$ is national income per capita for ith year in planning period, and r_j $(j=1,\cdots,n)$ is, corresponding to D_i $(i=1,\cdots,m)$, the proportions of total passenger capacity for jth year. We have

$$\Sigma^{n}{}_{1} r_j = 1.$$

Thus, $\{r_j | j=1,\cdots,n\}$ is total ording for third level.

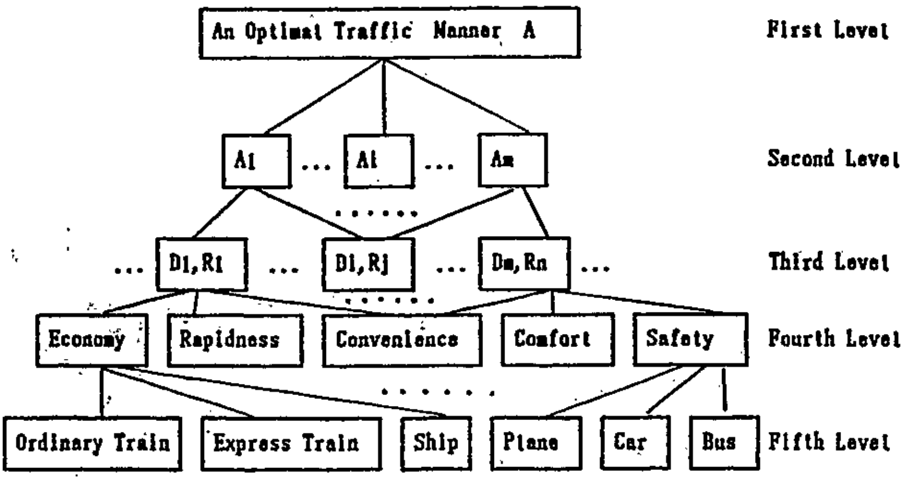

Fig 1. An Optimal Structure of Traffic Manners

As for the passengers (D_i,R_j), they usually choose traffic manner step by step. they give weights for technical characteristics of the manner, such as economy, rapidness, convenience, comfort, safety be shown on fourth level, then, the single ording for fourth level and total ording for third/fourth level are determined. Finally, according to technical characteristics of manners, the single ording for fifth level and total ording for fourth/fifth level are obtained by AHP, whose structural matrixes be gotten from the investigation data of dynamic O-D flow.

2. Quantitative Description of the Policy Leading.

The optimal choices of traffic manners with the opinions of Traffic Behaviour Theory is discussed above. As we know, the demands of passengers are taken into account more than the feasibility in choosing of traffic manners. Thus, it is a effectual way to get a balance between demand and supply of traffic that the behaviour be lead by means of the policies such as price policy. Following, a quantitative analysis for traffic policy leading will be discussed.

Let X_1 represents economy of the manner, X_2 represents rapidness, X_3 represents convenience, X_4 represents comfort, X_5 represents safety. As shown above, there is a weight vector and an ording for each (D_i,R_j) $(i=1,\cdots,m,\ j=1,\cdots,n)$, correspond to the ith sector and national income per capita for the jth year. As soon as weight vector for fourth level be changed in Fig 1, a new weight vector and a new ording for fifth level will be gotten. All above represent main views of policy leading.

A. The Preference Relation with Priority.

Two kinds of traffic manner are presumed, whose technical characteristic vector are X and Y, respectively

$$X=\begin{pmatrix}x_1\\x_2\\x_3\end{pmatrix} \qquad Y=\begin{pmatrix}y_1\\y_2\\y_3\end{pmatrix}$$

The preference relation is witten as $X \circledcirc Y$, which means that the passenger prefer X to Y. The symbol X=Y means the passenger think manner X as good as Y.

If there is a ording for X and a ording for Y, lut $x_1 \circledcirc x_2 \circledcirc x_3$, and $y_1 \circledcirc y_2 \circledcirc y_3$, then certainty,

(1) If $x_1>y_1$, then $X \circledcirc Y$.

(2) If $x_1=y_1$, $x_2>y_2$, then $X \circledcirc Y$.

(3) If $x_1=y_1$, $x_2=y_2$, $x_3>y_3$, then $X \circledcirc Y$.

B. Marginal Rate of Substituted.

The technical characteristics of traffic x_1, x_2, x_3 can be substituted each other, in which $x_1=\frac{1}{u}$ represents economic characteristic, u is average prices of tickets. It is a way to lead the transforming of traffic behaviours by changing valume of u. For example, a lot of passengers in (D_i, R_j) prefer X to Y. If policymaker want to transform a part of passengers from X to Y, they can success by raising u_x properly and so that $u_x>u_y$ or $u_x=u_y$.

If reducing Δx_1 can be replenished by increassing Δx_k (k=2, 3), then

$$-\frac{\Delta x_k}{\Delta x_1}, \quad (k=2, 3)$$

For simplity, $\frac{\Delta x_k}{\Delta x_1}$, (k=2, 3) is used as marginal rate of substitution, the negative symbol can be moved away. The marginal rate of substitution usually is not constant, even may be a non-linear function, but generally is function whose independent variable are D_i, R_j, and u_x. Lut

$$\frac{\Delta x_k}{\Delta u_x}=f_k(D_i, R_j, u_x) \qquad (k=2, 3;\ i=1, \cdots, m;\ j=1, \cdots, n).$$

The $f_k(D_i, R_j, u_x)$ is called marginal function of substitution, which have to be gotten through investigation.

For Y, technical characteristic vector of the other traffic manner, has the marginal function of substitution similarly,

$$\frac{\Delta y_k}{\Delta u_y}=f_k(D_i, R_j, u_x), \qquad (k=2, 3;\ i=1, \cdots, m;\ j=1, \cdots, n)$$

In limit case, there is

$$\frac{dx_k}{du_x}=f_k(D_i, R_j, u_x)$$

$$\frac{dy_k}{du_y}=f_k(D_i, R_j, u_y).$$

so

$$x_k=\int_{ux}^{u_x+\Delta u_x} f_k(D_i, R_j, u_x)\,du$$

$$y_k=\int_{uy}^{u_y+\Delta u_y} f_k(D_i, R_j, u_y)\,du_y.$$

C. The Policy Leading.

Lut

$$G_x=x_1+\sum_{k=2}^{3}\int_{ux}^{u_x+\Delta u_x} f_k(D_i, R_j, u_x)\,du_x.$$

$$=\frac{1}{u_x}+\sum_{k=2}^{3}\int_{ux}^{u_x+\Delta u_x} f_k(D_i, R_j, u_x)\,du_x.$$

$$G_y=\frac{1}{u_y}+\sum_{k=2}^{3}\int_{uy}^{u_y+\Delta u_y} f_k(D_i, R_j, u_x)\,du_y.$$

are value of synthetic substitution.

If $G_x>G_y$, then $X \textcircled{>} Y$.

If $G_x=G_y$, then $X \textcircled{=} Y$.

The traffic policy leading may be realized with the value of synthetic substitution. For instance, if $G_x>G_y$, while $G_x=G_y$ is what the government like, $G_x=G_y$ can be obtained by means of raising u_x, or reducing u_y, or both, which the additions u_x and u_y may be controled by the government.

As a part of the National Traffic Planning approved by the Ministry of Communications, the method presented in this paper is provided with feasibility.

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