The analyze of the impact of travel time cost on the competiveness of customized bus

Yuqiong Wang
School of Traffic and Transportation,
Beijing Jiaotong University
Beijing 100044, China
e-mail: 17114225@bjtu.edu.cn

Shunping Jia
School of Traffic and Transportation,
Beijing Jiaotong University
Beijing 100044, China
e-mail: shpjia@bjtu.edu.cn

Runbin Wei
School of Traffic and Transportation,
Beijing Jiaotong University
Beijing 100044, China
e-mail: 17120897@bjtu.edu.cn

ABSTRACT

As a new travel mode, customized public transport becomes the supplement of rail transit and conventional public transport to promote green travel. In order to study the impact of travel time cost on the competiveness of customized bus, a multi-mode transport network assignment model and experiments are designed. Besides, this paper studies two line modes including customized feeder bus and customized direct bus cross multiple regions. The example of this paper proves that with the increase of value of travel time cost, the competitiveness of customized feeder bus decreases firstly and then increases, while the competitiveness of customized direct bus across multiple regions will be steadily improved. Moreover, the operation of customized bus would raise the choice probability of public transit and improve the network traffic efficiency, and customized public transport has great development prospects.

CCS CONCEPTS

• Social and professional topics~Professional topics~Management of computing and information systems~Project and people management~Project management techniques

KEYWORDS

Public transport, customized bus, travel time cost, competitiveness, line mode

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1 Introduction

The customized bus makes up for the shortcomings of poor flexibility and unbalanced resource allocation of conventional public transit. The operation of customized bus will not only attract the original private car travelers, but also change the internal travel structure of traditional public transit.

The competiveness of customized bus is studied by many researchers. Jiang conducts a qualitative and quantitative analysis of the competitiveness of the customized bus compared with the traditional public transport, and draws conclusions of the rating evaluation [1]. Fu studies travelers' choice of customized bus, the results show that the users' perception of utility, success rate of reservation and ticket are the important factors which influence travelers' choice of customized bus[2].

Customized feeder bus and customized direct bus cross multiple regions are two line modes in actual operation. The customized feeder bus connects residential areas and subway stations, and delivers passengers to subway stations quickly, timely and comfortably. Customized direct bus cross multiple regions connects residential areas and central business district to provide the direct service.

With the development of social economy, the travel time cost increases gradually, and the competitiveness of customized bus towards to commuters will change accordingly in multi-mode transport network. However, almost a scholar does not pay attention to this and do corresponding research, so a multi-mode transport network assignment model is established to study the impact of travel time cost on the competitiveness of customized bus in this paper. Besides, we study two line mods including customized feeder bus and customized direct bus cross multiple regions, which could provide the suggestion of the selection of customized bus line modes.

2 Generalized travel cost

2.1 Car travel cost

The car travel cost consists of travel time cost, fuel and maintenance cost, and the cost of access to and get off the network, so the formula is expressed as

$$M_{rs,k}^{\text{car}}=\lambda\sum_{a\in k}t_a^{\text{car}}+g\sum_{a\in k}l_a+M_r^{\text{on}}+M_r^{\text{off}} \quad (1)$$

In the formula, $M_{rs,k}^{\text{car}}$ is the generalized cost of path k of car between (r,s) ,yuan; λ is the unit travel time cost, yuan/h; t_a^{car} is the travel time of road section a of car, h, t_a^{car} is solved by BPR function[3]; g is the unit fuel and maintenance cost, yuan/km; l_a is the distance of road section a , km; M_r^{on} is the cost of access to network, yuan; M_r^{off} is the cost of get off network, yuan.

2.2 Bus travel cost

The bus travel cost consists of travel time cost, ticket, and the cost of access to and get off the network, and the cost of transfer, so the formula is expressed as

$$M_{rs,k}^{\text{bus}}=\lambda\sum_{a\in k}l_a(1+\rho_a^{\text{bus}})/v^{\text{bus}}+f_{rs,k}^{\text{bus}}+M_r^{\text{on}}+M_r^{\text{off}}+M_r^{\text{transfer}} \quad (2)$$

In the formula, $M_{rs,k}^{\text{bus}}$ is the generalized cost of path k of bus between (r,s) ,yuan; ρ_a^{bus} is the crowding coefficient of segment a , ρ_a^{bus} of conventional bus is solved according to[4], ρ_a^{bus} of customized bus is 0; v^{bus} is the speed of bus vehicle, km/h; $f_{rs,k}^{\text{bus}}$ is the total ticket of path k of bus between (r,s) ,yuan; M_r^{transfer} is the cost of transfer, yuan.

2.3 Combined mode travel cost

The combined travel mode takes rail transit as the main travel mode, and travelers can travel by at most two modes. However, the subway travel cost is similar to the bus travel cost, so the repetitive specification will not appear in this paper. The travel cost of car-subway mode (bus-subway mode) consists of car(bus) travel cost, subway travel cost, and the cost of access to and get off the network, and the cost of transfer.

3 Multi-mode transport network assignment model

The Logit-SUE assignment model is established as following[5]

$$\min Y=\sum_{r\in \boldsymbol{O}}\sum_{s\in \boldsymbol{D}}\sum_{j\in \boldsymbol{J}}\sum_{k\in \boldsymbol{K}_{rs}^j}\int_0^{q_{rs,k}^j}M_{rs,k}^j(q)\mathrm{d}q+\frac{1}{\theta}\sum_{r\in \boldsymbol{R}}\sum_{s\in \boldsymbol{S}}\sum_{j\in \boldsymbol{J}}\sum_{k\in \boldsymbol{K}_{rs}^j}q_{rs,k}^j\mathrm{In}q_{rs,k}^j \quad (3)$$

s.t.

$$\sum_{j\in \boldsymbol{J}}\sum_{k\in \boldsymbol{K}_{rs}}q_{rs,k}^j=Q_{rs},\forall r\in \boldsymbol{O},s\in \boldsymbol{D} \quad (4)$$

$$q_{rs,k}^j\ge 0,\forall r\in \boldsymbol{O},s\in \boldsymbol{D},j\in \boldsymbol{J},k\in \boldsymbol{K}_{rs} \quad (5)$$

In the formula, $M_{rs,k}^j$ is the generalized cost of path k of mode j between (r,s) ,yuan; $\boldsymbol{K}_{rs}^j$ is the path set of mode j between (r,s) ; θ is the difference coefficient of travelers' understanding of path cost; Q_{rs} is the trip volumes of (r,s) , person /h; $q_{rs,k}^j$ is the passenger flow of path k of mode j between (r,s) , person /h.

The Lagrange function is constructed

$$Z=Y+\sum_{r\in \boldsymbol{O}}\sum_{s\in \boldsymbol{D}}\gamma_{rs}(Q_{rs}-\sum_{j\in \boldsymbol{J}}\sum_{k\in \boldsymbol{K}_{rs}}q_{rs,k}^j) \quad (6)$$

In the formula, γ_{rs} is the K-T multiplier.

Equation (7) is deduced from the K-T condition, and then Equation (8) is also deduced when $q_{rs,k}^j>0$.

$$\left[M_{rs,k}^j+\frac{1}{\theta}(\mathrm{In}q_{rs,k}^j+1)-\gamma_{rs}\right]q_{rs,k}^j=0 \quad (7)$$

$$M_{rs,k}^j+\frac{1}{\theta}(\mathrm{In}q_{rs,k}^j+1)-\gamma_{rs}=0 \quad (8)$$

The path flow can be obtained by substituting the result into (4). Then, when the network is in equilibrium, the calculation formulas of path selection probability and the path flow are as following

$$\alpha_{rs,k}^j=\frac{\exp(-\theta M_{rs,k}^j)}{\sum_{j\in \boldsymbol{J}}\sum_{k\in \boldsymbol{K}_{rs}^j}\exp(-\theta M_{rs,k}^j)} \quad (9)$$

$$q_{rs,k}^j=Q_{rs}\cdot\alpha_{rs,k}^j \quad (10)$$

In the formula, $\alpha_{rs,k}^j$ is path selection probability of path k of mode j between (r,s) .

4 Network and parameters value

The multi-mode transport network is shown as Fig.1, and the information of road, subway and bus is shown as Table 1 and Table 2. The value of important parameters: $g=1.22$ yuan/k [6]; $\theta=-2$ [5]; $Q_{OD}=5000$ person/h.

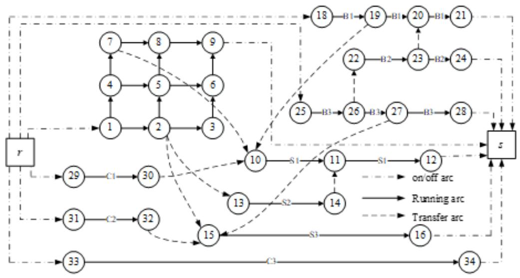

Fig. 1. The multi-mode transport network

Table 1. The information of roads

Section	Length/km	Travel time with zero flow/min	Capacity/(pcu/h)
1-2	4.7	5.0	1500
2-3	3.5	4.0	1000
1-4	3.0	3.0	1200
4-5	4.2	6.5	600
2-5	2.4	3.5	500
5-6	3.7	5.5	700
3-6	3.2	3.0	1200
4-7	4.8	5.0	1200
7-8	5.0	5.0	1500
8-9	3.5	3.5	1500
5-8	5.0	7.5	500
6-9	5.3	5.5	1200

There scenarios are design in this paper. A The original network without customized bus; B The network with customized feeder bus (C1,C2); C The network with customized direct bus across multiple regions (C3). The method of successive averages is used with a 10^{-3} limit of error.

Table 2. The information of subway and bus

Type	Num	Capacity/ (person/h)	Max capacity/ (person/h)	Speed/ (km/h)	Departure interval/min	Segment	Length/km
subway	S1	1000	2000	50	5	10-11	4.5
						11-12	3.0
	S2	1000	2000	50	3	13-14	7.4
	S3	1000	2000	40	5	15-16	9.0
Conventional bus	B1	600	1200	20	10	18-19	7.5
						19-20	5.2
						20-2	3.2
	B2	600	1200	25	15	22-23	9.6
						23-24	3.5
	B3	600	1200	20	10	25-26	2.5
						26-27	1.5
						27-28	11.7
Customized bus	C1	-	-	30	-	29-30	8.0
	C2	-	-	30	-	31-32	5.0
	C3	-	-	30	-	33-34	16.3

Note: the fee of C1 and C2 is 8 yuan, the fee of C3 is 15 yuan, and the standard for pricing of subway and conventional bus follows the existing standard in Beijing.

5 Results analysis

When the unit travel time cost equals the unit average income of residents in Beijing in 2018, that is λ=19.8 yuan/h[7], three scenarios have their solutions shown Table 3. Taking Scenario A as an example, the process of convergence is shown as Fig.2, It proved that the algorithm is convergent and efficient. The operation of customized bus would raise the choice probability of public transit and reduce average of travel time, and the optimizations of customized direct bus across multiple regions is significant than customized feeder bus.

Table 3. The solution of three scenarios

Scenario	A	B	C
The choice probability of customized bus/%	0	6.9	7.6
The choice probability of public transit/%	72.0	74.8	75.2
The average of travel time/min	44.1	43.9	41.0

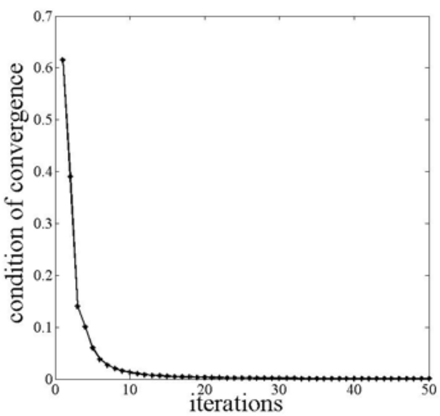

Fig. 2. The process of convergence

Under the condition that other conditions remain unchanged, the customized bus travel selection probability of different λ is shown in Fig.3, and the average of travel time is shown in Fig.4.

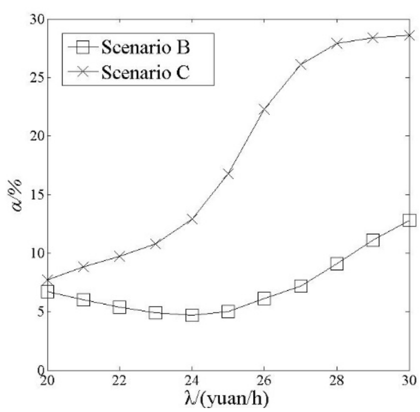

Fig. 3. The choice probability of customized bus

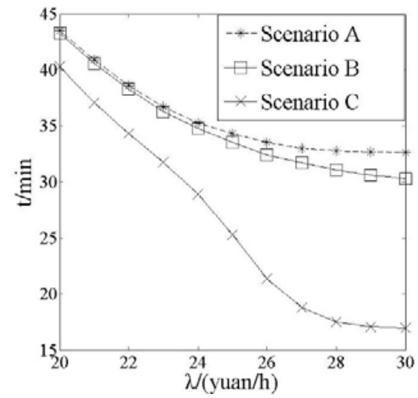

Fig. 4. The average of travel time

When λ=20~24 yuan/h, the choice probability of customized feeder bus decreases with the increase of λ. When λ=24~30 yuan/h, the choice probability of customized feeder bus increases with the increase of λ. When λ=20~30 yuan/h, the choice probability of customized direct bus across multiple regions increases with the increase of λ.Therefore, with the development of social economy, the competitiveness of customized feeder bus will be improved when the unit travel time cost reaches a certain level, and the competitiveness of customized direct bus across multiple regions will be steadily improved. Under different value of unit travel time cost, the competitiveness of direct line mode is stronger than that of the feeder mode.

In the range of λ=20~30 yuan/h, the average of travel time of the network with customized bus is less than that of the original network. With the increase of time cost, more travelers choose customized public transport mode, which improves the network traffic efficiency. Under different value of unit travel time cost, the direct line mode is better than the feeder mode.

6 Conclusion

- With the increase of unit travel time cost, the competitiveness of customized feeder bus decreases firstly and then increases, while the competitiveness of customized direct bus across multiple regions will be steadily improved.
- The operation of customized bus would raise the choice probability of public transit and improve the network traffic efficiency.
- Under the same conditions, the direct line mode has stronger competitiveness and more significant optimization effect on network than the feeder mode.

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REFERENCES

[1] R Jiang, J Zhuo,"Competitiveness of customized bus system and its planning strategy", Planners, vol.34,no.8,pp.113-119,2018.

[2] X Fu, Y Gu, Z Y Liu,"Scheduling activity and travel patterns in multi-model transit networks with customized bus services", Journal of Transportation Systems Engineering and Information Technology,vol.19,no.4,pp.20-27, 2019.
[3] Bureau of Public Roads, Traffic Assignment Manual, Washington, D.C.: U.S. Department of Commerce,1964.
[4] B F Si, M Zhong, X B Yang, et al, "Urban transit assignment model based on augmented network with in-vehicle congestion and transfer congestion",Journal of Systems Science and Systems Engineering,pp.155-172,2011.
[5] Y Li, B F Si, X B Yang, "A stochastic user equilibrium model and algorithm for urban transit network with transfer cost",Systems Engineering Theory&Practice,vol.34,no.8,pp.2127-2134,2014.
[6] Beijing Transport Institute,2019 Beijing transport annual report, Beijing: Beijing Transport Institute,2019.
[7] Beijing Municipal of Statistics,Beijing Statistical Yearbook 2018, Beijing: China Statistics Press,2019.