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Model and Algorithm for Traffic Network Design

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Abstract. Introduction Starts from the analysis of the different levels of service constraints impact to the network design, this paper combines the indicators in the levels of network service and road service, and then builds the bi-level programming model of road network design based on the level of service. And the paper solves the bi-level programming model based on the simulated annealing to verify that the saturation constraint values of the level of link service can be relaxed under the premise of ensuring the overall level of network service, by which road resources are be used fully with little impact of the road network.

Keywords: traffic network design, level of service, bi-level programming model, equilibrium allocation, the simulated annealing

1 Introduction

In view of the actual environment of traffic demand model and the difference of traveler's route choice behavior, this paper combines the application scope of bi-level programming model with the constraints of service level index, and gives a description of corresponding objective function and constraints in order to make the model more close to the actual situation[1-5].

Traffic demand model in different road network and traveler's route choice behavior exist difference, this paper investigates such a kind of traffic network. The travelers of this traffic network usually have fixed travel demand, and they know from experience that the crowded degree and the needed walking time of every line in the traffic network.

The small and medium cities of no less than 500,000 can be divided into this type of traffic network, because of their relatively small size and less turnover of people, the traveler's fixed traffic demand and the specific path selection are easier to be satisfied[6-8].

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2 Model for traffic network design by the user equilibrium allocation

Suppose a small city’s traffic network: it has a population less than 500,000, its urban area is not big and city land development is relatively balanced, their travelers have a fixed travel demand. The needed walking time of every line in the traffic network because the less turnover of people in this traffic network.

Considering the resident trip of small city is more regular and travelers usually have specific travel purpose, that is to say, most travelers’ starting point and destination are relatively fixed so the proportion of the traffic volume between origin-destination of every road to the total traffic is determinate.

When the existing roads of this kind traffic network can't satisfy travelers' traffic demand with the growth of travel demand, at this time we need to the study the network design problem in order to derive the optimal strategy.

Considering such traffic network is relatively stable and its traffic demand is relatively fixed and travelers know very well from experience that the crowded degree and the needed walking time of every line in the traffic network, therefore, we can approximately think that people completely know the travel time of each section in this traffic network.

At the same time, this paper doesn’t consider the difference caused by factors such as traveler’s income level and so on, it assumes that the criterion of all travelers’ route choice behavior is their shortest actual travel time. So this traffic network can be thought to approximately correspond with the two preconditions of UE (User Equilibrium), the lower model takes the UE model to describe traveler’s route choice behavior.

When choosing the objective function of the upper resource allocation, considering the objective function of minimum system travel cost is the most commonly used, we intend to apply this objective function. The premise of application of this objective function is that the traffic demand is fixed between origin-destination of the road.

We put the investment cost function as weighing ϕ in the objective function of the upper model because of without restricting maximum rating of investment cost. ϕ is the proportionality coefficient that synthesizes information about weighing of 2 purposes (minimum system travel cost and minimum investment cost function) and matching of measurement unit of travel cost and investment cost. The higher the value of ϕ , the smaller the investment budget; the lower the value of ϕ , the larger the investment fund.

3 Experiment Design and Discussion

For the first design goal of the example, the paper compares case 1 with case 2 in order to verify that the model adopts constraint of comprehensive service level evaluation index is better than the one only uses the capacity limit. Improved saturation of the two cases is shown at Table 1:

Table1 shows that most of the roads have a high saturation in case 1, and the service level of these roads is very low at this time, the traffic is in saturate flow state. Although the road is still in the connected state, but the road traffic condition is not stable and is easy to cause traffic congestion. So although the previous traffic network design problems only considered capacity limit could ensure that the traffic flow is less than the section capacity to solve the problem of optimal investment decision, but the improved roads have a poor service level, and form certain potential risks to the traffic.

Table 1. Improved Saturation of the Two Cases

road	Case 1		Case 2	
	Capacity increment (pcu/h)	Improved saturation	Capacity increment (pcu/h)	Improved saturation
1	540.0	0.99	1770.0	0.7498
2	740.0	0.90	1795.6	0.6848
3	0.0	0.09	0.0	0.0939
4	354	0.99	1318.9	0.7499
5	780	0.99	1882.1	0.7499

In order to solve this problem, the paper joins the comprehensive saturation evaluation index constraint in case 2 to ensure that the road service level is above C, the correction of the traffic network maximum saturation constraint is not considered at this time. The improved saturation of the roads as in table 4, it shows that all the saturation is lower than 0.75 and the service level is above C.

The actual traffic network saturation of the two cases is respectively 0.8623 and 0.6699. Through the above comparison: the model joins the service level constraint can better meet the traffic planner and traveler's expectation of road service level and keep the road service in reasonable level, and get better road network transformation scheme than previous model. But, the correction of the traffic network saturation constraint is not considered in case 2, the actual traffic network saturation is 0.6699, it does not form an active constraint to the service level from the whole aspects. So the following text studies the problem combines with case 3.

4 Conclusion

Traffic network design problem is a game between traffic planning department and traveler. The paper adopts the bi-level programming model to describe the game progress, and sets up the traffic network design model based on the user equilibrium allocation. The upper resource allocation problem is used to describe the traffic planner's decision, and it chooses the minimum system impedance as the objective function; the lower traffic flow problem reflects traveler's response to the decision, and it chooses the UE model to describe the traveler route choice behavior. In the process of modeling it join s comprehensive service level evaluation index constraint on basis of the previous research, makes comparative research on the three cases through different parameter values to verify we can get better traffic network retrofit scheme if the comprehensive service level evaluation index is added as limit condition in the traffic network design model.

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