

Design of Aided Decision-Making Program for Prioritizing Construction Projects in Urban Road Network Planning^{*}

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Abstract: The importance and complexity of prioritizing construction projects (PCP) in urban road network planning lead to the necessity to develop an aided decision-making program (ADMP). Cost-benefit ratio model and stage-rolled method are chosen as the theoretical foundations of the program, and then benefit model is improved to accord with the actuality of urban traffic in China. Consequently, program flows, module functions and data structures are designed, and particularly an original data structure of road network is presented, which has smaller data redundancy and makes dynamic modification easy. Lastly, the program is developed, and its application in the urban general transportation planning in Suzhou city achieves a good effect.

Key words: prioritizing construction projects, program design, urban road network planning, aided decision-making

The plan of urban road network is actualized by means of implementing construction projects, i.e. roads and intersections, while such constructing process influences reasonable allocation of a large number of funds and relates to whether the plan can take effect or not. Therefore how to give the priority sequence of construction projects becomes a focus of decision-makers.

Up to now, many traffic scholars have presented some effective methods of prioritizing construction projects (PCP), most of which ask for iterative structure modifications, traffic assignment simulations and cost computations of whole road network^[1, 2]. Furthermore, the amount of construction projects is commonly very large. Thus, lots of work results from those methods, which is impossible to be completed only by hand. So we have to develop practical program for PCP to adopt computer-aided decision-making. But this is a rather “aided” than “automatic” decision-making program, because factors taken into account are too many to absolutely exclude manual decision-making.

1 Theoretic Foundations

In order to design aided decision-making program (ADMP) for PCP in urban road network planning, above all, we should choose appropriate models and methods, which are supported by reasonable theory, specially are easy to be programmed and operated. Finally, cost-benefit ratio model is used for project evaluation,

while stage-rolled method is chosen as iterative frame, for some reasons as follows.

1) These models and methods are not only simple to understand but also based on reliable theoretical foundations.

2) In addition to its quantifiable index and its suitability to programming, the cost-benefit ratio model in this paper takes into account so many kinds of benefit resulting from construction project as to evaluate project objectively and credibly.

3) Stage-rolled method has a few of advantages. For instance, in this method, uncertain factors of funds, construction time, etc. have little effect on eventual priority sequence, and the number of iterations can be preset to suit different evaluation models. In addition, it is a dynamic method for using variable origin-destination (O-D) trip matrix. Furthermore, singly evaluating method and rolling method, another two PCP solutions, are both their special cases, so that program designed for them can be directly applied to those two ones.

1.1 Benefit model

Since cost computation is relatively simple, benefit model becomes the most important part of the cost-benefit ratio model, which is essential in PCP theories.

Ref.[1] proposed a benefit model expressed as

$$B(p) = C_0 - C_1 \quad (1)$$

$$C = \sum_{\alpha} c_{\alpha} \quad \alpha \in A \quad (2)$$

$$c_{\alpha} = v_v(k_i t_v + k_l l) \quad (3)$$

where B is benefit of project(s) p ; C_0 is the cost of original road network that does not contain p , C_1 is the cost of new net that is formed by adding p to C_0 ; C is cost of a general net such as C_0 and C_1 ; c_{α} is cost of link α ; A is the set of all links of this net; v_v , t_v , l , k_i and k_l are vehicle volume, average vehicle travel time, link length, time-related vehicle value coefficient and length-related vehicle value coefficient of link α , respectively.

The essence of this model is that the benefit of a project is caused by the decline in network cost before and after it is construed. In other words, entire net cost, including the part resulting from completion of the project, is calculated, so does net without this project, then the differences between those two costs can just be regarded as the project benefit.

The model above does not cover factors about bicycle, however, bicycle-mode trips share a large proportion of total trips of all modes in common Chinese cities. Thus, net cost is proposed to include the part related to bicycle-mode trips, and then formula (3) can be modified as

$$c_{\alpha} = v_v(k_i t_v + k_l l) + v_b k_p t_b \quad (4)$$

where v_b , t_b and k_p are bicycle volume, average bicycle travel time and passenger time value coefficient of link α , respectively. As a result, the improved benefit model is more reliable for its better accordance with traffic conditions in the cities of China.

1.2 Stage-rolled method^[1]

In stage-rolled method, the set containing all the construction projects within a given planning period is divided into several subsets, which will be individually arranged in different construction stages with respective interval and start-stop year. On the one hand, each subset is regarded as a single super-project, and then all super-projects are prioritized by ordinary rolling method; on the other hand, for each super-project, its projects are prioritized by singly evaluating method, namely are ranked according to their evaluation indices.

Fig.1 demonstrates the whole procedure of stage-rolled method, where N_0 (the root node of tree) is existent road net, N_n (the bottom one) is planned net; n is the number of stages(or subsets), level i represents the i -th rolling ($i = 1, 2, \dots, n$), N_i (the

most left node of level i) is the developing net after i -th rolling, other nodes are temporary nets for comparison, the very path from root to bottom corresponds to the final sequence of subsets.

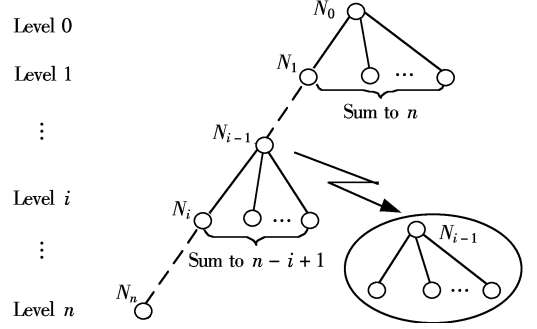


Fig.1 Tree diagram of stage-rolled method

Given result of the preceding iteration, the i -th rolling can be summarized as follows.

Step 1 Add the $n - i + 1$ remained subsets, respectively, to N_{i-1} to get $n - i + 1$ temporary nets (shown as nodes in level i), evaluate each of these subsets on its temporary net, and choose the optimal one as current subset.

Step 2 Add projects of the current subset respectively to N_{i-1} to get several temporary nets (shown as part in ellipse), evaluate each of these projects on its temporary net, and give their priority sequence.

Step 3 Remove the current subset from list of the remained and label its temporary net as N_i .

2 Program Frame Design

2.1 Flow charts

Fig.2 shows the flow chart of ADMP for PCP, and Fig.3 shows that of subprogram for evaluating project(s).

2.2 Module functions

The designed ADMP for PCP consists of the following main modules: ① To create project set and subsets; ② To dynamically modify road network; ③ To assign and assess traffic in network; ④ To evaluate project(s).

2.2.1 To create project set and subsets

The main functions of this module are summarized as follows:

1) Compare existent road network with the planned, and specify every project to form project set.

2) Divide the project set into several subsets, according to traffic functions, spatial relations,

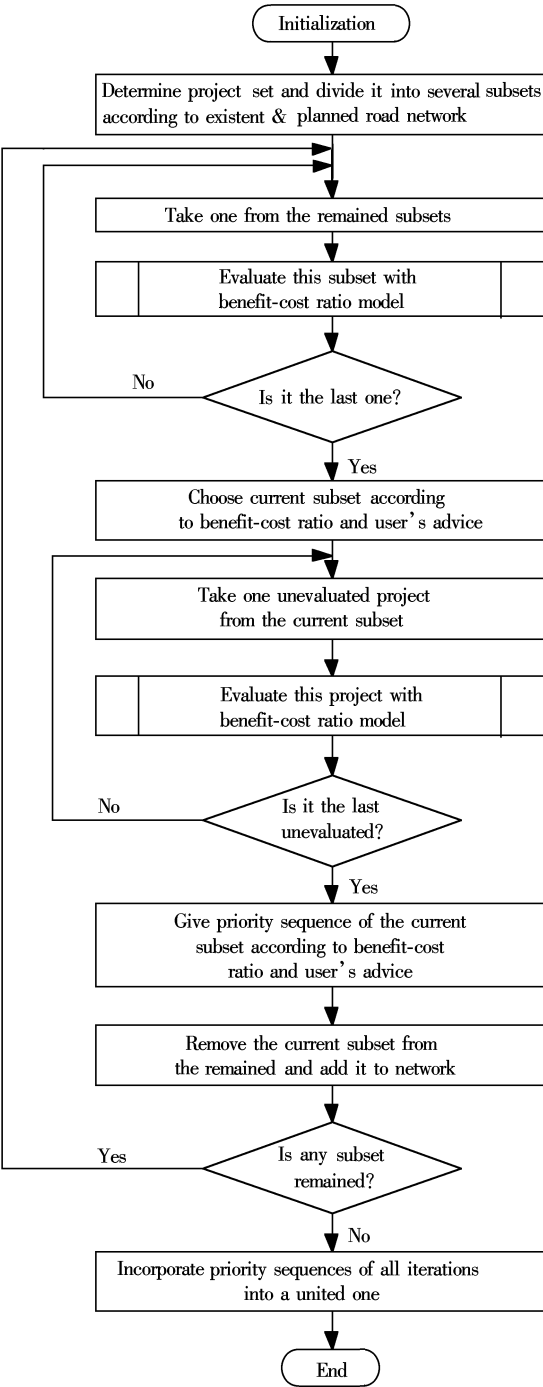


Fig.2 Flow chart of ADMP for PCP

construction scheme of projects and fund constraints, and individually arrange these subsets in different construction stages with respective interval and start-stop year.

3) Check integrity and consistency of all inputted data including attributes, number of projects and number of project subsets.

In fact, most work of this module has to be finished with user's conducts and inputs. So the reasonable and valuable advice of specialists are of great importance for executing this module.

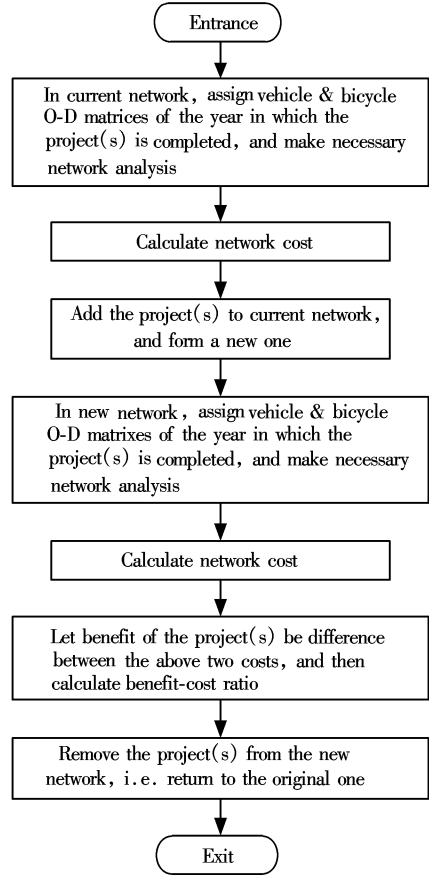


Fig.3 Flow chart of subprogram for evaluating project(s)

2.2.2 To dynamically modify road network

The main functions of this module are summarized as follows:

- 1) Add a project or projects to road network with simulation of constructing, i.e. dynamically modify the network;
- 2) Check integrity and consistency of network both in data and in topology.

The truth of PCP is simulation of constructing and succeeding evaluation of effects, and network's dynamic modification is the embodiment of simulation of constructing in program. Therefore, this module is the kernel part of ADMP, and also is a precondition of the third module.

2.2.3 To assign and assess traffic in network

The main functions of this module are summarized as follows:

- 1) Respectively assign predicted vehicle and bicycle O-D matrices of a given year to corresponding road lanes in a given network, and then obtain predicted vehicle volume and bicycle volume of every link, of that year.
- 2) Assess the traffic flow in the network; mainly

calculate predicted average travel time both of vehicle and bicycle, of every link.

This module provides data for the fourth module, and is the most complicated one. But in order to decrease complicity and to predict O-D matrices, the popular traffic analysis software packages, which are used in urban transportation planning and are capable of doing traffic assignment and assessment, should be adapted for this module.

2.2.4 To evaluate project(s)

The main function of this module is to calculate network cost and evaluate project(s), with inputted necessary parameters as well as traffic information outputted by the third module.

3 Key Data Structures

3.1 Project and subset

The project’s data structure has to make the necessary project operations easy and make data redundancy small. Therefore, it has to hold attributes at least including project ID, kind (new construction or reconstruction), cost, link sequence and node sequence, where link sequence lists all road links of this project, and node sequence lists newly-constructed and reconstructed intersections concerned. The first three attributes are of fixed storage space respectively, and can be stored in fixed structure, while the last two are of alterable storage space for alterable amount, and should be stored in dynamically linked lists.

In the same way, the data structure of project subset has to hold attributes at least including subset ID, interval (the length of construction stage), and project sequence, which is stored in a linked lists, as well.

Fig.4 shows the data structures of project and project subset, where arrow represents pointer, “...” abbreviated element and “^” represents null pointer, i.e. the end, respectively, of linked list.

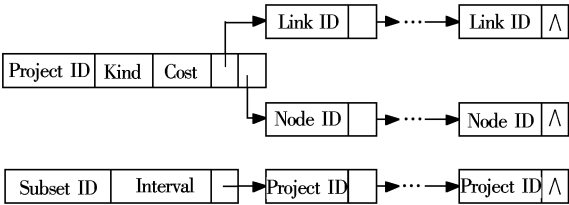


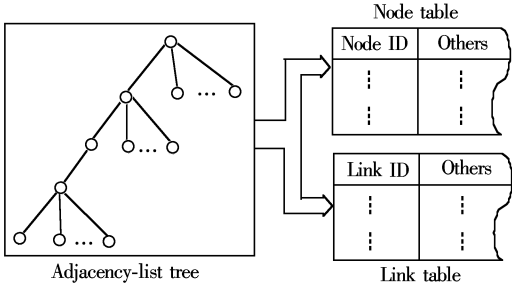
Fig.4 Data structures of project and project subset

3.2 Road network

The data structure of road network means repre-

sentation of network topology and of property data of nodes and links. Road network topology, a directed graph with a set of nodes and a set of links connecting these nodes, is commonly expressed as adjacency matrix, adjacency list, and adjacency multilists^[3, 4]. In this paper, adjacency list is chosen for a tradeoff among simple structure, efficient storage, and strong capability to network operations. On the other hand, property data of nodes and links can be respectively stored in node table and link table, which are relation database tables or ordinary linear lists. Node table holds fields of node ID, type, etc. and link table holds fields of link ID, start node, end node, class, etc. Thus, we can easily traverse network, search the shortest path^[5, 6] and do other network operations on adjacency list, and we can access, add, delete, modify and query property data on node table and link table, with the linkage between adjacency list and those two tables based on primary keys, e.g. node ID, link ID.

The above data structure only suits a single network, however, many road nets are involved in stage-rolled PCP, e.g. existent net, planned net, other temporary nets, which are interrelated and have a common major part. If these nets are expressed as several individual ones in above structure, there is no doubt that it will lead to huge data redundancy and to quite difficult modifications to road nets. To overcome these shortcomings, we proposed a new data structure, based on above version, of multiple road nets, i.e. a dynamically evolving net, which is shown in Fig.5.



every node, which is on the path from the root to the node.

Furthermore, node data of existent net and those of planned net are stored in a single node table, so do link data, namely data of each temporary net, including the existent and the planned, are just a subset of the node table and link table. The arrows in Fig.5 represent the forming of every adjacency list and its linkages to the node table and the link table.

4 Application and Conclusion

According to the theoretical foundations and design principles as stated above, the ADMP for PCP in urban road network planning is developed based on traffic analysis software — TranStar. In company with advice of local specialists and administrators, the program is applied to the urban general transportation planning in Suzhou city, where for the near term exist 58 construction projects, which total up to 205 km and ¥3.6 billion. In general, the result of executing program meets the requirements of traffic demand both in theory and in practice.

In conclusion, the ADMP for PCP in urban road network planning designed in this paper has the following characteristics: reliable theoretical foundations, original programming techniques and effective

application in practice, which are worth being used for reference.

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城市路网规划建设项目排序的辅助决策程序设计

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摘 要 针对城市路网规划建设项目排序工作的重要性和复杂性, 有必要开发相应的辅助决策程序. 首先选择效益/费用比模型和阶段滚动法作为程序的理论依据, 同时针对我国城市交通的现状, 对效益模型进行了改进. 然后设计了程序流程、模块功能、数据结构, 特别提出了一种数据冗余度小、动态调整方便的路网数据结构. 最后实现了程序的开发, 并在苏州城市综合交通规划中得到了应用, 取得了良好的效果.

关键词 建设项目排序, 程序设计, 城市路网规划, 辅助决策

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