SITUATION AND ADVANCEMENT OF HIGHWAY NETWORK PLANNING IN MAINLAND CHINA

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Abstract: This paper systematically introduces the situations and advancement of highway network planning in mainland China, including its achievements, applied methods, existing problems and the prospects, which can offer the references for others.

1. INTRODUCTION

In the recent ten years, China highway network planning has been advanced rapidly and reached a new level both in application of theories and methods and in depth and extensiveness of studies. In order to strengthen the management and the macro-control of highway construction, and to prevent the randomness, blindness and duplication in the construction decision, the Ministry of Communications of the People's Republic of China issued "The Compilation Methods for Highway Network Planning" in 1990, so as to make the planning work more programmed, standardized and scientific. At the same time, the relevant government agencies at all administrative levels (provincial, city, regional, and county) were required to conduct a 30 year long-term highway network plan to make highway construction match the economic development.

The planning work lasted four years, and experienced tremendous advancements. The achievements were made not only in the methodological research but also in practical applications, which include data collection, investigation, development prediction, network layout and assessment. These contents reflect the latest development of highway network planning in China, this paper will give a brief introduction of them.

2. PLANNING WORK AND ACCOMPLISHMENTS

The nation-wide 30-year long-term highway panning involves in all the provinces, municipal cities and autonomous regions, and never before have so many people and material resources been used. In order to do well the work, full preparation has been made for the participant training, basic data collection and modern planning theory and method application.

2.1 Working Progress

To build an efficient national highway trunk system, the Ministry of Communications, in accordance with the guiding principles of "Planning as a whole, Sharing the responsibility and Jointly constructing", organized the concerned units and experts to do a lot of research based on the historical experience at home and abroad. The end product of the research is a report entitled "The Layout Planning of National Trunk Highway System" which was approved by the State Council in 1992 as the official document for guiding highway construction. The planning principles addressed in the report are based on the Chinese economic development structures, social values, demographic patterns, as well as the characteristics of existing transportation modes. It makes clear that the national highway truck system, which consists of five vertical lines connecting the north and the south of China, and seven horizontal lines connecting the east and the west, is an important part of the national highway network. This system will carry heavy inter-city passenger and freight traffic volumes and it will be completed in a sequence of consecutive National Five-year Plans. Once it is in place, a round-trip within 400-500 km travel radii or a one-way trip within 800-1000 km travel distances can be done in one day by it.

In 1993, another official document entitled "The Layout Planning of Main Stations of the National Highway " was put forward, in which 45 highway hubs were identified on the entire national highway network. In the same year, an in-depth assessment was carried out to evaluate the functionality, connectivity, and historical significance of the original highway plan. As a result of this assessment, some adjustments were made to the original plan, which led to a final National Artery Highway Network Plan. This plan considers the needs to meet the travel demand and the utilization of the existing highway infrastructures.

In addition to the work coordinated by the Chinese Ministry of Communication, all provinces, municipalities, and regions also conducted their own network planning on a 30-year span. Such massive and detailed highway planning had never been conducted at the city or regional level in the history of Chinese highway construction. The successful completion of these projects resulted in the publication of "A Drawing Collection of the National Highway Network Planning for the Years 1991-2020." It has become a milestone in Chinese highway construction history.

2.2 Primary Results

One of the most important effects from this series of projects is the full realization of the significance of highway network planning. The history of Chinese highway development since the Seventh Five-year Plan and the past 30 years of highway network planning has clearly demonstrated that planning is the first important step for building effective highway network systems. It serves as a basis for making decisions in capital investment and management systems. Careful planning maximizes cost effectiveness in highway construction and eliminates any unnecessary spending. The systematic planning can guide the direction network development to avoid any waste of funds.

Clearly defined objectives are the next achievement from the massing planning activities. The final 30-year highway planning blueprints lay out national highway systems with the inter-provincial highway network at the national level and intra-provincial highway network at regional levels. The blueprints provide the efficient means to establish highway construction plans and can serve as a decision making tool in highway management

systems. Due to wide participation from various concerned organizations, this plan was well publicized and well received by the general publics.

Another benefit coming from the massive planning activities is the hands-on practical training for many highway engineering professionals. Since conducting a systematic long-term highway planning is a relatively new subject for many involved in highway engineering in China, great progress has been made in both planning theories and modeling techniques. A group of specialized planning experts have merged.

Finally, because of these planning activities, a set of highway planning related documents have been published serving as official specifications and guidelines for Chinese highway planning. These publications include "A Collection of Research Papers for Highway Network Planning" and "A Drawing Collection of National Highway Planning." These papers reflect years of research findings, planning methodological development, and relevant data collection procedures. These documents are serving as guidelines and references for national highway planning activities.

3. DEVELOPMENT OF HIGHWAY PLANNING METHODOLOGY

In general, the planning methodologies adopted for highway network planning in China can be classified as follows.

3.1 Four-Stage Method

This method places the traffic volume analysis as its emphasis to determine its development targets. Under the guidance of the target, some network plans with the different levels can be put forward, and then their scales and preliminary layouts can be decided. Through OD surveys and analyses, the future traffic flow in the highway network can be predicted. With the application of the assessment indices or parameters, especially with the traffic flow conditions, the layout plans of the network can be readjusted, and the construction scales and projects also can be determined. The planning process by using the four-stage method is a continuous readjustment and optimization in the light of the actual traffic flow conditions.

The core of the four-stage method is the analysis and prediction for traffic demand through the whole planning process. Based on the motor vehicle OD surveys, the prediction starts from the social and economic development trend. The second prediction is the traffic products, the third is the traffic distribution and the fourth is the traffic assignment to the specific route lines in the highway network.

The layout optimization and the network assessment can be done in accordance with travel time of different plans. Through a comparison of the travel time, it can be decided which plan is the optimum or whether to change the route lines. The readjustment and optimization of the network layout can also be achieved by evaluating the adaptability of the network to the traffic quality so as to determine whether the network distribution can meet the traffic demands or whether the arterial line can go with the main traffic flow direction.

There are three important subsystems in evaluating proposed highway projects, namely technical assessment, economic assessment, and social assessment. The technical

assessment involves the evaluation of highway functionality such as network density, connectivity, type of facility and percentage of paved highways, and traffic characteristics such as average speed and degree of congestion. The economic assessment contains the measurements such as the ratio of benefit to cost, net present value, and internal rate of return, payback time, and capital deficit (the difference between the available fund and actual cost of the project). These measurements are used in comparing the projects, such as the built plan vs. the no-built plan. The social assessment consists of estimating the impact of proposed project on the environment such as air quality, noise, and vibration. The social assessment also includes the estimation of potential disturbance of proposed project to natural land features and inhabitants. The fuzzy-logic models are often used to carry out social impact assessment. The combination of all three subsystems determines the feasibility and effectiveness of proposed highway network plan.

Using motor vehicle OD survey as the basis, the four-stage model has many advantages in predicting traffic flow and providing information for system performance evaluation. The results from OD survey provide valuable information for research of the multi-modal transportation system too.

3.2 Total Quantity Control Method

Total quantity control method starts from the total traffic demands of an area. The method places the layout optimization as its emphasis and uses the optimization models to determine the highway network scale and the percentage of the highway mileage in each class of facility. Based on the analysis of the total demands derived by the social-economic development and the distribution about the region's nodes, the optimized tree principle in the network theory is adopted to determine each route alignment and the general layout of the highway network according to its function, position and role. The analysis of the traffic volume on the routes is done with the help of computer models and experienced panels of expert. On the basis of all the above, the technical class of the route lines can be decided and the construction sequences can be prioritized according to the urgency of each project.

Under the current assessment procedure, this method proposes the highway network assessment system including road characteristics, traffic characteristics, level of service, and accessible performance. The measurements of the road characteristics include the network capacity, network classes, and percentage of paved roads. The measurements of the traffic characteristics involve the traffic volume, vehicle average running speed, and traffic density. The measurements of the level of service include the degree of network congestion, rate of mileage in saturation flow, and the frequency of traffic accidents. The measurements of the accessible performance involve the connective degree, network density, and the node accessibility. In the quantitative analysis, the first step is to assign numerical values to the network classes, vehicle average running speed, the degree of congestion, the frequency of traffic accidents, the network connective degree, and the network density. The second step is to conduct assessment of the highway network based on synthesizing above results.

To plan the highway network layout, the "optimized tree" principle is adopted to determine the main highway profile. The first step is to determine the key nodes in the region and then to estimate their importance by using the measurements like the population and G.D.P of the nodes. The next step is to estimate the importance of each highway link according to the importance of the nodes connected by it and then to determine an optimized tree in the

network by maximizing the importance. The optimized tree represents the main trunk lines in the highway network, and at this time the network is a tree-like structure. By taking the link importance in a unit of mileage as an objective, the increase of accessibility and decrease of travel cost as constraints, the optimization of the network can be realized with the maximized objective function. Some optional links can be added between the nodes, which will turn the original layout of tree-like structure into network structure. Finally, through a classification analysis, the lines that connect the same category nodes can be taken as one class so that the administrative levels of the network may be classified.

The quantity control method does not include the OD surveys of motor vehicles. In order to determine the class scale of the network, traffic volume distribution on individual links have to be predicted. The increase of traffic volume on each link should be estimated according to the increased travel speed. To implement the plan, an urgency function of *f(I,S,B)* is adopted. In this function "I" is the importance of the links; "S" is the coefficient of traffic volume on the links; and "B" is the coefficient of link administrative levels (country, province, county and township). Through calculations, the degree of urgency associated with each link can be obtained, based on which the order of importance for the proposed construction projects is prioritized.

3.3 Traffic Location Method

The traffic location method provides the on-site analysis to identify the highway network problems. With the prediction of the social, economic, and transportation development and the correlative analysis, the concept of "traffic field" is used to predict the future traffic volume. The prediction of the general scale of highway network can be achieved with the help of such theories and techniques as connective degree, bionic density method and density upper bounding method. The study of the highway layout is undertaken with the traffic location line and other methods while the network optimization is often achieved by the analysis of a single factor or multiple factors.

The basic principle of the bionic density method is to follow the directions in which the travel time from any arbitrary point to the center of the network is the shortest. Under the same condition, the total mileage in the network is always the shortest. With the imitation of the spider net for the highway layout, the total length in the highway spider net can be calculated and the general scale in the highway network can be predicted. The density upper bounding method holds that the development level of highway density should follow the law of growth curve. It has to experience the initially growing period, rapidly growing period, slowly growing period and the limitation. According to the law of growth curve, with the reference to the highway development history of other countries, the network scale can be determined based on the correlative analysis of highway network density to the region's population and the gross domestic product.
It is a new and explorative approach to predict future traffic volume with the theory of traffic field. In this method, the planned area is taken as the electrical field and the movements of passenger and freight due to the economic center's attraction are taken as the traffic field. In this case, the prediction for traffic demands is carried out with deducing highway OD flow by means of electricity principles.

There are two levels in highway network layout and optimization. The optimization on the first level includes the work of identifying traffic location lines, transportation development strategy, highway traffic network and network flow. Specifically, the work is

to identify the area or the corridor where the traffic volume would be the greatest in the form of traffic location lines in which highway routes should be planned. Then, after studying the regional economic development strategy, planners can assess the highway transportation strategic significance in the area, determine the region's transportation network strategic layout, and attain the optimization purpose for traffic development strategy. For the optimization of traffic flow and the network, the optimized tree method is often adopted to determine the smallest tree in the mileage, the biggest tree in the traffic volume, the biggest tree in congestibility and the best tree in the connection of various nodes. Through calculating the overlapping numbers of the above four kinds of trees, the importance of the highway network can be determined. The optimization on the second level is to basically determine the arterial lines' alignment through the comprehensive analysis of the above three factors, and then decide the different network administrative levels according to the lines' function and role, and finally determine the highway network layout.

4. EXISTING PROBLEMS

Although China has made great progress in highway network planning, there are still some problems that need to be addressed. A uniform, consistent planning model needs to be developed yet. More work needs to be done in developing a standardized procedure for highway system's evaluation and optimization. The lack of a well-programmed and validated computer software is an urgent problem that could preclude further progress in highway planing. Comparing with developing countries, China is still behind in the application of advanced computing technologies in highway planning activities, such as computer graphic capabilities, GIS and GPS technologies. Specially, there are still some misunderstandings in the planning objectives and guiding principles. The problems are summarized in the following paragraphs.

4.1 Planning Objectives

The present planning work mostly sets to "meet the needs of traffic" and " improve the traffic functions in the network" as the main objective. This kind of planning, essentially, progresses around the traffic volume and its guiding principle is "supply-follower type". However, it is rather difficult to do accurate estimation for traffic volume. Particularly, the long-term traffic prediction involves in many factors, including dynamic economic development in the future, relation of economic increase to the traffic volume, relationship between highway traffic and other transport modes, the temporary changes of traffic distribution and influence of road supply on the economy and traffic demand. The errors from any of the above are difficult to be controlled, and the accumulation of these errors will often indicate itself in the traffic prediction. As the highway network construction demands great financial and material resources, the irrational scale, density and alignment of the network will surely affect the development speed and prospect of an area. Therefore, there will be great risk and blindness if only the seemingly accurate but unknown traffic volume is used to determine the highway network scale and layout which have an extensive and lasting impact on the social and economic development.

Because of the above reasons, the highway construction scale cannot entirely set to "meet the needs of traffic" as its objective, but take the basic goal of human pursuit --- "to promote sustainable and peaceful social development" as its standard. Suiting traffic

demand itself is not the purpose, but the means to approach the goal. It is wrong to think that meeting the traffic needs under any circumstance can promote the realization of the planning objective. Its effectiveness and reasonableness are limited in the certain range. To a certain traffic demand, there may be many ways to treat it. It can be transferred, or replaced or limited, but not be met only with a supply. When the traffic prediction is not accurate, wrong results will be produced for the highway network scale and layout by only meeting the traffic demand, hence a serious impact on the sustainable development of the economy.

4.2 Traffic Prediction

The present methods for predicting future traffic volume heavily depend on what had occurred in the past. As we have all witnessed, the Chinese economic development has been very dynamic; resulting in constant and sometimes unpredicted changes in the distribution of employment opportunities. The economic restructuring in an area certainly brings about the great changes in social and economic development, which in turn will shift travel patterns. The past experience cannot always serve as guideline for the future.

Considering the potential environmental impacts, it is not a rational idea to meet the demand by merely expanding roadways. The solutions for traffic congestion should come from both the supply and demand side of the system. Because of the elasticity of the traffic volume and many other functions in the social and economic development, it is not possible to solve highway congestion problems by merely widening the roads and increasing the network density. When the traffic demand for a particular part of highway goes beyond the facility's capacity, some form of demand management measurements should be taken to control the traffic growth, such as guiding traffic to alternative route or promoting alternative travel modes. That is, the prediction of traffic demand should not purely rely on the past tendency; an unlimited increase is impossible. There should be a reasonable limitation, which can be formed either by the existing supply conditions or by the intended management strategies.

4.3 Evaluation System

Assessment to the highway network includes many contents. First, it is to check whether the layout meets the needs of the regional social-economic development, whether matches the future distribution of employment patterns and demographic changes. In other words, a qualitative and quantitative analysis should be done to the general network layout. The assessment not only requires the indices reflecting its technical characteristics, but also requires the vivid and direct macro-indices reflecting its covering to towns, resources, and industrial and agricultural bases. Second, it is to evaluate the structure of the highway network such as netting degree of highway and types of connecting nodes. Finally, it is also to assess the operation and service of the highway network, which needs some measurements such as travel speed, travel time, and the degree of congestion. Due to spatial and temporal characteristics of highway network and traffic flow, a complete evaluation must be carried out over space and time.

Although great efforts have been made on the evaluation index system of the highway network, the current problems are those, in general, there are too many specified technical indices, too many abstract and average-value indices, and lack of necessary refinement. In the further, more attention should be paid to the non-technical evaluation indices. These

indices should be able to display the spacial characteristics of the network vividly, show the social-economic needs and the environment protection demands clearly, and reflect the impacts of highway construction on the industrial layout and resource development as well as the quality of people's lives properly.

4.4 Planning Dynamic

The highway network planning, especially the long-term planning has a long lasting effect. As many factors may change over time, some new developments could take place, which may not be accounted for in the original plan. To accommodate new changes, readjustments need to be done with updated new information. Otherwise, the original network plan would not be functioning as expected. It is wrong to think that highway network planning is a one-time task. To make an effective plan, it is necessary to continuously make adjustments according to new situations. Planning is indeed a dynamic process. To preserve the original goals of the plan and minimize the amount of readjustment, efforts must be made in comparing the original plan with the readjusted one. The readjustment needs expenditure, the magnitude of which depends on the administrative level of readjusted network. The structure of highway network is composed of main trunk facilities, arterial highway facilities and local connectors, the cost of readjustment will reduce gradually from the first to the last.

5. PROSPECTS

Having introduced the situation and discussed existing problems, according to the main points of current researches, we will present the future development of highway network planning in China in this section.

5.1 Make Clearer the Planning Principles

As discussed previously, the aim of highway network planning should go with the strategy of sustainable development and the principle of "promoting the continuous and peaceful social development." The planning objectives are not simply to "meet traffic demand". It is about to promote healthy economic development, to protect natural environment, and to provide mobility to the labor force.

The fundamental consideration for determining the reasonable pattern and layout of highway network is to fully take advantage of the existing topography, which involves in such factors as the socioeconomic considerations and environment. By means of the lever of highway network planning, we can also make the distribution of productive force, utilization of land resource and social environment be readjusted and optimized. In order to achieve the above goals, it is necessary to have the cooperative work from different departments and to mobilize the experts from various disciplines, such as sociology, economy, traffic operation, and national institution for land use planning, to participate in highway network planning. The planning results should be evaluated in detail from all perspectives. In dealing with the relationship between the travel demand and transportation supply, there should be bi-directional and dynamic planning. Under no circumstances should the transportation demand alone be used to determine the future development of highway network.

5.2 Gradually Establish Highway Planning System

The highway planning is one of the key components of the national economic development planning. It has a great impact on the social development. It is also the subsystem for a comprehensive multi-modal transportation planning. In the interior of the highway trade, the highway planning includes the planning of highway basic facilities, transportation station layout, the systematical development of automobile transport, the other equipped facilities, service system development, and highway maintenance programs. As to the main components and phases of the planning, highway planning includes the long-range layout, the medium long-range construction and short-range construction. From the management levels, the planning involves the planning work of national trunk lines, national lines, provincial highways, and county and township roads. As regard to the content and scale, the planning includes the general work, special work and key work. From the geographical point of view, planning is made up of nationwide, regional, provincial, and local work.

In order to perfect the highway planning system continuously, not only the plan of highway network layout is needed, but also a comprehensive highway system plan, which is composed of the plans of station, transportation, management, and other special plans. At the meantime, it should be noted to coordinate and connect with the development of other transportation modes. It is necessary to consider the medium long-range plan between the long-range and the five-year plan so as to link up the 30-year plan, 10~15-year plan with 5-year plan for the future continuous development.

5.3 Strengthen the Basic Research

According to the practical needs of the planning work, such systems as base data collection, analysis and transmission should be set up step by step, which can clearly and systematically show the development situations of highway traffic and provide service for the management and planning at all levels. There are tremendous opportunities in applying GIS to transportation planning, the research in GIS application started several years ago in China and is currently making great progress at all levels. Utilizing GIS will definitely enhance the efficiency of highway planning and make data manipulation much easier. It is anticipated that the full application of GIS for highway planning will be realized at all planning agencies by the end of this century.

Another progress will be made in the area of the application of basic planning theory. After years of highway planning and construction in China, a great deal of information has been accumulated that is used in establishing models and calibrating the planning parameters. A set of scientific, reliable, and practical methodologies is in the process of being developed. The results will be applied to the actual planning. A great effort will also be invested to strengthen the researches of basic models, technical and economic indices, and highway capacity. With well-organized research activities in all areas related highway planning, it is expected the quality of planning work will be improved in the near future.

5.4 Improve the Technical Environment of Planning

In order to carry out the goals of highway planning work successfully, the technical environment in the planning work should be improved. The main improvement will be the continuous training of planning professionals. The highway planning personnel should consist of professionals with the knowledge and expertise in economics, sociology, land

utilization, environmental science, and comprehensive highway transportation. They must understand the planning area's past and present economic development conditions and be fully aware of the area's future potential development patterns. The other improvement will be to have full use of the information through the most current information exchange technology, and to conduct data collection and data processing through a common database structure. This requires setting up a comprehensive database. The database combined with GIS will provide a powerful planning tool and promote the establishment of the ultimate planning model combining transportation with land use.

As the world is approaching the 21st century, China is experiencing a great change in all aspects of life. Highway Transportation as a key component in the national socioeconomic development is and will always be leading the way to the next plateau. It is our hope that this paper will give a comprehensive overview of the status of highway planning in China today.

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