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Application and Development of Systems Engineering in Road Traffic Management

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Abstract: Traffic management is an important contribution in the sustainable development of urban traffic. The complexity of traffic problems determines the difficulty of traffic management. Therefore, traffic management needs the guidance of scientific theories. This paper explores traffic management systems engineering for management road traffic. First, the paper looks at the contents of road traffic management from a systems perspective. Second, the paper briefly describes systems engineering, and explains the necessity and feasibility of the combination of the traffic management and systems engineering. At last, the paper puts forward the concept of traffic management systems engineering using a systems framework.

Key words: Traffic management, systems engineering, traffic management systems engineering.

1. Introduction

With the development of China's economy, the standard of living is increasing, therefore, demand for automobile transportation is strong, and motor vehicle ownership is increasing rapidly. By the end of 2017, according to the statistics from the Traffic Administration Bureau of the Ministry of Public Security of the People's Republic of China, there are 310 million motor vehicles and 385 million drivers of motor vehicles. The rapid growth of the number of motor vehicles and drivers brings convenience to people's work and life, but also brings serious traffic problems. Traffic problems such as traffic jams, traffic accidents and traffic pollution have become one of the main factors that restrict economic development, and are major challenges to traffic management.

Traffic is not only a technical problem, but also a social problem. The emergence of traffic problems is the result of a variety of factors. The complexity of traffic problems increases the difficulty of traffic management. In China, when people cannot cope with traffic problems very well, they always say, "Traffic management is a systems engineering". There is no doubt that it is right. However, there are two problems that need to be explained clearly: Firstly, how does traffic management become a systems engineering? Secondly, what is systems engineering? This paper will explain these two problems and combine the two to explore the traffic management systems engineering.

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2. Traffic Management

2.1 The Definition of Traffic Management

The definition of traffic is the movement of the space position of humans or things, if the movement occurs on the road, then is road traffic. Traffic in this paper refers to road traffic, and traffic management refers to road traffic management.

At present, in China, the basic description to traffic management is as follows: In order to realize the road traffic order, safety and smooth as the objective, the state administrative organization, according to the relevant laws and regulations, standards and norms, adopting scientific management methods, to the elements (such as human, vehicle, road and traffic environment) of road traffic system, carries out effective organizing, coordinating and controlling

activities [1].

The above definition clarifies the objective of traffic management, which shows the main body of traffic management is an "organization" and reflects that the objective of traffic management is road traffic system. Thus, we can consider that traffic management belongs to system management. According to the theory of system science, the system management regards the objective of management as a system and the function of management as a management system at the same time [2]. Therefore, traffic management should include two systems: road traffic system and its management system. The former is the objective of traffic management, and the latter is the "organization" established to manage this objective. In this study, the "organization" is called "traffic management organization system" for the present.

2.2 The Contents of Traffic Management

2.2.1 The Aspect of Road Traffic System

The objective of traffic management is a road traffic system which is a complex system consisting of human, vehicle, road, environment and other elements. In order to clarify its content logic, this paper describes the contents of traffic management from the perspective of the three major relations of systems (as shown in Fig. 1, two-way arrows are used to indicate having the mutual relation).

(1) From the perspective of the system elements

The basic content of system management is the management of the elements of the system. The management to "Human", "Vehicle", "Road" and "Environment" is the basic content of traffic management.

"Human" refers to traffic participant. The traffic management contents of "Human" mainly include the management of all types of drivers, as well as the traffic safety education for all traffic participants. "Vehicle" refers to the means of traffic. The traffic management contents of "Vehicle" mainly are motor vehicle management and non-motorized vehicle management. "Road" refers to road. The management contents of "Road" are mainly the reasonable settings of road traffic facilities. "Environment" refers to the things that affect the "Human" or "Vehicle" when they

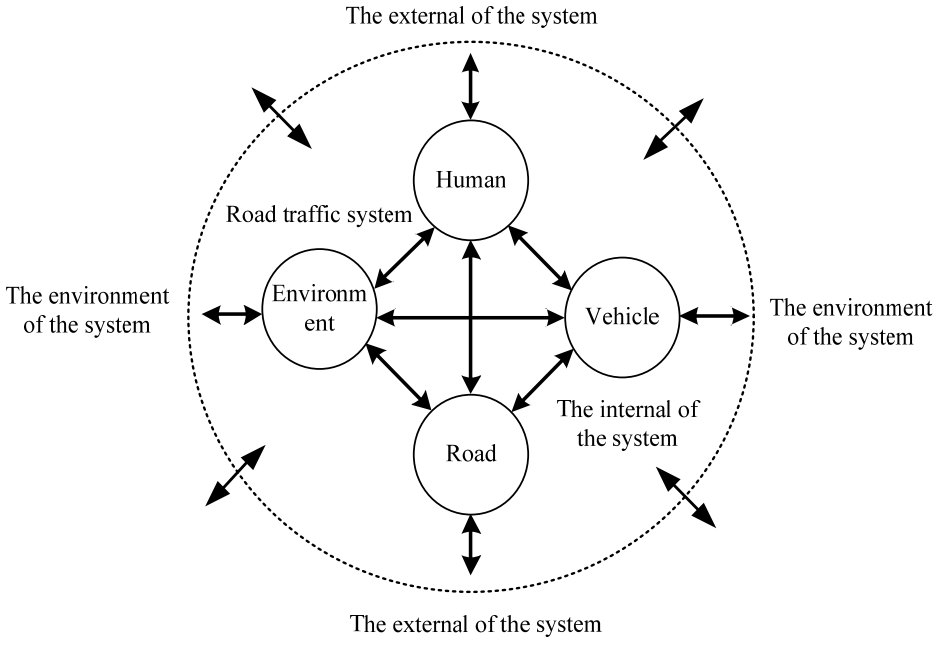

Fig. 1 The relation diagram of road traffic system.

are on the "Road", such as traffic flow status, traffic facilities, weather conditions. Traffic order management, speed management, traffic law enforcement and so on, all belong to the "Environment" aspects of the traffic management content.

(2) From the perspective of the relations between the system elements

There are organic connections between the elements of a system (as shown in Fig. 1). It is an important aspect of system management to deal with the relations between system elements. Traffic management should handle these relations well.

The relation between the elements means that there is a mutual influence between them. For example, there is mutual relation between "Human" and "Road" which means that each has an impact on the other. In reality, the phenomenon of pedestrians jaywalking across the road is an impact. This phenomenon indicates that the two elements of "Human" and "Road" may each have problems and should seek solutions from both aspects. On the one hand, we should carry out "civilized traffic" education for pedestrians, but on the "Road", there also should be humanized street crossing facilities to provide the conditions for pedestrians to regulate their traffic behavior. Therefore, in terms of "Human" and "Road" relation, the traffic management contents cover the reasonable setting of road traffic facilities and traffic safety education etc.

(3) From the perspective of the relations between system and its elements

The relations between system and its elements must be considered when making traffic management policies, because such relations reflect the coordinated development of system and its elements. The elements should be developed under the constraint of system resources to avoid the "short board" effect of the system.

The relations discussed above belong to the internal problems of road traffic system. By paying close attention to these kinds of relations, it improves the coordination, safety and efficiency of road traffic system.

(4) From the perspective of the relations between the system and its environment

The environment of traffic system is the system of social economic activity and ecosystem. Traffic development cannot be done at the expense of environment, and traffic system must be adapted to its environment. To pay attention to the relations between traffic system and its environment is to pay attention to the sustainable development of traffic system and the protection of ecological environment. From this point of view, traffic management involves the idea of policy and planning of traffic development, which also indicates that traffic managers should value the idea of sustainable development. What kind of value concept the traffic management should have is an important research topic.

2.2.2 The Aspect of Traffic Management Organization System

Traffic management organization system is an "organization", which is established to manage the road traffic system, and is the main body of traffic management. The systems engineering method should be used to manage the "organization" to better serve the development of the road traffic system. For this reason, we should first define the task of the "organization".

We can observe that there are different levels of traffic management contents, namely: macro, meso, and micro level, which may correspond to three aspects of the contents: the system and its environment, the system and its elements, system elements and the relations between them. Thus, the structure of the traffic management organization system may be divided into three layers: the macro management layer, the meso management layer and the micro management layer, which are in charge of the three aspects of management contents.

The above study has combined the traffic

management contents from the internal and external relations of road traffic system. The main contents of traffic management belong to the internal category of road traffic system, and the goal is to coordinate internal relations and improve system efficiency. But to understand the external relations of the system can help traffic management to have the macroscopic vision and lofty values. Only under the guidance of the correct concept, adopting the scientific theories and methods, can the desired goal of traffic management be achieved.

3. Systems Engineering

3.1 The Definition of Systems Engineering

Systems engineering in China was born in aerospace engineering practice, and gained popularity in other fields. During the formation of Qian Xuesen's system science thought, systems engineering has three following definitions:

Definition 1: Systems engineering is the technology of organization management.

Definition 2: Systems engineering is a scientific method of planning, research, design, manufacture, test and using of the organizational management system and it is a scientific method which has universal significance to all systems.

Definition 3: Systems engineering is a scientific methodology with universal significance. It considers the problem from a systematic point of view and uses engineering methods to study and solve problems.

Based on above definitions, in China we consider that systems engineering is not only a technology, a method, but also a methodology [3].

3.2 The Understanding of Systems Engineering

This study follows the thought of Qian Xuesen to understand systems engineering. Below we first understand systems engineering from the name, then understand systems engineering from the development process of the systems approach, and finally explain the meanings of the approach of systems engineering.

3.2.1 Understanding Systems Engineering from Its Name

The name of systems engineering consists of two words: "system" and "engineering". System is an organic whole composed of many parts. The concept of system is to emphasize the whole, and emphasize that the whole is an organic whole that is composed of various parts which are interrelated and restricted by each other [4]. So what does "engineering" mean? Qian [5] regards that if a work is for a specific purpose, can it be called engineering, such as hydraulic engineering, mechanical engineering, civil engineering. And if this particular purpose is the organization or the management of the system, then it can be regarded as systems engineering.

3.2.2 Understanding Systems Engineering from the Development of the System Approach

Systems engineering originates from the scientific analysis and development of system. The way to recognize and deal with problem as a system is a system approach. In ancient times, in view of the limitations of human cognition, most of the system approaches are qualitative. With the large scale and complexity of social practice, the system approach need be not only qualitative, but also quantitative. To solve complex problems, the demand for quantitative is increasingly intense. However, excessive quantitative cannot solve some social practical problems well. People realize that system approach should be a combination of qualitative and quantitative, from the qualitative to the quantitative comprehensive integration. Because there is a need to solve practical problems and people's further in-depth understanding of system the approach has evolved. The system approach has evolved from the initial qualitative to quantitative, then to the combination of qualitative and quantitative, and then to the integrated qualitative and quantitative. In this process, operations research, system analysis and systems engineering have emerged.

This study argues that operations research is a

quantitative system approach and system analysis is a system approach which is the combination of qualitative and quantitative, and systems engineering is a system approach which is from qualitative to quantitative integration. Systems engineering has inherited and shared the techniques and methods of operations research and system analysis [6].

3.2.3 The Understanding of the Systems Engineering Approach

The objective of systems engineering research is complex system, one of its characteristics is that there are many contradictory factors and uncertain factors in the system [7]. Taking a problem as systems engineering means that the problem is a complex practical problem that needs to be solved. On the other hand, the thought and approach of systems engineering must be adopted to deal with this problem. When deals with problem, the procedure of systems engineering is to determine the overall framework before doing internal detailed design. The outstanding feature of the systems engineering approach is the combination of qualitative and quantitative under system thought. In China, the systems engineering approach that people often say, can be simply understood as using quantitative system approach to deal with complex problems.

4. Traffic Management Systems Engineering

4.1 Proposing the Concept of Traffic Management Systems Engineering

Any kind of social activity will form a system, whose organization, establishment, management and efficient operation will form a systems engineering [5]. Traffic management is a social practice activity, the object of its practice is road traffic system, and the main body of the practice is an "organization" system which composed of humans, and to combine the two is still a system. Traffic management is a social practice activity and its organization, establishment, management and efficient operation that will form a systems engineering. Therefore, traffic management is a systems engineering.

Different systems have different characteristics. For different systems, systems engineering adopts different specific methods to deal with. It usually says that using systems engineering to solve practical problems, refers that, to combine the systems engineering theory with the actual things, and propose a specific method to solve specific problem [3]. Thus, systems engineering is not a kind of system organization management technology, but the general name of all kinds of system organization and management technology. Systems engineering is a general name, it contains a number of professional names such as military systems engineering, environment systems engineering, education systems engineering [5]. So, the traffic management systems engineering should be a member of the systems engineering professional family.

Traffic is social, the complexity of problems faced by traffic management which makes systems engineering very useful. The causes of traffic problems are often at the source. Therefore, the idea of solving traffic problems should be from the macro to the micro which is just the basic viewpoint of systems engineering. The applying of the systems engineering theory to traffic management practice is the need of scientific management traffic. Traffic management practice is bound to enrich theory and method of systems engineering, and traffic management systems engineering should be a characteristics theory of systems engineering.

Hence, this study proposes the concept of traffic management systems engineering.

4.2 The Research Objective of Traffic Management Systems Engineering

Traffic management systems engineering takes the contents of traffic management as the research objective. The second part in the paper has shown that traffic management, on one hand, takes the objective of road traffic system as a system, and management

function (called traffic management organization system in the paper) as a system at the same time. Therefore, the road traffic system and the traffic management organization system constitute the research objective of traffic management systems engineering, as shown in Fig. 2.

So we can understand the research objective of traffic management systems engineering is a system, which contains two subsystems: the road traffic system and the traffic management organization system. The former is the objective of traffic management, which embodies the purpose of traffic management activities. The latter is the main body of traffic management, which embodies the organizational nature of the traffic management activities. The latter should serve the realization of traffic management objectives.

4.3 The Content System Framework of Traffic Management Systems Engineering

Traffic management systems engineering is to regard and solve the problems of the traffic management from the point of view of systems engineering. It is the specific application of the viewpoint of systems engineering and is a specialized technology which combines the characteristics of traffic management practice. Evaluation and decision making method is an indispensable link of systems engineering. Hence, system thought, the systems engineering approach and the characteristics of traffic management objectives are the basic meaning of the content system of traffic management systems engineering. Based on these understandings, this study argues that there are four parts of the content system framework of traffic management systems engineering, as shown in Fig. 3.

In summary, this study gives the definition of traffic management systems engineering as follows: Traffic management systems engineering is the characteristic theory of systems engineering. It is the product of the integration of systems engineering and the traffic management practice, is the application practice of the concept, method and technology of systems engineering, and is to apply systems engineering to manage traffic, make the road traffic system become internal harmony, adapting to environment, function

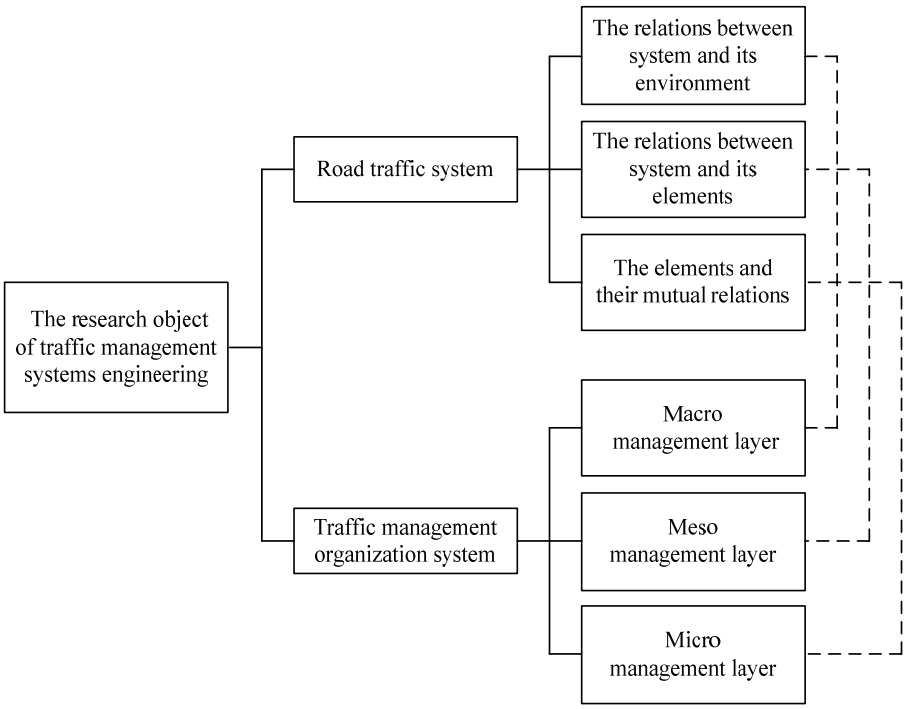

Fig. 2 The research objective of traffic management systems engineering.

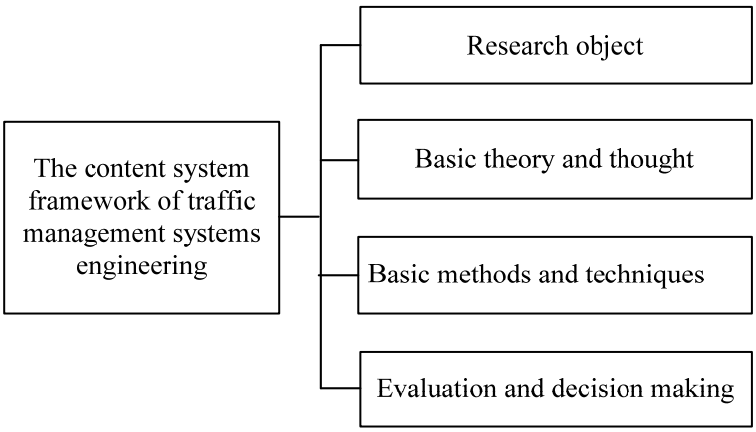

Fig. 3 The content system framework of traffic management systems engineering.

good system. In short, traffic management systems engineering is based on system point of view to regard road traffic system and its management organization activities, and then manage it with systems engineering.

5. Conclusion

Traffic management is the management to traffic system and the goal is to reach the whole optimal of traffic system rather than the local optimum, and this needs the whole idea, the general situation consciousness and system thinking. The management to traffic system should be good at dealing with the relations of traffic system and its environment, traffic system and its element, the element's mutual relations, and at the same time, there should be a corresponding management organization to deal with these relations. China as a developing country, every element of the traffic system may not be the best, but through scientific management, the traffic system can achieve a global optimum, which is just the idea of systems engineering. It is a meaningful practice activity to scientifically management traffic under the guidance of the theory of systems engineering. Traffic management systems engineering put forward in this study is a useful exploration of this practice, which is the application and development of systems engineering in road traffic management.

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