Chapter 10
Typical Intelligent Transportation Applications

CHU Duanfeng and CAO Yongxing

Intelligent transportation system (ITS) is a new development direction of modern transportation management and construction. It is a hot and frontier field of transportation engineering. The development and application of intelligent transportation technology has greatly improved the traditional traffic organization and management mode. It provides more and better solutions to alleviate traffic congestion, improve traffic safety, and reduce traffic pollution. ITS is an effective means of coordinating "people-car-road (environment)," gradually achieving the goal of safety, efficiency, energy conservation, environmental protection, and comprehensive traffic. In recent years, with the country's strong advocacy and the joint efforts of intelligent transportation practitioners, a large number of intelligent transportation springs up. The system is applied in the practice of traffic construction, organization, and management. This chapter describes four intelligent intersections with typical characteristics. General application system introduces the background, system composition, and function of each system. In each system, an instance analysis is provided.

10.1 Urban Traffic Status Monitoring and Index Evaluation System

In recent years, urban road congestion and road traffic conditions have become more complex. The total amount of traffic is getting bigger and bigger, and the probability of occurrence of accidents increases, seriously threatening people's lives and property safety. To improve urban road traffic safety level, road traffic safety

CHU Duanfeng (✉) · CAO Yongxing
Intelligent Transportation Systems Research Center, Wuhan University of Technology, Wuhan, Hubei, China
e-mail: chudf@whut.edu.cn

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management departments need to master the state of urban traffic safety and monitor it and understand traffic safety risks. Relevant departments can prescribe the right approach, taking targeted measures to improve the level of urban road traffic safety.

10.1.1 System Profile

How to make urban road traffic decision-making management scientific, refined, and informationized is very urgent. How to describe the traffic operation state more precisely instead of the traditional signal light of only red, yellow, and green color. Using accurate numerical value to quantify road traffic congestion and providing scientific basis for government decision-making management becomes the inevitable trend of ITS.

It is necessary to realize scientific quantification of the road traffic operation state by measuring real-time traffic status so as to make government traffic decision management informatization, refinement, and sensitization. Beijing, Shanghai, and other cities have developed a numerical description of the state of real-time road traffic—a road traffic index, i.e., in a specified space and time norm to show the running state of urban road traffic accurately.

By establishing a complete set of basic theory, calculation method, application system, and deliver congestion index based on road traffic index, it can make a quantitative evaluation of the overall or regional operation of urban road traffic, analyze and predict short-, medium-, and long-term traffic development trend, estimate the degree and scope of traffic congestion, and formulate scientific and reasonable traffic management for traffic management departments. All these are important to make decision-making, provide quantitative basis of traffic organization and traffic law enforcement, and provide dynamic traffic travel information service to the public.

All countries around the world attach great importance to traffic safety by strengthening management, developing new technologies and methods to improve road traffic safety. Traffic safety is also a hot research point in traffic circles. New theories and research techniques have been developed. Domestic research on the related index system of urban road traffic safety is mainly focused on traffic safety evaluation index system and evaluation method.

10.1.1.1 History and Current Situation of Traffic Data Acquisition and Preprocessing

Traffic data is the basis of traffic condition monitoring and forecasting. Its timeliness, accuracy, and comprehensiveness will directly determine the effect of traffic condition monitoring and prediction. The following is a brief introduction of researching history and current situation of traffic data acquisition and its preprocessing methods.

In 1976, some scholars first mentioned traffic flow and occupation rate data obtained from expressway induction coil data, in which error data recognition through single parameter threshold method. First, a fixed upper and lower limit threshold for each traffic parameter was set, and values exceeding the corresponding threshold are regarded as error data, and the error data is processed by culling method. In 1990, in order to overcome the problem of unreasonable data omission caused by the single parameter threshold method assuming that various traffic parameters are independent of each other, a combined parameter identification method based on traffic flow theory is proposed by scholars to establish the relationship between traffic density and traffic flow. The template defines the acceptable area of traffic parameters, considers the traffic data outside the area as error data, and adopts the culling method to deal with error data. In 2002, according to traffic flows from induction coils on the Northern Virginia Highway, quantity, speed, and occupation rate data, some scholars have proposed an idea to use historical trend method and exponential smoothing method to repair fault data.

In 2012, Chinese scholars divided the fault data into missing data and error data by obtaining 5 min fixed sampling interval traffic flow for urban main road vehicle detector. If traffic is significantly smaller than a sampling interval in the historical trend value, it is regarded as missing data, and the combined parameter method based on traffic flow theory is used to identify errors data.

By analyzing the development history and present situation of traffic data acquisition and its preprocessing research field, the following five points can be obtained.

1. According to the obtained type of traffic data, the existing traffic data acquisition and its preprocessing methods can be divided into two kinds—local traffic parameter data acquisition and its preprocessing and interval traffic parameter data acquisition. Traffic parameters acquisition and its preprocessing methods can be divided into single location vehicle detector data preprocessing and multi-continuous consideration.
2. The existing methods of data acquisition and preprocessing of traffic parameters are mainly focused on highway, expressway, and ETC which are continuous flow road type. Research aiming at the urban main road isometric cut-off road types is less.
3. Among the identification and repair of the conservation law of traffic flow in existing traffic parameter data acquisition and preprocessing methods, the only two literatures not only have their own defects but also lack data preprocessing of vehicle detection at a single location device.
4. Existing data acquisition and preprocessing methods of interval traffic parameters are mainly focused on research based on GPS data vehicle study on the method of obtaining road travel time data.
5. At present, inductive traffic control system, road toll system, vehicle tracking and positioning system, and other related services systems have been widely used in various types of roads in China and will continue to accumulate a lot of data to study the new traffic data acquisition and preprocessing methods. A data source is

helpful to improve existing traffic condition monitoring under low-cost condition database for measurement and prediction.

10.1.1.2 History and Present Situation of Traffic Condition Monitoring

The early road traffic monitoring system mainly takes emergency as the monitoring object. With the rapid development of social economy and the rapid increase in traffic demand, the morning and evening peak time on roadways is longer, more roads are congested. As a result, the demand for monitoring traffic congestion is increasing, and the content of traffic condition monitoring is extended to include traffic automatic detection of traffic events and automatic detection of traffic congestion. History and the present situation of the traffic event automatic detection research field can be summarized as follows.

1. A number of AID (Automatic Incident Detection) have been developed by relevant scholars since the 1960s, which can be divided into pattern recognition-based algorithms (Goferman, Pattern Recognition, Monica algorithms, etc.), algorithms based on statistical theory (including Bayesian algorithms, HIOCC algorithms, ARIMA algorithms, etc.), algorithms based on mutation theory (represented by McMaster algorithms), and algorithms based on artificial intelligence.
2. Most AID algorithms use special vehicle detectors, such as induction coils, to obtain traffic flow, speed, or percentage. Based on the rate data, the input variables of the algorithm mainly include the space-time comparison of the measured traffic data, the measured traffic data and its comparison of predicted values, etc.
3. Different AID algorithms have their unique advantages and disadvantages, so as to further improve the detection effect of traffic events, some researchers have tried to apply data fusion technology to traffic event detection and made some progress. Hence AID calculation is the research trend in this field.
4. Relevant system data have the advantages of low cost and wide coverage; if they can be used for AID purposes, the algorithm can greatly improve the effect of traffic event state monitoring under lower cost conditions.

Overall, China's current urban road evaluation index system is relatively mature, but not much attention is paid to the measures taken after evaluation. The starting point of traffic safety evaluation index is to evaluate the present situation of traffic safety level. It is estimated that the monitoring index of road traffic safety condition is to prevent and avoid possible adverse traffic conditions in the future. The safety evaluation index starts from each subsystem of the road traffic system and carries on the urban road traffic safety from the inside. The monitoring index is designed for the road traffic management department, so that relevant departments can efficiently and quickly take some measures to eliminate the hidden dangers affecting traffic safety. The monitoring index of urban roads traffic safety state starts from the macro-management level and combines the urban economic level and the road environment condition together while the evaluation index is from the micro-influencing factors of road traffic safety. They complement each other, inseparably.

10.1.2 System Composition

10.1.2.1 Factors Influencing Traffic Safety in Cities

This section deals with urban roads in terms of driver behavior, traffic flow, weather conditions, road conditions, and management organization factors. The influencing factors of traffic safety state are analyzed. Among them, the driver behavior analyzes the driver information receiving and processing. The traffic flow mainly analyzes the driving characteristics of large vehicles and the speed of traffic flow to traffic safety. The weather factor analyzes the influence of temperature, humidity, visibility, and precipitation on the normal running. The vehicle analyzes the impact of plane alignment, longitudinal section, and linear continuity on road traffic accidents. Management factors analyze the influence of traffic safety equipment installation, driver behavior supervision, and management on traffic safety.

1. Analysis of driver behavior impact.

   The main participants in the road traffic system are motor vehicle drivers, pedestrians, and non-motor vehicle drivers (electric vehicles, bicycles). The factors that cause traffic accidents are different. Among human factors, motor vehicle drivers account for a large proportion of accidents.

   (a) Driver's information processing characteristics.

   When the road traffic system is running normally, the driver needs to constantly judge the road condition and driving conditions, and respond to this, operating the vehicle to continue driving. In essence, it can be thought of as a mental acquisition of information and process information according to feedback.

   By receiving external environmental information, the driver transmits it to the central nervous system from the sensory organ and responds to its exercise organs, then manipulate vehicles, and continue or change the operation of vehicles. If the response of the sensory organs is biased, it will lead to abnormal operation of vehicles. This information must be fed back to the central nervous system for correction and then transmitted to the motor organ to fix order. The driver's mood, health, and fatigue affect driving safety to a great extent. Whether the information is correctly received has a great impact on the following action. The driver has a certain timeliness in the processing of information. If the information cannot be processed quickly and accurately, it is likely that a traffic accident will occur.

   (b) Driver's driving ability and fatigue characteristics. Drivers' reasonable operation mainly affected by their driving ability.

Driving ability refers to the correct judgment, reaction, and manipulation ability of the driver. When the driver is tired, driving ability will go down a lot. After 12 hours of continuous driving, the probability of serious traffic accident is 1.5 times than that of 8 hours. In addition, traffic accidents caused by drivers driving for more than 7 h in a row account for about 1% of the total number of traffic accidents 1/3. Statistics also show that driver fatigue causes 40% ~ 70% of accidents.

The fatigue degree of the driver is related to the amount of information received by the driver during the driving process. Road traffic system is a complex, real-time changing system. When the traffic is complicated, the excessive tension of the driver's mental activity can cause fatigue to appear early; if the amount of information is insufficient, long monotonous operation will also make the driver feel tired earlier. When road traffic conditions suddenly change, the driver often does not have enough psychological preparation and cannot deal with the emergency correctly.

Affected by fatigue, the driver's attention, judgment ability, visual acuity, and accuracy of speed perception decline and can lead to narrow vision, faster pulse, higher blood pressure, increased reaction time, dyskinesia, and so on. So when the driver is tired, it is more likely to cause traffic accidents. The right thing to do is to stop and rest immediately or take other actions to restore normal driving capacity when you find yourself tired. Experiments show that a few short breaks during driving are more efficient than a long rest at the same period of time, and the reasonable allocation of work and rest time can effectively avoid driving fatigue.

2. Analysis of traffic flow factors.

   (a) Analysis of the influence of large-scale vehicles on road safety.

   The general permissible speed of urban main roads in China is 40 ~ 60 km/h; this has certain requirements for the performance of the vehicle. Traffic participants on urban roads are complex and diverse, the performance gap of the model is large, which has a great impact on urban road traffic safety. All types of vehicles in the road traffic system and kinetic energy are different, which will produce some transverse and longitudinal interference, which is also the cause of traffic accidents. The impacts of large vehicles on urban road traffic safety are as follows.

   - Poor reliability.

     The reasonable configuration of vehicle assembly can ensure the continuous operation of the vehicle in the road traffic system. The main assembly of large vehicle is less, the performance of the whole vehicle is unstable, and the safety and reliability are poor. Large vehicles on roads take a lot of space to keep running, it is easy to collide with other vehicles, and it increases hidden dangers.
   - Poor braking performance.

Because the mass of heavy vehicle is generally large, huge inertia can lead to longer braking distance. The deviation of large-scale vehicle, tail-flick, rear-end and collision are easy to occur. So, we are going to enhance the active and passive safety of vehicles that cannot be ignored to improve the level of road traffic safety.

- Poor manipulation stability.

  The stability of vehicle operation includes the stability of longitudinal driving and the stability of transversal channel. The phenomenon of fast migration and swing occurs when heavy vehicles move, which is mainly caused by the lag of technical performance of heavy vehicle chassis.

- The speed is discrete.

  According to relevant statistics, the maximum speed difference between large and small vehicles that can be reached is 60 km/h, which has a significant impact on urban road traffic safety.

(b) Analysis of the influence of speed on road operation safety.

When drivers are driving vehicles, they simply respond to the road condition information and estimate surrounding safety in time, and then operate the vehicle. But when the speed increases, time left for the driver's reaction time is greatly reduced, which greatly increases the possibility of the nervous system making false judgments and the occurrence of traffic events. This increases the probability of accidents. In addition, the time and distance required to brake turning adds as the increase of speed. The collision speed of traffic accident is also larger than the driving speed. When the vehicle is being driven at a normal or slow speed, the driver can start to brake to slow down from the long distance of obstacle. Whereas the speed difference between the highspeed vehicle and obstacle which occurs collision is much larger than the original speed difference. Speeding gives the driver the illusion that he cannot correctly estimate the distance between the front and the rear. The speed of the vehicle is estimated, the probability of the traffic accident is greatly increased, and the damage of the traffic accident is also increased.

3. Analysis of the influence of weather factors

The reliability of human physiology and psychology to various weather reactions is the most important manifestation of road traffic safety. Certain amount of air pressure, temperature, and humidity in the fixed environment can affect the driver's senses and even cause adverse reactions in the body. In addition, rain, haze, heavy snow, and other weather phenomena will affect the visibility of vehicles while driving, resulting in slippery ground, traffic environment congestion, and so on, which increases the chances of the driver making a wrong decision. A large number of driver behavior experiments have shown that meteorological factors can have an impact on human physiology and psychology.

Through the above analysis, various climatic factors and different performance levels in terms of the driver's psychology which affects the vehicle operating state, road conditions, and traffic environment have different mechanisms of action: weather changes the road friction coefficient, visibility and vehicle driving stability will be affected. In some geographical climates, haze, heavy snow, heavy rain, and so on are closely related to traffic accidents, which are destructively increased, resulting in huge property losses and casualties. Therefore, in addition to improving road conditions and driver safety awareness, it is also of great significance to investigate the probability of traffic accidents under unfavorable weather conditions.

4. Analysis of road factors.

   When the driver is driving on the city road, the driver's visual judgment is most directly affected. It is the plane alignment and cross section of the road. The actual driving speed of the driver is the observation of the pavement condition and the three-dimensional line form, traffic conditions after the decision. Road alignment is directly related to traffic safety and urban roads are not only designed. It is necessary to consider the dynamic driving requirements, but also to consider the psychological and physiological state of the driver while driving continuously, and to ensure the linearity of the road continuity. From the point of view of road conditions, the data of many urban road traffic accidents show that unreasonable city road route combination and ergonomics design may cause road traffic accidents. Designing a road should take into account a comprehensive study considering the urban road function, land utilization rate, natural environment, climatic conditions, traffic safety, and so on, and fully consider safety, management convenience of transportation, which reduces road safety hidden danger as far as possible, eliminate accident black spot, and improve road traffic safety fundamentally.

5. Analysis of the impact of management factors on traffic safety.

   Traffic safety management is the life of road development. Road traffic system is a complex, real-time system, so road traffic management is also a huge work, has an important influence on everyone's life, and property, and needs managers and participants in different industries of society to coordinate with each other, establish perfect laws, regulations, and management system, and strengthen urban road operation and management.

   Road traffic safety management can be divided into the management of the subject and object of road traffic system. Participants including drivers, pedestrians, passengers, and their unsafe behavior will lead to traffic safety risks, and even directly lead to traffic accidents, thereby leading to urban road traffic safety state deterioration. The road traffic system consists of traffic environment and road condition. These will lead indirectly to judgment error, operation error, and information receiving error. Transport carriers, roads conditions, weather conditions, and management decision-making factors may lead to changes in traffic safety conditions, as shown by traffic events. Therefore, the probability of traffic accidents increases greatly when unsafe behavior occurs in the participants, and the design of means of transportation. The design of road and the design of driving workspace affect the decision-making of road traffic safety management, the selection of drivers, personnel management factors such as education, training mechanisms, and road traffic safety education for other traffic participants. There exist management decision-making factors in the aspect of traffic safety, total control, safety supervision and inspection, as well as traffic accident prevention.

10.1.2.2 Urban Road Traffic Safety Monitoring Index System

This section explains the principles and methods of constructing the indicator system. Then the complicated road traffic safety system is divided into traffic system. The system is divided into three parts: subject, object, and non-main participant.

1. Monitoring of road traffic safety.

The urban road traffic safety state refers to the traffic safety level of a city in a certain period of time, with the following attributes.

(a) Predictability. The state of road traffic safety points to the future, that is, pointing out the potential hidden dangers in road traffic safety. These hidden dangers are likely to develop into traffic accidents.
(b) Social Property. The sociability of road traffic safety state is one of the attributes of road traffic safety state, as well as the whole society. The sociality of road traffic safety state is one of its attributes, which is closely related to the whole society and involves everyone's life, work, and travel. When the road traffic safety is elevated to public safety, all participants in social activities must be taken seriously. This level of improvement has disrupted traditional transportation. Therefore, the definition of casualties and economic losses to strengthen the safety awareness of traffic activity participants, and make the more main body from the traffic management department formulate rules and regulations.
(c) Objectivity. The objective existence of road traffic safety state refers to the uncertainty of traffic participants and the complexity of road conditions, and road traffic safety risks always exist, which determines the objectivity of traffic safety risks.
(d) Instability. The traffic system contains many complex and integrated factors (driver's unsafe behavior, pedestrian's behavior violations, vehicle insecurity, road hazards, and environmental factors) that are the result of these uncertainties. People in social traffic activities are in an unstable state of safety. Time, place, and destruction of road traffic accidents, the degree, the scope, and whether the traffic hazards are transformed into traffic accidents make road traffic safety unstable. Due to the existence of uncertain traffic participants such as people and vehicles, the traffic state of the environment cannot be predicted. Therefore, it is very important to study the current situation of urban road traffic safety, correct remedy measures, and timely countermeasures and predict the possible situation in the future.
(e) Dynamic. The change in terms of the influencing factors on traffic safety state, the subject of road traffic participation, the road traffic system is bound to occur.

The comprehensiveness of the social system and the intricacy of the road traffic system illustrate the various state of road traffic safety in cities. In the road traffic system, different regions, and different time periods, the influence weight of some elements or indicators is diverse due to different regions and time periods, so the geographical background and time background should be planned and limited as follow:

(a) Geographical background. In the index system of urban road safety monitoring, the regional background is country, city, and province. The division of regional level is in the middle of China's administrative division. The administrative units of urban regions are relatively complete and suitable for urban transportation. More attention is paid to improvement of safety and that facilitates collection and collation of data, which is more experimental and practical than county-city level comparison.
(b) Time background. The time background level of road traffic safety state research can be divided into weeks, months, quarters, and years.

Data availability and physical monitor ability take into account drivers, vehicles, roads, etc. In the complex road traffic system, the factors affecting the state of urban road traffic safety require careful analysis.

Monitoring and control can effectively grasp the state of urban road traffic safety. Therefore, road traffic safety needs monitoring. The object is the key factors in the man-car-road system: driver error, weather factors, vehicle performance, exterior driving environment, etc. It is the existence of these factors that lead to traffic accidents.

Road traffic system is a complex subsystem of social system, which is affected by economic development, climatic conditions, geographical location, and production. Many factors include a variety of terrain and climate, as well as a territory with a large latitude span, which requires the urban road traffic safety monitoring index system to have certain applicable conditions. Therefore, road traffic safety monitoring should follow the limitation of regional background level, that is the period and region corresponding to the monitoring index system should be set up. Taking into account our practice, the government's comprehensive, feasible implementation of the index system and road traffic safety regional monitoring keep consistent, the provincial or prefecture level of the administrative region shall be determined.

2. Principles and methods for the construction of monitoring index systems.

Construction of urban road traffic safety risk monitoring index system to track, evaluate, and study road traffic safety status has certain benefits. Many factors need to be considered in the design of the road traffic safety risk monitoring index system, and there are many monitoring factors or indicators available. Therefore, the selection of indicators should follow certain principles and be representative.

(a) Scientific and implementable

The scientific nature is based on the theory of system science, and the non-majority information is collected and analyzed to find out the occurrence interval and distribution range of abnormal data. Scientific is reflected in the understanding of indicators, index data, the acquisition should be scientific and reasonable. Implementation refers to the use of modern intelligent transportation technology from monitoring equipment or networks traffic information data obtained in the network that can be processed, and these indicators can reliably and effectively predict the safety of urban road traffic, the weak link of the whole level.

(b) Combining qualitative and quantitative principles

Road traffic safety status index includes quantitative index and qualitative index. On the basis of qualitative analysis, the characteristics of road traffic system are measured by quantitative index, and the historical data are objectively quantified and reflect urban road traffic safety state, in order to make the monitoring results more scientific and objective. Through the function of the index, the quantitative calculation, expression, and quantification of qualitative indexes make the evaluation more convenient. For hard-to-reach indicators data or some missing index data can also be supplemented by certain methods.

(c) Real-time and predictive combination

The state of road traffic safety is dynamic, so the corresponding monitoring refers to the standard should also have real-time performance to truly reflect the characteristics of the traffic system represented by the index. On the other hand, indicators may also have design indicators should be as forward-looking as possible, traffic management departments try to make good use of indicators including design indicators and realize the fact that measures are taken through indicators to deal with security risks in time.

(d) Integration and independence

The actual index system operation extension has certain limits to the index quantity. This requires the indicators to be representative and comprehensive, and to grasp the core problems in the urban road traffic system, but there must also be some independence, that is, the index design can reflect the corresponding characteristics of the influencing factors, and there cannot be too many indicators between them that will have an impact on the monitoring results.

(e) The stability and strain are combined

Stable road traffic safety monitoring index can objectively reflect the hidden dangers of urban safety. However, different geographical and temporal contexts may adjust indicators to ensure their application, and the weight of indicators also varies with the situation.

(f) Government order is combined with test-ability.

The relevant laws and regulations of the government refer to the design of road traffic safety status indicators guidelines. Test-ability means that the selected index is easy to quantify and then easy to calculate. By means of qualitative indicators, we can obtain the monitoring results within the monitoring index system. In addition, the testing results should be specific and in the legal system.

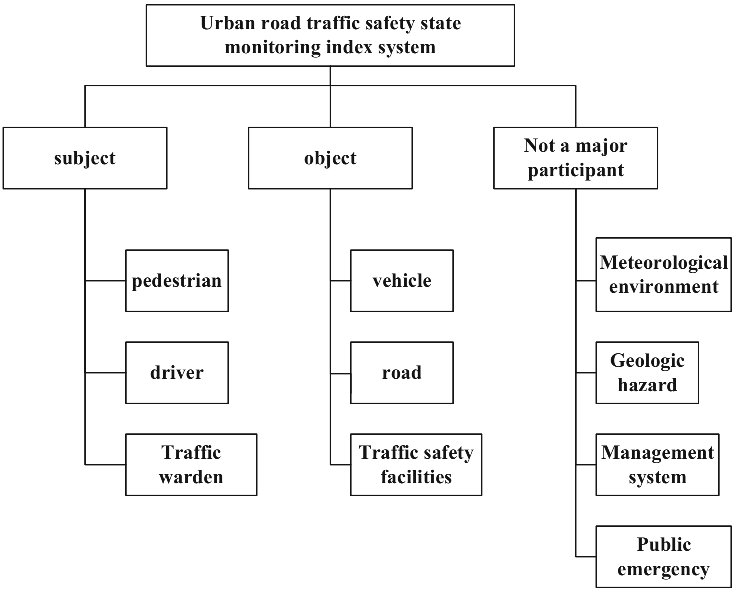

Fig. 10.1 Monitoring index system of urban road traffic safety

3. Construction of monitoring index system.

   The road traffic system is mainly divided into the main body of participation, the object of participation, the organization and management of the traffic system, and generally from these three parties, to establish traffic safety monitoring indicators, as shown in Fig. 10.1.

4. Methods of index screening and evaluation.

   In order to overcome the subjectivity of the initially determined index system, a better correlation index, and for some indexes with less monitoring function of traffic safety state, other high efficiency indexes are screened twice. At present, commonly used the methods of index screening are mainly analytic hierarchy process, principal component analysis, gray cluster method, rough set method information sensitivity screening method, and expert consultation method.

10.1.2.3 Domestic and Foreign Road Traffic Index Summary

The Texas Institute of Transportation defines travel time index (TTI), road congestion index (RCI), and other quantitative indicators to analyze key highways. The travel time index is the ratio of actual travel time to free flow travel time. For example, TTI = 1.35 denotes that travel time in free flow is 20 min and the actual travel time is 27 min. Road Congestion Index is the ratio of vehicle miles to lane miles, which is calculated after weighting to measure road traffic density and describes the intensity and persistence of congestion. When the index is greater than or equal to 1, it indicates that road network congestion is unacceptable. By calculating the ratio of the average travel speed to the corresponding free flow speed, the U.S. Highway Capacity Manual (Highway Capacity Manual, HCM2000) divides the highway service level into six grades to evaluate the road operation and reflect the average perception of all drivers to the traffic flow they are in, where A represents a free flow situation where the ratio is greater than or equal to 90%, and the represents a ratio of less than 33%; and the delay is serious. The U.S. Federal Highway Administration uses congestion severity as a measure to quantify congestion, which is defined as the total vehicle delay per million km. Based on American HCM2000, some research institutions integrate the relevant indicators and use limited samples to establish a congestion index system, which include travel speed, driving speed, delay rate, driving speed ratio, delay ratio, etc. In this way, they can judge road traffic congestion.

Domestic traffic field also has some theoretical research and practical accumulation of traffic index. The Beijing Traffic Congestion Index is calculated according to a time period of 15 min. This calculation is combined with road grade, travel speed, and the kilometers of driving. It reflects the traffic congestion level of the road network from a macro perspective. In this case, the value range is 0~10, which is divided into five levels. In this situation, 0~2 (including 0 and 2), 2~4 (including 2 and 4), 4~6 (including 4 and 6), 6~8 (including 6 and 8), and 8~10 (including 8 and 10) correspond to the levels of being smooth, being basically smooth, being slightly congested, being moderately congested, and being heavily congested. The higher the value, the more serious the traffic congestion is. Zhejiang Province has also introduced a traffic operation index, which comprehensively reflects road network traffic. As with the Beijing Traffic congestion Index, the range of values is 0 ~ 10, which is unblocked to 5 levels of serious congestion. Based on the standards of Zhejiang Province, the traffic operation indexes in the major cities in Zhejiang provinces, which include Hangzhou, are successively launched and applied. Shenzhen has established a traffic index calculation model based on the average diving speed, travel time, and the rating from experts. This city gradually calculates the traffic index of different spatial ranges such as road sections, gateways, districts, and the whole city from point to line and from line to surface. In this case, the value ranges from 0 to 5, which correspond to 5 levels: being smooth, being basically smooth, being slow, being slightly congested, and being congested. The larger the traffic index, the longer the travel time compared to smooth conditions (such as early morning hours). For example, in the level of being congested, the time spent on the road is at least twice as long as that in the smooth condition. In addition, companies such as Gaude Software and Beijing Siwei also introduced congestion delay index and traffic congestion index, which are used for horizontal comparison and the analysis of traffic operation among cities in China.

10.1.3 Example: Application of Shanghai Road Traffic State Index

According to the above contents, the application case of Shanghai road traffic state index is expounded. In 2016, using historical data of the state index, Shanghai made analysis and judgment of its road traffic condition of working days of 2014–2015, to provide reference for traffic decision and management.

For this reason, the peak period of the working day is defined—morning peak: 7:00–10:00, noon peak: 14:00–16:00, evening peak: 16:00–19:00. We follow the statistics in the 2011–2014 Road Traffic Congestion Analysis Report. The three index areas, in which the congestion index is greater than 50, the accumulated congestion time exceeds 1 h, and the working time exceeds 100 days during 1 year during the peak period, are defined as heavily congested areas. Compared with the road traffic congestion in Shanghai in 2014, the analysis of this in 2015 is as follows.

10.1.3.1 Urban Express Network

Frequent congestion areas in the expressway network during the peak working day of 2015: no change in spatial location; there was a slight decrease (3), namely: outer ring (Wuzhou-Tongji), inner outer ring (Shanghai-Yu-Hujia), and outer ring. Outside (Shanghai-Yu-Jiyang); congestion days increased, with an average increase of 14 days; extreme congestion index greater than 70 reduction. On the whole, the space position of frequent congestion of expressway has not changed, the number of congestion days has increased, and the degree of extreme congestion has been decreased.

10.1.3.2 Ground Road Network

Frequent congestion areas of the ground road network during the peak working day of 2015: no change in spatial location; volume slightly increased, respectively: Tian Lin, Sichuan North Road business district, Ruihong New City; congestion days have increased, an average increase of 7 days; the extreme congestion index of more than 70 is basically the same as in 2014; the congestion range is expanding from the inner ring to the central ring. On the whole, the space position of frequent congestion on the ground road has not changed, the number of congestion days has increased slightly, and the congestion range is presented by the inner ring.

10.2 Network Control System for Key Operating Vehicles

10.2.1 System Profile

With the development of China's national economy and highway construction, the number of road passenger transport and cargo transport is increasing rapidly. The accident rate of corresponding road transportation is high, and 80% of the major road traffic accidents occur in operating enterprises. An important issue that need to be addressed urgently is improving the supervision level of key operating vehicles and reducing the loss of life and property of the public.

In order to strengthen the monitoring of key operating vehicles, reduce road traffic accidents, and realize multi-department joint supervision and law enforcement, National Network Control System for Key Operating Vehicles came into being. The network joint control system for key operating vehicles refers to a dynamic monitoring and monitoring system for operating vehicles based on satellite positioning system technology, which is established by road transportation management agencies at all levels and related enterprises.

This system includes the public service platform of vehicle dynamic information regarding the national road transport, the supervision platform of local road transport management agency, the enterprise monitoring platform of road transport and the social monitoring platform. The system is in charge of the dynamic information of key operating vehicles, which include the chartered vehicles for tourism, three or more types of buses and the vehicles transporting hazardous chemicals, fireworks and firecrackers, and civilian explosives. The dynamic information of the key operating vehicles is connected to the network, and vehicles movement and dangerous driving are monitored in real time. Besides, it monitors the movement trajectory and the dangerous driving behavior of such vehicles and collects the relevant data. The system has the functions of issuing the information such as early warning, scheduling to the vehicles, and receiving the information such as emergency calls and offline reminders from the vehicles. The network joint control system for operating vehicles uses information technology to manage the scattered and mobile operating vehicles, effectively solving the problem of "being invisible, inaudible, and uncontrollable" in road transportation supervision.

10.2.1.1 Development Background and History of Network Control System for Key Operating Vehicles

1. Road Transport Security and Movement Requirements.
   In 2009, the Ministry of Transport adopted effective technical approach for the joint supervision of operating vehicles across regions and departments to solve the problem that the provincial road transport management departments could not supervise vehicles in other provinces. Besides, in order to ensure the transport security of the Shanghai World Expo and the effective supervision of the key

operating vehicles entering Shanghai, the Ministry of Transport decided to integrate the existing dynamic monitoring resources of the industry and build the network joint control system for operating vehicles. These provide the effective technical support for cross-regional and cross-departmental joint supervision of key operating vehicles.

In April 2010, the system was officially launched, with access to 30 provincial regulatory platforms involving more than 800 GPS operators and enterprise monitoring platform. Since the opening of the system in Shanghai World Expo, Guangzhou Asian Games, Shenzhen Universiade Road transport security work has played an important role in services and security. During the period of the Shanghai World Expo, a total of 1.155 million times of cross-regional trains were forwarded to Shanghai from the national platform. Additionally, during the period of the Guangzhou Asian Games, a total of 427,000 times of cross-regional vehicles were forwarded to the Guangdong platform.

2. Dynamic Regulatory Requirements for Large Operating Vehicles.

The accidents caused by large-scale vehicles are of high severity, which can easily cause mass death and injury. It has always been one of the key concerns of the work of road traffic safety. In November 2009, Zhang Dejiang, then Vice Premier of the State Council, was in “Special Information” No. 1618. “The use of modern information technology for the implementation of vehicle transport safety management, is an important measure to strengthen the construction of road traffic safety.“ In July 2010, the State Council issued the “Notice of the State Council on Further Strengthening the Work Safety of Enterprises” (Issued by the State Council [2010] No. 23). This notice indicates that a satellite positioning device with a driving record function should be installed and used in the certain vehicles within 2 years. These include the vehicles transporting hazardous chemicals and civilian explosives, the chartered vehicles for tourism, and the three or more types of buses.

In order to implement the principle of Document No. 23 of the State Council, the Ministry of Transport cooperates with the Ministry of Public Security, the State Administration of Work Safety, and the Ministry of Industry and Information Technology. They jointly issued the “Notice on Strengthening the Dynamic Supervision of Road Transport Vehicles” (Issued by the Ministry of Transport [2011] No. 80). This document clearly requires that the newly- produced vehicles mentioned above must be equipped with standard satellite positioning devices. The Ministry of Industry and Information Technology will not publish the product announcements of the vehicles that do not meet the regulations. Furthermore, the public security will not examine their qualifications and the transportation departments will not issue the road transport certificates for them. The road transportation management department will suspend the qualification examination of vehicles that have not installed on-board terminals or have not been connected to the national network joint control system for key operating vehicles. In terms of setting standards, the Ministry of Transport issued two key requirements, which are Vehicle Terminal Technical Requirements of Vehicle Satellite

Positioning System for Road Transport and Platform Technical Requirements of Vehicle Satellite Positioning System for Road Transport, on February 28, 2011, and March 25, 2011. The promulgation of these two standards has laid a solid technical foundation for the unified regulation of the operation of the national network joint control system for key operating vehicles.

In March 2014, the Ministry of Transport, the Ministry of Public Security, and the General Administration of Safety Supervision jointly issued the Dynamic Supervision of Road Transport Vehicles Management measures, wherein the dynamic supervision and management of road transport vehicles are clearly defined. In January 2015, the Ministry of Transport issued the National Measure for the Assessment and Management of the Network Joint Control System for Key Operating Vehicles. Besides, the revised version of it was issued in September 2016. A revised version of the method is presented. Consequently, the technical level, application degree and standardization degree of the network joint control system for key operating vehicles have been further improved due to the implementation of this measure.

10.2.1.2 System Framework of Networked Control System for Key Operating Vehicles

The network control system of key operating vehicles in China adopts the system structure of longitudinal classification and horizontal docking. Longitudinal classification means the system is divided vertically into ministerial public exchange platform, provincial monitoring platform, and regional and enterprise monitoring platform; horizontal docking refers to different levels of platform docking traffic, public security, safety supervision, environmental protection, and other government departments and related enterprises information resources to achieve information sharing and joint supervision. The system framework and architecture are shown in Fig. 10.2.

1. Ministerial Public Exchange Platform.

   The National Public Exchange platform is responsible for cross-regional information exchange of roaming vehicles between provinces and information sharing between relevant departments of the State Council. The national public exchange platform is the first data center of the national key operating vehicle dynamic information, through collecting the vehicle dynamic information of each provincial monitoring platform, the vehicle transportation information reported by the enterprise and the transportation administration database, and establishes key operating vehicle static information and dynamic information database to form a data center covering the national key operating vehicles; the national public exchange platform is the data exchange center, which adopts a unified data exchange standard. The national public exchange platform can realize data exchange with provincial monitoring platforms and realize information sharing with other ministries and commissions. The national public exchange platform

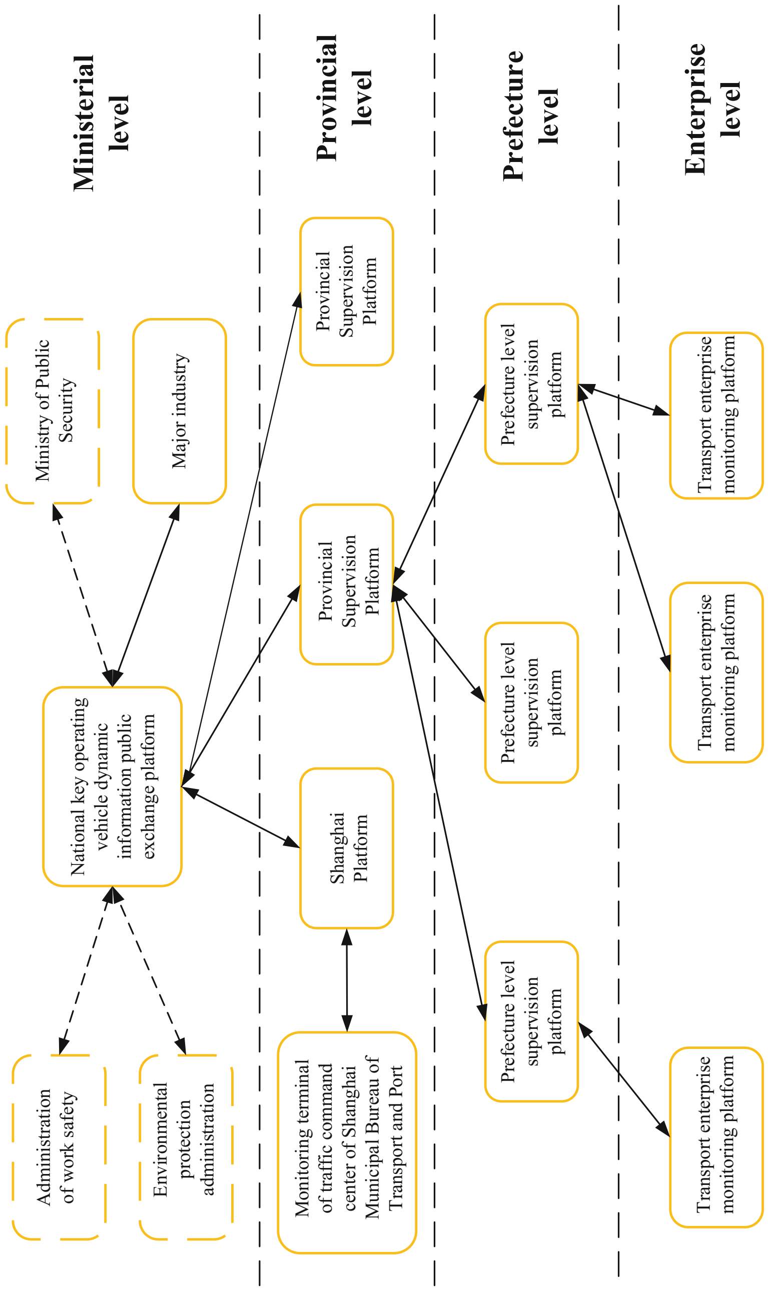

Fig. 10.2 System architecture of networked joint control system for operating vehicles

and the operation monitoring center of the system can make necessary analysis and statistics on the operation of the connected provincial monitoring platform.

2. Provincial Regulatory Platforms.

   The provincial monitoring platform is responsible for cross-regional information exchange of roaming vehicles between regions and letters between relevant local departments. The provincial monitoring platform is responsible for transmitting the dynamic information of key operating vehicles to the national public exchange platform and receiving the whole country's dynamic information of cross-provincial vehicles transmitted by public exchange platform.

3. Regional Regulatory Platforms.

   To realize the supervision of the key operating vehicles within the jurisdiction, supervise and examine the access of the vehicles of the transport enterprises within the jurisdiction, combined with industry management needs to conduct comprehensive supervision of local and foreign vehicles operating within their jurisdiction.

4. Enterprise-Level Monitoring Platform.

   To realize the safety supervision of the vehicle, to transmit the positioning data to the superior supervision platform in time, and to ensure the data, the authenticity, accuracy, and effectiveness of the upload data, timely correction and handling of speeding, fatigue driving, and other illegal driving behavior.

10.2.1.3 Main Functions of Networked Control System for Operating Vehicles

Real-time monitoring function: the network control system of operating vehicles can communicate with the vehicle terminal in real time through the monitoring platform to the vehicle position, driving track, driver driving status, driving behavior, and other information for real-time monitoring.

Scheduling management function: in order to ensure the special capacity requirements in large-scale activities and other scenarios, the operating vehicle network control system, transportation tasks can be uniformly scheduled and distributed through real-time detection of the capacity usage of transport enterprises in different regions. And then implement cross-regional, cross-departmental joint scheduling and control.

Data playback function: the operating vehicle network control system can detect the running condition of the vehicle at the same time. The status data are collected and sorted to complete dangerous driving behaviors such as vehicle mileage, driver speed up, sharp turn, etc. The data can provide basis for driver assessment and enterprise transportation efficiency assessment.

Remote control function: when the system detects the driver's dangerous driving behavior or driving state, it can pass through the vehicle terminal. The driver is warned and the vehicle is warned and reported at the monitoring center. The operator at the monitoring center can adjust the information of vehicle camera and other sensors, and monitor the running state of the vehicle remotely.

10.2.1.4 Main Features of Networked Control System for Operating Vehicles

In the key technology, the network control system of operating vehicles has solved the problem of cross-regional and cross-departmental information exchange and sharing. What's more, it realizes the integration application of vehicle data and the mastery of vehicles motion dynamics and distribution. The network joint control system fully integrates the existing provincial road transport monitoring system resources to complete the key operating vehicles in the provinces. On the one hand, the cross-regional exchange of dynamic information of key operating vehicles is realized; on the other hand, as an all-open system, the data exchange channel is established. Now the information communication between the same area and different government management departments lays the foundation for the multi-department in the coordination office, emergency linkage, and other parties.

The networked control system realizes the effective combination of dynamic and static information of vehicles. The collection of traditional road transportation information is a summary of static data, which cannot provide real-time information to managers. Through the network joint control system, the vehicle dynamic position information, the vehicle transportation administration information, and the vehicle cargo transportation information can be forwarded to the corresponding platform in real time, so that the receiving platform can not only clearly understand the vehicle's driving track, but also know the cargo information and attribute information of the vehicle.

The network control system realizes the unified centralization of data at the ministerial level, can effectively grasp the overall operation of the national road transport industry, strengthen the supervision of the road transport industry, improve the information management level and decision analysis ability of the road transport industry, and provide data support for modern logistics industry, emergency command system, network congestion analysis, traffic economic operation analysis, and so on.

10.2.2 System Composition and Service Functions

The network control system of key operating vehicles is mainly composed of two parts: vehicle mobile terminal and monitoring center at all levels. The vehicle terminal transmits the vehicle positioning information and the driver status monitoring information to the monitoring center through the wireless communication system, and the monitoring center can also transmit the dispatching instructions to the vehicle terminal through the wireless communication system, so as to realize vehicle monitoring and scheduling.

10.2.2.1 On-Board Mobile Terminal

On-board mobile terminal consists of microprocessor, data memory, satellite positioning module, vehicle status information acquisition module, wireless communication transmission module, real-time clock, data communication interface and other host modules, as well as satellite positioning antenna, wireless communication antenna, emergency alarm button, voice message reading device, and other external equipment. The main functions of the vehicle mobile terminal are as follows.

1. Positioning function.

   The terminal can provide real-time location status information such as time, longitude, latitude, speed, elevation, and direction, which can be stored to the terminal and uploaded to the monitoring center by wireless communication. At the same time, the terminal can receive the location request of one or more monitoring centers to upload the location information, and can suspend the real-time reporting of the corresponding centers according to the requirements of the monitoring centers. When the communication is interrupted (blind area), the terminal can store not less than 10,000 positioning information in the way of first in, first out, and upload the stored location information after resuming the communication. The terminal also supports uploading location information using time, distance interval, or external event trigger. When the terminal is dormant, the location information should also be uploaded at a certain time interval, and the interval of time and distance can be set by the monitoring center. The terminal can also automatically upload location data to the location mode and interval set by alarm vehicle or key vehicle monitoring center.
2. Communication Function.

   Car mobile terminals support a variety of wireless communication networks based on 2G, 3G, and 4G. When the wireless network in the location of the vehicle supports packet data transmission, the vehicle terminal should first choose the packet data transmission mode; when the location does not support packet data transmission, it can switch to short message mode to transmit data; when the local wireless communication network is impassable, Beidou satellite communication mode can be adopted according to the need.
3. Information Acquisition Function.

   (a) Driver identity information. Terminal support through the IC card to collect driver qualification information, and upload to the monitoring center.
   (b) Electronic waybill. The terminal supports the collection and display of electronic waybill information, and upload to the monitoring center.
   (c) Vehicle CAN bus data. A terminal supports the acquisition of vehicle parameter information through a CAN bus, and upload to the monitoring center.
   (d) Vehicle loading status. The terminal determines the loading status of the vehicle by means of the interface of the vehicle load state detection device or manual input (no load, half load, full load), and upload to the monitoring center.

(e) Image information. The terminal has the function of image information acquisition and storage, and supports monitoring center control, timing, and event-triggered mode to achieve image information collection, storage, upload, and retrieval upload function.
(f) Audio information. The terminal has the function of collecting and storing audio information, and supports monitoring center control and event trigger to achieve audio information collection, compression, storage, upload, and retrieval upload function.
(g) Video messages. The terminal has video information collection and storage function, and supports monitoring center control and event trigger to achieve video information collection, compression, storage, upload, and retrieval upload function.

4. Driving Record Function.

The terminal has the function of vehicle driving record and supports the functions of real-time upload, conditional retrieval upload, and data interface export of driving record data.

5. Warning Function

When the terminal triggers the warning, it should immediately upload the warning information to the monitoring center or send the short message prompt information to the designated mobile phone as needed, and can receive the instruction of the monitoring center to cancel the warning. The warning mobile phone number can be set remotely by the monitoring center. Terminal warning function is divided into manual alarm and automatic warning. Manual alarm is the alarm triggered by the driver according to the actual situation on the spot, including when there is an emergency such as robbery, traffic accident, vehicle failure, and so on, the driver uploads the alarm information to the monitoring center by triggering the emergency alarm button, and closes the voice reading module. If the terminal has image, video, and audio acquisition function, the function should be enabled immediately. Manual alarm should have the function of preventing misoperation.

The terminal is triggered according to the conditions set by the monitoring center. The specific content includes the following 8 types.

(a) Automatic alert means that the driver does not do anything to the terminal. The terminal is triggered according to the conditions set by the monitoring center.
(b) Area reminder: triggered when a vehicle enters or leaves a restricted area; the monitoring area can be set remotely by the monitoring center.
(c) Route deviation warning: triggered when the vehicle leaves the set route; the monitoring route can be set remotely by the monitoring center.
(d) Over-speed alert: the terminal can be triggered by a preset speed threshold or by receiving information from the monitoring center, to remind the driver that he is currently speeding.

(e) Fatigue driving warning: when the vehicle or driver's continuous driving time exceeds the fatigue driving time threshold, the fatigue driving time threshold can be set remotely by the monitoring center.
(f) Battery under-voltage warning: terminal detection vehicle battery voltage below the preset value triggered. At the same time, the terminal must use the built-in backup battery power instead of taking electricity from the vehicle battery.
(g) Power off reminder: the terminal is triggered when the main power supply is cut off. Timeout warning: when the stop time exceeds the system preset time.
(h) Terminal fault alert: triggered when the external equipment connected to the terminal host is abnormal, and uploaded to the monitoring center.

6. Human-Computer Interaction.

   The terminal has the function of human-computer interaction and can interact with the driver. The terminal should be able to provide information to the driver through voice reading equipment and display equipment combined with signal lights or buzzers, and the driver can operate the terminal by means of keys, touch screens, or remote control.
7. Information Services.

   The terminal supports the monitoring center to send the information directly and the driver to report the information actively; it can prompt the driver to the dispatching information, logistics information, and so on through the display equipment or the voice reading equipment, and the driver can return the response information to the monitoring center by a keystroke. The terminal can store at least 50 records of all information types and support information query function.
8. Multi-Center Access.

   The terminal supports connecting two or more monitoring centers at the same time and can obtain the information sent by the monitoring center. The terminal should regularly connect to the set monitoring center and obtain the information sent by it according to the set time interval.

10.2.2.2 Monitoring Platform

The monitoring center is divided into government supervision platform (Government Monitoring and Management Platform) and enterprise monitoring platform (Enterprise Monitoring and Management Platform). The government supervision platform is based on computer system and communication information technology. The system platform for the management of vehicle terminal and access platform is realized by satellite positioning technology. The enterprise monitoring platform is a satellite positioning system platform built by the enterprise or commissioned by the third-party technical unit. Based on the computer system, the vehicle terminal and user in the service range are managed by accessing the communication network. The system platform of safe operation monitoring is provided to realize real-time monitoring of vehicle safety operation in the platform.

Government platforms are connected by special line networks or Internet VPN, and enterprise platforms and government platforms can be connected by Internet or special line networks. The vehicle terminal is connected with the enterprise platform or the government platform through the wireless communication network.

1. Government Regulatory Platform

   Through the platform interface and statistical analysis function, the government platform mainly realizes the data walk to the superior platform and the lower-level government. The management of government platform and the supervision and service of enterprise platform and its basic function include the following points.

   (a) Access platform management. Access platform management includes access platform configuration management, information query, and assessment functions. Among them, access platform configuration management has access platform parameter configuration, access platform parameter query, and access platform parameter statistics and other basic functions. Access platform information query has the basic situation of the platform: Platform online vehicles, platform history online vehicles, platform off-line vehicles, platform running log and platform inspection log and other query functions. The assessment of access platform includes automatic check-up of platform, manual check-up of platform, dynamic data transmission of platform, online of platform vehicle, dynamic data transmission and quality, etc. It has the access platform by day, week, month, season, and year to carry on the examination function.
   (b) Report export function. All query results and statistical analysis results in the platform support EXCEL export.
   (c) Vehicle data timing function. Regularly sends the normal report vehicle list and abnormal vehicle list to the access platform.
   (d) Alarm and alarm management. The government platform shall have the function of receiving alarm information reported by the access platform, including emergency alarm, deviation route alarm, overspeed alarm, area alarm, fatigue driving alarm, etc. When an alarm is generated, the vehicle dynamic position information and static information and related information can be prompted and displayed by sound, light, picture, and text. If the subordinate regulatory platform or the enterprise platform does not report the alarm processing information within the agreed time, the regulatory platform shall automatically send an alarm disposal request to it.
   (e) Basic information management. The government platform has the functions of network docking and data exchange with local transportation and government information systems. The basic data management should have the function of querying and managing all kinds of vehicles, employees, and transportation enterprises.
   (f) Dangerous goods vehicle/business management function. The dangerous goods vehicle management function has the dangerous vehicle inquiry and the dangerous goods vehicle statistics function. The dangerous goods

transportation enterprise management includes the dangerous goods transportation enterprise inquiry, the dangerous goods transportation enterprise statistics, and the dangerous goods transportation enterprise appraisal function.

(g) The functions of 7-shift passenger vehicle/enterprise management, tour charter/enterprise management, freight vehicle/enterprise management are similar to those of dangerous goods vehicle/enterprise management.

(h) Vehicle dynamic monitoring and management. The government platform has the functions of vehicle real-time monitoring, single monitoring, and so on. It provides the functions of vehicle tracking, message sending, and vehicle photographing, supports the historical data query function of feedback message, vehicle driving record data and photo, can play back the historical track of the designated vehicle, and supports the prompt of vehicle events at the historical track point.

(i) Statistical analysis. The government platform should have the total number of access platforms, the number of online platforms, the number of vehicles entering the platform, the statistical analysis function of online vehicle number, and platform vehicle alarm. Among them, the statistical analysis of vehicle management includes vehicles online statistics report, vehicle cross-regional statistics report and vehicle alarm statistics report, and vehicle information online analysis, vehicle online/month-on-month analysis, vehicle alarm/month-on-month analysis, vehicle across regions, year-on-year/month-on-month analysis, and other comprehensive analysis functions, including regional vehicle statistics analysis, key transport vehicles statistics analysis, enterprise vehicle terminal installation rate statistics, and regional enterprise platform online coverage statistics.

(j) Platform operation monitoring management. It includes server status monitoring, platform resource monitoring, and other functions and can monitor the consumption of server resources.

2. Enterprise Monitoring Platform

Some functions of the enterprise monitoring platform are the same as those of the government platform. The characteristic functions of the enterprise platform are as follows.

(a) Alarm information processing. The enterprise platform has the function of processing the alarm information reported by the terminal and the alarm information generated by the analysis of the enterprise platform. The alarm information processing process includes alarm information confirmation, alarm disposal, alarm processing registration, and alarm information processing status tracking. Alarm processing can be based on different types of alarm vehicle monitoring, photo, alarm release and send information disposal, through the sending of information to achieve the purpose of reminding the driver. The enterprise platform should support the real-time transmission of alarm information and alarm processing result information to the government platform and respond to the alarm disposal request instruction issued by the government platform. All alarm and alarm processing information should be recorded and provided with query function.

(b) Monitoring function. Vehicle monitoring and management includes the functions of vehicle up and down line warning, vehicle scheduling, vehicle monitoring, vehicle tracking, vehicle roll call, vehicle search, area inspection, and vehicle remote control. At the same time, the enterprise platform has the function of playing back the specified vehicle history track in the specified time period and supports the joint query of multi-region and multi-time period.

(c) Management functions. These include terminal parameter configuration management (such as IP address configuration, alarm parameter configuration, area setting and route setting configuration, terminal firmware upgrade, etc.), terminal account opening, closing account, vehicle deactivation, vehicle sublease and terminal transfer, SIM card management, vehicle management, employee management, fleet management, etc. The business functions of the enterprise monitoring platform are as follows.

- Off-line alarm. Alarm when the vehicle deviates from the preset route range beyond the threshold.

  Key points of route monitoring. It supports the monitoring of the critical point time of the vehicle's driving path, that is, when the vehicle does not arrive or leave the specified position according to the specified time, it prompts in real time.
- Driver identification. Identify the driver's identity information uploaded by the terminal.
- Fatigue driving warning. When the continuous driving time of the vehicle or driver exceeds the fatigue driving time threshold, the fatigue driving time threshold can be set remotely by the monitoring center. The special business functions of passenger transport are as follows.
- Line passenger route query function.
- Monitor vehicle over-staffing by photo or video, provide direct call function to vehicle terminal, remind driver over-staffing, provide warning, record, and process over-staffing.

10.2.3 Example: Driving Behavior Monitoring and Early Warning System

This section takes Wuhan University of Technology as an example to further explain its function. The driving behavior monitoring and warning system is divided into two parts: (1) vehicle driving behavior safety auxiliary warning system and (2) remote information release and monitoring early warning. Through the two-level monitoring of the vehicle end and the monitoring center, the driver of the operating vehicle can be monitored in all directions in real time, and the

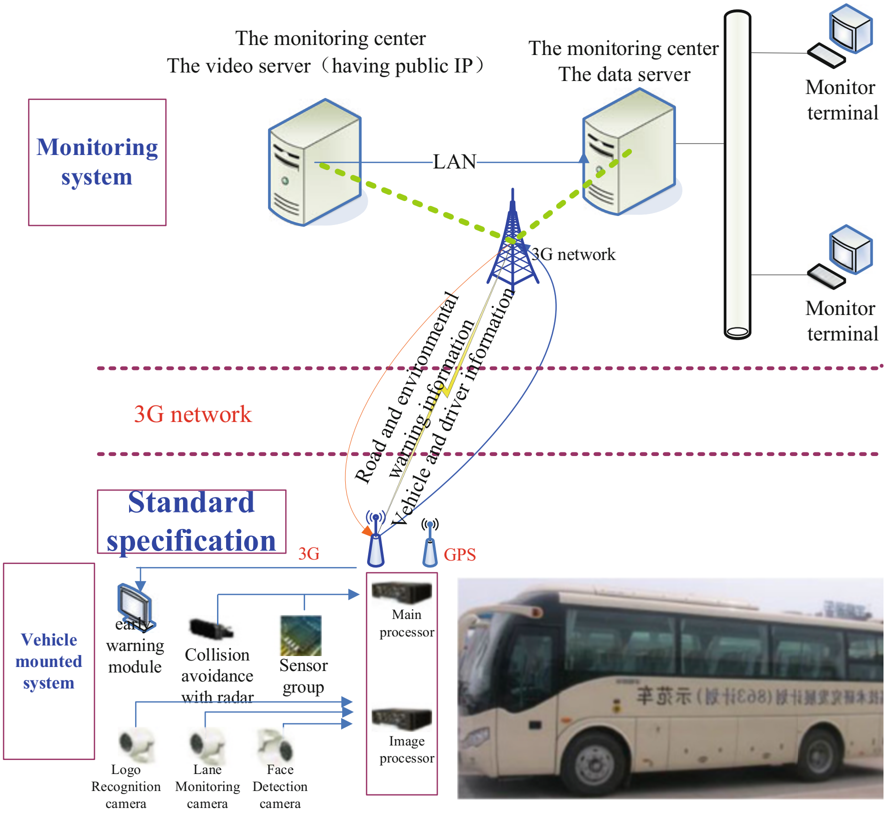

Fig. 10.3 Overall structure of the driving behavior monitoring and warning system

dangerous driving behavior can be identified, warned, and recorded. The overall structure of the system is shown in Fig. 10.3.

1. Vehicle driving behavior safety auxiliary warning system. Vehicle terminal system works by collecting driver operation, driver shape, the state of speeding, the state of not keeping safe distance, the state of lane deviation, bad driving, state identification, and early warning.
2. Remote information release and monitoring and warning system. The remote end monitoring and warning system can take regular photos of the driver, diagnose the terminal of bad driving behavior and analyze all kinds of reports by collecting the recorded data sent by the vehicle end, and issue safety warning information to all kinds of dangerous conditions. In addition, it also undertakes the function of information management of passenger transport company.

10.2.3.1 Vehicle Terminal System

1. Vehicle Status Information Collection.
   The information that the system needs to collect comes from three aspects.
   (a) Vehicle sensor or data signal sent by vehicle CAN bus after vehicle ECU processing. The position is mainly in the vehicle panel and the terminal in the instrument table.
   (b) Self-contained information processing modules, sensors (including additional sensors, cameras, millimeter-wave mines); and reach, ultrasonic probe, etc.
   (c) GPS signal acquisition module and vehicle side environment information (transmitted through wireless transmission module antenna) and so on.
2. On-board System Integration.
   The integrated hardware platform of vehicle terminal center control realizes the integration of vehicle and driver status information acquisition unit, obstacle ranging and speed measurement unit, vehicle location information, geographic information acquisition unit and road environment information acquisition unit, and completes the storage and interaction of driver operation information, driver status information, traffic sign information, road marking and lane deviation information, GPS information, and so on. The multi-channel image is mixed output to the TFT screen for voice broadcast and interface display of the early warning module; all kinds of state and early warning information are transmitted to the central master control platform in 3 ways, and all kinds of instructions of the central master control platform can be received to provide support for bad driving behavior detection and multi-way early warning.
3. Monitoring and Warning of Bad Driving Behavior.
   Through the experiment and analysis of the driver's bad driving behavior, the online detection of typical bad driving behavior and the early warning of all kinds of dangerous driving behavior are realized, including overstepping gear, glide, first step clutch and then brake, long time off-hand driving, no turn light, wrong steering wheel operation gesture, stop and stop without flame-out, turn and brake at the same time, slam on the throttle, and rapid braking of the vehicle.

10.2.3.2 Remote Information Release and Supervision Platform

The development of vehicle remote information release and supervision platform integrates information transmission and processing technology such as database technology, network communication technology, wireless communication technology, and large capacity data processing technology, specifically, a GIS spatial database for the management of geographic information, road maintenance, traffic control geographic information, road maintenance, traffic control, speed, Oracle, and other large-scale relational database platform to establish vehicle real-time status database. On the Net/J2EE platform, an enterprise-level application system based on B/S architecture is developed, including the transportation vehicle management subsystem—which realizes the management of the basic information of the vehicle, the basic information of the driver, the information of the transportation, and the data maintenance system of the transportation line GIS. The information publishing platform based on LAN and GPRS, CDMA transmission can realize real-time update of related basic data such as vehicle equipment GIS. Through the online monitoring system and the corresponding communication module to transmit a variety of forms of transport vehicle status data (text data, voice, image), real-time monitoring of transport vehicles can be achieved.

10.3 Intelligent Networked Vehicle Testing and Evaluation System

10.3.1 Background and Development

Intelligent network-connected automobile is an important part of ITS, which is promoted by new technologies such as intelligent vehicle, vehicle-road cooperation, and so on. Intelligent Networked Automobile aims to realize the full space-time real-time information interaction between vehicle and X (person, car, road, cloud, etc.) through modern sensing technology, information fusion technology, wireless communication technology, intelligent control technology, etc., so that it has high reliable functions such as environment perception, intelligent decision-making, cooperative control, and so on. Finally, it realizes the complete automatic driving under man-car-road cooperation. Different from the traditional vehicle road test field, testing and evaluation is an essential link in the development of intelligent network-connected vehicle technology. The emphasis of intelligent network-connected vehicle testing is to examine the environmental perception ability, intelligent decision-making ability, and automatic control and cooperative control ability of the vehicle. At the same time, the real time and reliability of the V2X communication system and the information security technology are also investigated. The demonstration zone for intelligent connected vehicles integrates the function of technology R&D and technology testing. Moreover, it generally contains functions such as standard customization, industrial incubation, and industrial chain cultivation. The connotation of vehicle road test field, autopilot technology test field, intelligent network vehicle, and intelligent traffic demonstration area is shown in Fig. 10.4.

Meanwhile, numerous technologies related to artificial intelligence have been applied in the research and development of the perception and decision-making of intelligent connected vehicles. Test data from real road scene is essential for the training and learning of intelligent perception and decision-making algorithms. Therefore, the intelligent connected vehicle test system can not only perform functional tests on vehicles, but its test data is also an important cornerstone to promote the development of intelligent driving technology.

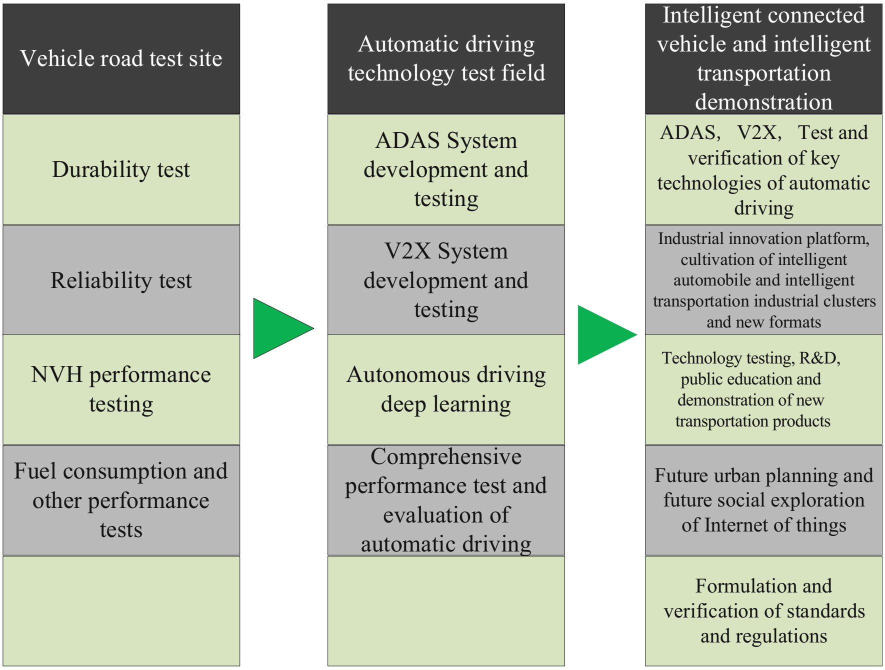

Fig. 10.4 The connotation of the three basic concepts

10.3.1.1 The Development of U.S. Intelligent Connected Vehicle (ICV) Testing

1. Establishment of Test Specifications for Intelligent Connected Vehicle.
   At the national level, the National Highway Traffic Safety Committee of the United States (NHTSA) released Preliminary Statement of Policy Concerning Automated Vehicles in May 2013. In this document, for the first time, the level of automotive automation is refined and clearly defined, and it provides guidance for the independent formulation of autonomous driving technical regulations by states. In September 2016, the U.S. Department of Transportation (DOT) officially released the Federal Automated Vehicles Policy, which proposed guidelines for the performance of autonomous vehicles and provided guidance and specifications for the safe design, development, and testing of highly automated vehicles (HAV), and it also identified 15 assessment contents, including data recording and sharing, system security, vehicle network security, post-crash behavior, object/incident detection and response, etc. In July 2017, the U.S. House of Representatives passed the Self Drive Act. Chapter 7 of the bill stipulates requirements for various participants, such as evaluation agencies, autonomous driving system providers, component suppliers, tested vehicles and on-board equipment, and participation in testing as well as information that must be submitted. In September 2017, the U.S. Department of Transportation and the

National Highway Traffic Safety Administration issued Automated Driving System 2.0: A Vision for Safety. This document replaced the federal self-driving car policy issued in 2016, reduced the content of the safety assessment from 15 to 12, and gave the safety goals and implementation methods of these 12 items. The guide encourages research and development entities to fully consider these 12 items when developing autonomous driving systems, and design a self-recording process for various evaluations, tests, and verifications. The guide encourages research and development entities to regularly publish their safety self-assessment results to the public, and demonstrate its various methods to achieve security; NHTSA will also regularly update the guide based on the development and improvement of technology to reflect lessons learned, new data, and the opinions of stakeholders.

2. Construction of a Closed Test Field for Intelligent Connected Vehicles

    Currently, the U.S. Department of Transportation has designated a total of 10 autonomous driving pilot test sites, which are located in different regions such as the northeast, southwest, and south of the United States. These test sites distributed across the United States have differentiated climatic conditions and geomorphological characteristics, which make smart connected cars tested under more abundant conditions. Among them, Mcity, jointly funded and constructed by the University of Michigan and the State of Michigan, is the world's first closed test site to test V2X technology. It was officially opened in July 2015. The test site is located in Ann Arbor, Michigan, covering an area of 194 acres with the total length about 8 kilometers. A variety of roads and roadside facilities are set up in Mcity to simulate the real road environment, including high-speed experimental areas for simulating highway environment and low-speed experimental areas for simulating urban and suburban areas. Among them, the low-speed test area that simulates the urban area completely imitates the construction of ordinary towns, including two-lane, three-lane, and four-lane highways, as well as intersections, traffic lights and signs, etc., providing real road scene elements such as surfaces, signs and markings, slopes, bicycle lanes, trees, fire hydrants, and surrounding buildings.

GoMentum Station is located in Contra Costa County, California. It is the largest autonomous driving technology and connected vehicle technology test site in the United States. It is jointly constructed and operated by the local transportation authority, automobile manufacturers, communication companies, and technology companies. Now that the test site is located in the San Francisco Bay Area, close to Silicon Valley, it has attracted many technology companies, automakers, and network-connected equipment manufacturers to enter the test site.

At present, GoMentum Station has paved 32 kilometers of roads and streets, including overpasses, tunnels, railways, and other facilities and has the geological characteristics of hills, slopes, and various road surfaces to achieve various test scenarios, as shown in Fig. 10.5.

Fig. 10.5 Inner scene of GoMentum Station

10.3.1.2 The Development of Domestic Intelligent Connected Vehicle (ICV) Testing

1. Establishment of Test Specifications for Intelligent Connected Vehicle.
   In December 2017, Beijing issued the Beijing Autonomous Vehicle Road Test Management Implementation Rules (Trial) and related documents and identified 33 open test roads with a total of 105 kilometers. In March 2018, Shanghai issued the Shanghai Intelligent and Connected Vehicle Road Test Management Measures (Trial), delineating the first phase of 5.6 kilometers of open test roads; Chongqing, Shenzhen, Baoding, and other places have also issued corresponding road test rules. After initial attempts by local governments, in order to implement autonomous driving road tests in various regions, further clarify the management requirements and division of responsibilities for road tests, standardize and unify local basic test items and test procedures, on April 12, 2018, the Ministry of Industry and Information Technology, Public Security Bureau, and the Ministry of Transport jointly issued the Management Specifications for Road Testing of Intelligent Connected Vehicles (for Trial Implementation), which set strict requirements on test subjects, drivers, and vehicles respectively. The Measures proposes to the test subject the nature of the test entity, business scope, accident compensation capability, test evaluation capability, remote monitoring capability, event record analysis capability, and compliance with laws and regulations; it proposes to sign a labor contract or labor service contract, and process the test driver with autonomous driving training, no major traffic violation records, and other 8 requirements. Six basic requirements are put forward including the test vehicle registration, mandatory project inspection, man-machine control mode conversion, data recording and real-time return, specific area testing, and third-party agency testing and verification. At the same time, in order to ensure that the violating party is held accountable for traffic violations and traffic accidents

during the test period, the "Management Regulations" clarifies the basis for the determination of traffic violations and accident liability, as well as the corresponding handling and punishment departments, and stipulates that the parties shall be involved after an accident. It also stipulates the reporting requirements of the parties, the test subjects, and the provincial and municipal departments after the accident.

2. Construction of a Closed Test Field for Intelligent Connected Vehicles

   In June 2015, the Ministry of Industry and Information Technology of the People's Republic of China approved Shanghai to build a pilot demonstration zone for the National Intelligent Connected Vehicle (Shanghai). In June 2016, the demonstration zone was officially put into operation, becoming China's first intelligent network connection demonstration zone. Since the opening of the park, more than 200 test scenarios have been built in the Shanghai Intelligent Networking Closed Test Zone and more than 450 days and more than 5000 hours of test services have been provided to more than 40 companies.

Following Shanghai, places of Chongqing, Beijing, Hebei, Zhejiang, Changchun, Wuhan, and Wuxi have successively built smart connected vehicle test demonstration zones. Relying on local advantages and the distribution of characteristic resources, demonstration zones have actively promoted test and verification for semi-closed and open roads.

10.3.2 Test Verification Technology and Test Method

10.3.2.1 Analysis of Requirements for Test Verification of Intelligent Connected Vehicles

Intelligent networked vehicles use on-board sensors to sense the environment and integrate modern communication and network technologies to realize intelligent information sharing, and realize safe, comfortable, energy-saving, and efficient driving through processes such as intelligent decision-making and collaborative control. The research of intelligent networked vehicles and related intelligent technologies has not only become the development engine of the current combination of information technology, sensor technology, and cognitive science, but also can be applied to future smart transportation and smart cities to reduce road traffic accident rates and casualties. It can improve transportation efficiency and driving experience, and at the same time promote and drive the development and reform and innovation of the automobile industry, and provide key technical support for related research and applications in the field of national defense and security.

The technological progress and application promotion of intelligent networked vehicles need to be supported by a complete test and evaluation system. The specific requirements are mainly reflected in the following four aspects.

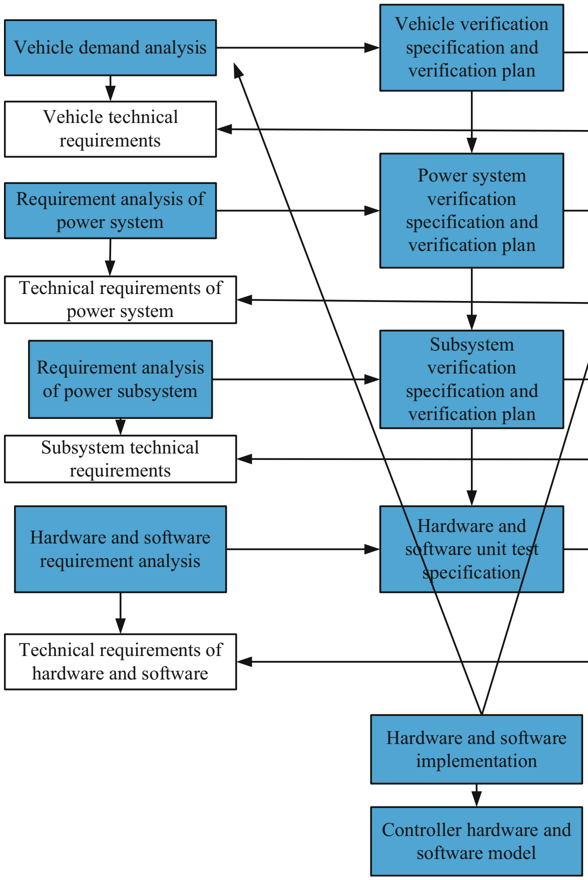

Fig. 10.6 V-mode development process of the entire vehicle

1. Requirements for Technology and Product Development.

   In the process of automobile development, the V-mode development method has been widely used. Testing and evaluation at each stage of development is the prerequisite for the realization of the V-mode development; the rapid development of intelligent networked vehicles has made it cover more and more functions. More and more user working conditions are targeted, so a lot of testing and evaluation work is needed for function and performance testing, as shown in Fig. 10.6.

2. Standard Requirements

   Different from the development of traditional cars, the performance of intelligent networked cars is highly related to the traffic environment and driving behavior. Therefore, the method of directly introducing foreign standards in the traditional automotive field is no longer applicable. It is necessary to study and formulate standards and specifications in line with China's national conditions.

3. Legal Requirements.

   Intelligent networked vehicles, especially high-level autonomous and driverless vehicles, need to be supported and restricted by sound laws and regulations. On the one hand, in order to encourage technological innovation and promote technological development and industrial upgrading, it is necessary to vigorously promote autonomous driving/unmanned vehicles to enter public roads for testing and even commercial applications; but on the other hand, it is necessary to ensure that autonomous driving/unmanned vehicles entering public roads have sufficient safety, will not pose a danger to public safety, and will not interfere with normal traffic order. The test methods need to be coordinated with legal regulations to jointly promote the development of intelligent networked vehicles.

4. International Demands

   Developed countries in the automotive industry such as Europe, the United States, Japan, and South Korea have all begun to build closed test grounds and pilot demonstration areas for intelligent networked vehicles, and related testing and evaluation systems and standards are being improved. We need to further accelerate the construction of intelligent networked vehicle evaluation platforms and test demonstration areas, promote the research and formulation of relevant standards as well as regulations, accelerate the docking with foreign advanced technologies, absorb advanced international experience, and promote the research and development of China's intelligent networked vehicle technology as well as industrial application.

10.3.2.2 Common Test Methods

With the continuous advancement of technology, the main content of automotive testing methods not only includes sensor-based measurement principles, methods, tools, data processing, etc., but also develops into widely used in-the-loop test methods that place the object in simulation operation. The following mainly introduces several in-the-loop test methods and real-vehicle test methods that have been common in automotive testing in recent years.

1. Model in the Loop, MIL

   Model-Based System Engineering (MBSE) is a mathematical and visualization method used to solve related problems in the design of complex control, signal processing, and communication systems. It is widely used in motion control, industrial equipment, aerospace, and automotive-related applications, making it a major development and testing method.

   The model provides an abstract method of the physical system, which allows engineers to ignore irrelevant details and focus on the most important parts to think about the overall design of the system. All the work in the project relies on the model to understand the complex real-world system. In MBSE, the model is an executable specification that is continuously refined throughout the development process (usually the development is guided by requirements expressed in text form, and these models are then converted into code with code generation). Compared with specifications written on paper, executable specifications can enable system engineers to have a deeper understanding of the dynamic performance of their strategies. The models are tested in the early development stage before coding, and product defects are exposed to the project, and continuous verification and testing during the development process will be applied so that engineers can focus on the research of algorithms and test cases to ensure the completeness and unambiguity of the specification. They do not have to spend time dealing with cumbersome, error-prone tasks, such as creating test fixtures. After the model is established, they will add model-based testing to ensure that the model does capture the requirements correctly.

Unlike "static" written designs, executable specifications can be evaluated during model-based testing. This can usually be done by changing a set of model parameters or input signals, or by viewing the output results or the response of the model. The sequence of simulation performed based on the model is also called model-in-the-loop testing. The test data for model-in-the-loop testing come from a test vector database or a model of the actual system. Executable specifications usually include not only functional design models and software logic, but also equipment and environment models, links to high-level requirements, and other files, and usually include verification data for automated simulation results evaluation. The results of model-in-the-loop testing can be used to verify whether the software behavior is correct and to confirm the initial requirements of the development process. The information collected through model-in-the-loop testing will become a benchmark for code verification.

2. Software in the Loop (SIL)

General software-in-the-loop testing refers to the evaluation of the code generated in the simulation or the handwritten code on the host to realize the early confirmation of the generated code. But this kind of test is only for the generated code and does not consider the correlation between the code and the model. Therefore, when a code problem is found during the test process, it is necessary to manually locate which model is the problem.

In addition, there is also a comparison test method between software-in-the-loop and model-in-the-loop, which mainly realizes the synchronous execution of model and code. This method inserts control code into the test code generated by the model to record status information and sends it to the modeling platform. After the analysis, the execution process of the model is displayed synchronously in the way of highlighting; at the same time, the test process can also obtain the currently monitored global variable information, and the tester can analyze whether the specific modeling is correct or meets the actual needs by monitoring the global variable information.

The key point of the software-in-the-loop testing method is to ensure that the generated code and model are executed synchronously, and the execution process should be intuitive enough for users to view. In addition, because additional control codes are added to the test code, there are differences between the test code and the product code, which will inevitably pose an impact on the performance of the code, so it is necessary to consider how to minimize this impact. Specifically, the following issues need to be considered when designing the test plan.

(a) The test process should accurately reflect the execution process of the model. The graphically described model and monitoring variable information must be correctly displayed during the test. When the code generated by a certain model element instance is executed, the model element instance must be highlighted. In the state diagram model, when a state transition occurs, it can automatically switch to the next state that meets the transition conditions. In addition, monitoring variable information also needs to be consistent with the code execution.
(b) The test process should be intuitive. The intermediate information of the test process should be clearly reflected in the graphical modeling. The more intuitive the test process is displayed in the modeling, the easier it is to check errors. At the same time, the display of the test process should learn from the display methods of existing tools to make it more convenient for modelers to use.
(c) The impact of the test process on the system under test should be minimized. For any kind of in-process test, the test process should minimize the impact on the system under test. At the same time, for the test code, if too much control code is inserted during the execution of the test, there will be a large inconsistency between the test code and the graphical model. Therefore, less code should be added to the automatically generated test code.

3. Hardware in the Loop (HIL)

The development of the automotive system project is a systematic project with high technology and heavy workload. The development of the entire vehicle and various parts and components is carried out at the same time. In order to ensure the progress of the project, putting the hardware in the test loop is a technical form that combines physical components and software models and is widely used in component testing or control system testing. Generally speaking, hardware-in-the-loop test systems can be divided into four types: the first type, the real controller is placed in the test loop, and the pressure or electrical signals of the remaining components are incorporated into the controller with real signals or signals simulated by the simulation environment. The control loop does not include the power loading device; the second type is to use a computer to quickly build its controller model, place the controlled object as a physical object in the simulation loop, and construct an in-loop test system. This process is also called rapid prototyping. The third type uses the dynamic characteristics of the power loading device to simulate the rest of the system to load the physical components, and the signals output by the physical components are fed back to the system model to form a system loop; the fourth type is mainly based on the second type. It incorporates the process quantity of the loop system model or the output quantity of the physical component into a larger controller to control loop.

The development of automotive hardware-in-the-loop test system is the most important measure to implement concurrent engineering to realize simultaneous development. Adopting the computer simulation test system can better solve the following problems.

(a) In the synchronous development project, it is necessary to solve the controller test in the absence of control objects and prototype vehicles in the initial development stage.
(b) Complete tests that cannot be carried out in practice or are expensive, and it is convenient to carry out accurate limit test, failure test, and the reproduction of various failures, making the test more comprehensive and complete.
(c) The dangerous situation is simulated without actual danger, and the test can be repeated and carried out automatically.
(d) The optimization of control strategy, the possible influence of each parameter, and the sensitivity of parameter changes can be verified quickly and economically, and conflicting targets can be found and coordinated early.
(e) The duplication and changes in the development process can be avoided to the greatest extent. Since the simulation has verified various operating states and functions, it avoids most of the errors in the design and greatly reduces the development risk.
(f) The cost of hardware and testing is reduced to a minimum, and the research time and development cost are greatly saved.

4. Real vehicle test method.

Model-in-the-loop, software-in-the-loop, and hardware-in-the-loop are suitable for testing controllers, components, systems, or assemblies, but when these parts or assemblies are assembled together, unexpected failures or problems often occur, so the entire vehicle must be tested and evaluated. The testing and evaluation of the whole vehicle generally requires the aid of a proving ground or large-scale testing equipment.

The automobile proving ground is the place where the whole automobile road test is carried out. In order to meet the actual testing needs of intelligent networked vehicles, the automobile test field facilities mainly include the following three aspects.

(a) Intelligent road network infrastructure. The smart road network infrastructure mainly includes participants (workers and scene dummies) and their accessory wearable devices: smart car fleets, including standard smart passenger cars, commercial vehicles, buses, taxis, etc. Vehicles need to install vehicle networking terminal equipment based on communication functions, which can realize a variety of network communications (5G/4G+, DSRC, LTE-V, etc.), and can collect real-time operating data of the monitored vehicle: road infrastructure, including bends, ramps, overpasses, tunnels, T-junctions, crossroads, crosswalks, lane markings and other traffic signs as well as street lights, traffic signs, road shoulder stones, roadside buildings, road test signal transceiver equipment, etc.

(b) Network communication environment. In the demonstration area, a comprehensive coverage of short-distance and long-distance communications such as vehicle-vehicle, vehicle-road, vehicle-cloud computing, and road-cloud computing will be formed, so as to realize the integration of the three networks of in-vehicle network, inter-vehicle network, and vehicle-cloud network. The in-car network uses mature technology to establish a complete vehicle network; the inter-car network uses LTE-V technology, DSRC technology, and IEEE802.11 series wireless local area network protocols to form a dynamic network; the car-cloud network uses 5G/4G+ and other communication technologies to form a dynamic network and connect wirelessly to the Internet.

(c) Test for service support facilities. The automobile test site needs to be equipped with a vehicle preparation room for the test unit to adjust the vehicle, as well as a computing center for storing and processing test data, a control center, and other equipment that provide support for testing services.

10.3.3 Case: The Closed Test Zone in Shanghai International Automobile City (F-Zone)

This section takes the closed F-Zone in the pilot demonstration zone of the National Intelligent Connected Vehicle (Shanghai) as an example, focusing on the venues, equipment, and testing capabilities of the closed test zone.

The F-Zone closed test zone covers an area of 2 square kilometers. It is invested and constructed by Shanghai International Automobile City (Group) Co., Ltd., and cooperates with the professional team of China Automotive Technology Research Center to participate in the field service and operation. The test site has built more than 100 test scenarios to meet various types of unmanned driving and V2X on the basis of existing municipal roads, covering application categories such as safety, efficiency, communications, new energy vehicles, etc.

10.3.3.1 Test Environment

1. Test area. F-Zone has built test roads with a length of 3.6 km, covering various types of traffic roads such as T-junctions and crossroads. At the same time, there are road facilities such as simulated tunnels, simulated tree-lined roads, and simulated gas stations. Currently, more than 50 V2X test scenarios can be implemented in the test area.

2. Office area. F-Zone provides 4 closed, well-equipped vehicle preparation rooms, as well as supporting service areas such as parking, office, storage, and functional areas such as data centers and control centers, as shown in Fig. 10.7.

Fig. 10.7 Environment of F-Zone office area

Table 10.1 Scenarios of network connection tests and quantity

Scene type	Security	Efficiency	Information service	New energy vehicle application	Communication ability test
Number	33	6	6	3	2
Ways of communication	V2V	V2I	V2P	V2C	Unlimited
Number	21	15	2	8	4

10.3.3.2 Testing Ability

F-Zone can provide two types of tests, connected type and autonomous driving type, and each type of test covers a variety of working conditions and applications.

1. Network test.

   F-Zone provides more than 50 types of networking tests, covering security, efficiency, information service, new energy vehicle applications, and communication capability tests, and can be combined into a variety of custom scenarios, as shown in Table 10.1.

   Among them, the safety test includes non-motor vehicle crossing warning, road slippery warning, vehicle conflict avoidance at intersections under the influence of sight distance, forward collision warning, emergency vehicle warning, emergency brake warning, red light warning, and no signal intersection traffic, accident ahead reminder, speed zone reminder, road construction reminder, blind spot warning, crossroad pass assist, overtaking assist, reverse overtaking reminder, left turn assist, pedestrian crossing warning, abnormal road warning, abnormal vehicle warning, post-accident warning, early reversing warning, following distance reminder, reverse driving reminder, restricted lane warning, vehicle size warning, night meeting car reminder, pedestrian crossing assistance, bus signal priority, and other test items.

The efficiency test items mainly include automatic parking, cooperative fleet, congestion reminder, automatic payment for arrival, green wave band traffic, dynamic lane management, etc.

Information service test items include smart parking guidance, charging/refueling reminders, in-vehicle signs, local map downloads, bus stop/outbound reminders, and information services based on ITS big data.

New energy vehicle application test items include charging map guidance, wireless charging, charging pile usage information prompts, etc.

The communication ability test items include the communication ability test under different signal blocking conditions such as tunnel traffic and tree-lined road traffic.

2. Autonomous driving test.

F-Zone provides flexible scene design, which can be combined into multi-level and multi-type custom scenes to meet the behavioral ability test of autonomous driving under normal driving conditions, and the collision avoidance ability test under dangerous conditions, as well as the exit mechanism and response. At the same time, it supports the test of the driver's ability to respond to misoperations in low-level autonomous driving.

The test content of the behavioral ability test is shown in Table 10.2.

37 dangerous driving scenarios set in collision avoidance test, as shown in Table 10.3.

The exit mechanism test refers to the test that requires the driver to take over or stop safely when the system fails or goes beyond the operational design domain (ODD). It mainly includes pre-start self-check, automatic driving mode visual prompts, detection and response to automatic driving mode (intervention and cancelation) restrictions (ODD), detecting and responding to technical failures, safe stopping, and other items.

The detection and early warning scenarios for driver misoperation include the driver leaving the steering wheel with both hands, deviating from the driving direction, dozing/sleeping, leaving the driving position, and other possible scenarios.

10.3.3.3 Test Equipment

The equipment of the closed test site in F-Zone mainly include communication network system equipment, positioning system equipment, video surveillance system equipment, road environment simulation equipment, test equipment, data acquisition equipment, etc., as shown in Table 10.4.

Table 10.2 Test items for self-driving vehicle behavior ability

Detect and respond to speed limit changes and suggested speed	Detect and respond to stopped vehicles	Go through the cross and turn	Comply with local car driving laws	Detect and respond to emergency vehicles
Leave the traffic lane and stop	Detect and respond to lane changes	Find a parking space through the parking lot	Follow the police/ first responders who control traffic (as a traffic control device)	Give way to emergency vehicles at crossroads, three-way intersections, and other traffic control situations
Detect and respond to oncoming vehicles approaching	Detect and respond to static obstacles in the vehicle driving lane	Detect and respond to traffic restrictions (one-way streets, no turning, ramps, etc.)	Follow the construction workers who control the traffic mode (slow motion/stop sign bracket)	Give way to pedestrians and non-motor vehicles at intersections and crosswalks
Detect overtaking areas and no overtaking areas to overtake	Detect/ respond to traffic signals and stop/ yield signs	Detect and respond to the person directing traffic in the work area and unexpected/ planned incidents	Citizens who respond to smart transportation after a collision	Keep a safe distance from vehicles, pedestrians, and non-motorized vehicles on the side of the road
Follow the car (including stopping and starting)	Pass a roundabout	Make appropriate first-pass decisions	Detect and respond to temporary traffic control equipment	Detect/respond to detours and/or other temporary changes in traffic mode

10.4 Traffic Organization and Management System for Large-Scale Event

In recent years, with the continuous development of urbanization and the people's living standards, more and more large-scale events have been held in major cities. Absolutely, the large number of people and vehicles attracted by the holding of large-scale events will cause huge traffic pressure on the city's daily traffic facilities and may cause congestion. Therefore, various traffic management measures are used to ensure the safety and smoothness of traffic during large-scale events. It can help minimize the impact on background traffic demand, and ensure that event participants quickly, orderly, and timely evacuate large-scale events during emergencies. Therefore, traffic organization and management system came into being.

Table 10.3 Collision avoidance test

Working conditions	Scenes
Vehicle breakdown	Off the road
The vehicle turns and loses control	
The vehicle goes straight and loses control	
Run the red light	Cross the road
Run the stop sign	
The vehicle deviates from the lane when turning	Off the road
Deviating from the lane when the vehicle is going straight	
The vehicle is off the lane when reversing	
Conflict with animals when the vehicle is turning	Animal
Encounter animals when the vehicle is going straight	
Conflict with pedestrians when the vehicle turns	Pedestrian
Conflict with pedestrians when the vehicle is going straight	
Conflict with cyclists (bicycles, motorcycles, electric bicycles, etc.) when the vehicle is turning	Non-motor vehicle
Conflict with a cyclist when the vehicle is going straight	
Conflict with other vehicles when the vehicle is reversing	Reversing
Turning vehicles conflict with vehicles traveling in the same direction	Lane change
When a stationary vehicle starts, it conflicts with a vehicle traveling in the same direction	
Vehicle changing lanes conflict with vehicles traveling in the same direction	
Vehicle drifting conflicts with vehicles traveling in the same direction	
Vehicle steering conflicts with oncoming vehicle	Driving in opposite directions
Conflict between a vehicle traveling straight and an oncoming vehicle	
When the vehicle follows the car, the steering conflicts with the preceding car	Follow the car
The vehicle approaches accelerates vehicle ahead	
The vehicle is approaching a vehicle driving at a lower and constant speed ahead	
The vehicle is approaching a vehicle that is slowing down ahead	
The vehicle is approaching a stationary vehicle ahead	
The vehicle turned left at a traffic lighted intersection and collided with the oncoming vehicle	Pass the road
The vehicle turns right at a traffic lighted intersection	
The vehicle turns left at an intersection without traffic lights and conflicts with the oncoming vehicle	
The vehicle goes straight at an intersection without traffic lights	
The vehicle turns at an intersection without traffic lights	
Avoid obstacles when turning	
Avoid obstacles when the vehicle is going straight	Off the road
Non-collision hazard	Others
Obstacles encountered when the vehicle is turning	Obstacle
Obstacles encountered when the vehicle is going straight	
Others	Others

Table 10.4 Device information

Environmental simulation equipment	Simulation equipment of road	Traffic signs board	Traffic signs
		Traffic lights	Traffic signal indication
		Road cone	Warning for keeping distance
		Floor tape	Simulated lane line
		Traffic signal control equipment	Traffic signal control
	Simulation equipment of traffic participant	Dummy	To simulate road pedestrians
		Car model	To simulate road vehicles
		Non-motor vehicle (model)	To simulate road non-motorized vehicles
		Animal model	To simulate road animals
		Others	/
	Simulation equipment of information environment	DSRC device	DSRC communication
		LTE-V equipment	LTE-V communication
		Wi-Fi communication equipment	Wi-Fi connection
		High precision map	Location targeting
		Information induction equipment	Induction display
		GPS differential base station	GPS high-precision positioning
Test equipment	Robotic driver		Driving operation
	RT-RANGE		Relative positioning
	VBOX		Data and image recording
	Four wheel alignment table		Wheel alignment
Data acquisition equipment	Vehicle data acquisition, road test data acquisition		Data collection
	Microphone		Acoustic signal collection
	Camera		Image signal acquisition
Infrastructure equipment	Spherical surveillance camera		All-round monitoring in the test area
	Microwave radar		Road monitoring
	Road feature detection camera		Junction monitoring

(continued)

Table 10.4 (continued)

	Traffic violation detection equipment	Snapshot and video recording
	RFID access control equipment	Access control

10.4.1 A Brief Introduction to the System

In recent years, Chinese comprehensive national strength has been continuously strengthened. With the increase of market economic activities and the improvement of people's material and cultural living standards, large-scale cultural and sports events, conventions and exhibitions, commercial promotion activities, and other large-scale events in cities have been held more frequently. Over the past several years, China has successfully hosted large-scale events such as the 2008 Beijing Olympic Games, the 2010 Shanghai World Expo, and the 2010 Guangzhou Asian Games. The holding of these large-scale events has enriched the material and cultural life of Chinese citizens, increased our international influence, and promoted economic development. However, the large number of spectators attracted by this has also brought a great impact and influence on urban traffic. As large-scale events are held in a short period of time, a large number of spectators will be concentrated in the venue and its surrounding areas, which will put great pressure on the traffic near the venue, cause road congestion and traffic accidents, and even affect the traffic and residents of the city.

In 1988, the Federal Highway Administration defined planned special events as events that occurred at a specified time and at a designated location that could cause an unconventional increase in traffic demand, such as exhibitions, entertainment activities, sports events, and holiday gatherings.

In China's first special regulation for the safety management of large-scale events, the Regulations on the Safety Management of Large-scale Social Activities in Beijing, the definition of large-scale social activities is as follows: Large-scale social activities refer to the sponsors renting, borrowing or other temporary occupation of places and venues, theatrical performances, sports competitions, exhibitions, garden parties, and other group activities held for the public.

With the holding of large-scale events, the demand for the road network has increased sharply, breaking the original balance of traffic supply and demand. To bring urban traffic back to a new balance, there are two commonly used methods: increase supply and decrease demand. Measures of increasing supply, such as improving road conditions and other hardware facilities, cannot be completed in a short period of time and will cause a waste of resources after large-scale activities are over. The demand can be reduced by reducing the scale of the event, but this method weakens the influence of the event and cannot achieve the purpose of holding large-scale events.

At present, there are relatively few domestic cases that specialize in large-scale event public transportation evacuation. Most of them are macro-expositions on large-scale event transportation organization and planning methods. Research in this area has great theoretical value.

Regarding the research on large-scale events, before the U.S. Federal Highway Administration defined planned special events in 1988, it mainly focused on the experience summary of traffic management for international super-large sports competitions. After that, progress focused on theoretical research on traffic organization management for large-scale events was made.

Foreign research on large-scale event traffic organization can be roughly divided into two categories, one is the summary of experience after the large-scale event is held; the other is the theoretical research on the problem of large-scale event traffic organization and management.

According to the traffic organization and management of the 2000 Sydney Summer Olympics, the 2002 Salt Lake City Winter Olympics, and the 2004 Athens Summer Olympics, the experience of traffic organization and management of foreign large-scale sports events is summarized as follows.

1. Organization and Management of Public Transportation

   They established a dispatch center and service fleet dedicated to public transportation services for large-scale events and equipped with sufficient bus transportation capacity. For the Sydney Olympics, a private bus company composed of more than 2200 buses took on 35% of the spectator traffic for the event transportation services; the Salt Lake City Winter Olympics set up a total of 4 bus dispatch centers to ensure the normal operation of the public transportation service system during the Olympics. About 1000 buses were used exclusively for public transportation services for spectators.

   A public transportation priority strategy was implemented. During the Athens Olympics, in order to ensure the priority of public transportation vehicles, special bus lanes were set up on some arterial roads, with bus priority control signals, and traffic control was implemented in the streets of the central area. Only local vehicles and public buses were allowed to pass. Dedicated bus and carpool lanes on some roads near the competition venues to give priority to ensuring smooth public transportation was set up; the 2000 Sydney Olympic Games used government subsidies to provide free ground bus or rail transportation to spectators holding tickets for the competition of the day, which increased the share rate of public transport trips.

2. Planning for Parking Lot and Transportation Hub

   In order to meet the parking needs of large-scale events, a temporary parking lot is planned and constructed near the event venue, and other transportation interchange hubs are planned to alleviate traffic congestion caused by large-scale events. During the Sydney Olympics, a total of 197 temporary parking lots were planned and constructed, and shuttle buses were installed between the temporary parking lots and large-scale event venues. During the Athens Olympics, the planned transportation interchange hub was used to effectively alleviate the traffic congestion caused by the Games.

3. Transportation Needs for VIP and Other Special Personnel

   As for international large-scale events, there will be heads of state, government officials and other VIPs, event sponsors, news media reporters, and other personnel. Different from the transportation needs of ordinary audiences, these special personnel must be guaranteed to arrive at the event safely, quickly, and on time. In response to this part of the traffic requirement, the events set up individual lanes and adjust travel time to guarantee their travelling priority. And priority should be given to parking lot planning and right of way at intersections. Both the Athens and Sydney Olympics have adopted the measures and have been effectively used.

4. Traffic Demand Management

   Foreign traffic demand management measures often adopted for large-scale events include using fare strategies to adjust the distribution of traffic travel time and space; using parking fees to reduce the proportion of private car travel. The Athens Olympics uses discounts on all-day passes to reduce the traffic flow of large-scale events during peak hours; the Sydney Olympics has significantly increased the parking fees around the venues to reduce the travel of private cars and ease the traffic pressure around the venues.

   Traffic demand management measures in cities where large-scale events are held include off-peak commuting to and from work, holidays during the event, advocating remote office work at home, and prohibiting some vehicles from passing in specified areas. Both the Sydney Olympics and the Salt Lake City Winter Olympics adopted the above measures to reduce the amount of urban background traffic.

5. Traffic Information Release and ITS Application

   Utilize the Internet, TV, radio, and other methods to release traffic status information in a timely manner, and adopt the ITS to organize and manage traffic for large-scale events and monitor the operation of vehicles. The Sydney Olympic Games carried out the Olympic traffic information guide sign planning and distributed the "Traffic Information Handbook" free of charge. Both the Salt Lake City Winter Olympics and the Athens Olympics have used ITS technology extensively and played an important role in the organization and management of large-scale event traffic.

   The United States Transportation Research Council published a comprehensive report Traffic Planning and Management of Large-scale Events in 2003. The report outlines the organizational departments, managers, and technical programs related to the traffic planning and management of large-scale events.

   In September 2003, the U.S. Federal Highway Commission also published a report on the planning and management of large-scale events—Travel Management for Large-scale Events. The report is a relatively comprehensive and systematic literature on the organization and management of large-scale events. It not only analyzes and studies the definition of large-scale activities and its traffic characteristics, but also comprehensively discusses the preparatory planning of large-scale activities, the mid-term traffic operation and implementation of measures, and the later analysis and evaluation.

The domestic research on the transportation theory of large-scale events started relatively late, and only after the successful bid for the Beijing Olympic Games did relevant transportation research institutions intervene in this research field. In recent years, with the frequent holding of large-scale events, domestic research on the transportation organization of large-scale events has gradually increased. The traffic organization and management during the event played a role in guaranteeing the success of the Shanghai World Expo and the Guangzhou Asian Games.

Generally speaking, foreign research on the transportation organization and management of large-scale events started earlier and has achieved relatively rich research results. A more systematic and comprehensive large-scale event transportation organization and management method has been proposed, and it has been successfully applied to various activities. Domestic research on the transportation organization and management of large-scale events started relatively late, and there are few systematic studies on large-scale event traffic demand forecasting, transportation organization planning, traffic demand management, and transportation planning program evaluation.

10.4.2 Composition of the System

The traffic organization and management of large-scale events are different from the regular traffic organization in cities. Conventional urban traffic organization and management has a certain degree of stability and regularity. Traffic management methods are usually implemented in accordance with mature policies based on collecting historical data and investigating and analyzing current traffic. The transportation organization and management of large-scale events have the characteristics of large total volume, concentrated time and space distribution, hierarchical demand, multiple sources, and single sinks, and different types of large-scale events should often adopt different organizational management methods.

This section first introduces the principles of large-scale event traffic organization and management, and then further explains various traffic organization and management methods, including large-scale event traffic demand forecasting and management, large-scale event traffic organization planning, large-scale event traffic information release, and emergency traffic organization planning. It sets up the basic system composition of the large-scale event traffic organization and management system.

10.4.2.1 Analysis of Traffic Characteristics of Large-Scale Events

To conduct traffic demand forecasting for large-scale events and research on traffic organization and management methods, we must first analyze the traffic characteristics of large-scale events. This section starts from three aspects: traffic demand characteristics, traffic flow characteristics, and traffic organization and management characteristics. The differences between large-scale event traffic and urban normal traffic are as follows.

1. Traffic Demand Characteristics of Large-Scale Events.

The total traffic demand is large and the time is concentrated. The traffic demand induced by large-scale activities is significantly greater than the traffic demand generated by the city's land use of the same scale. During large-scale events, the amount of traffic attraction generated per unit area exceeds the traffic attraction generated by conventional land in the city by dozens or even hundreds of times.

For example, the Shenzhen Bay "Chun Jian" Stadium, where the opening ceremony of the 26th World University Games in Shenzhen was held in 2011, has an area of less than 1 km, but attracted about 50,000 participants.

Large-scale events that provide one-time services usually have a fixed start time and end time, which makes the traffic demand for large-scale events concentrated in time. For example, when the opening ceremony of the Shenzhen Universiade was dismissed, 50,000 participants had to be evacuated within one hour, and traffic demand was highly concentrated in time distribution.

The traffic demand is hierarchical. Different from the conventional urban traffic demand, the traffic demand for large-scale events has obvious priority. Especially for large-scale events with international influence, the participation of international and domestic VIP guests has a greater impact on transportation. According to the priority of traffic demand, meeting the travel needs of large-scale events at different levels while minimizing the impact on urban background traffic is an important goal of large-scale event traffic organization and management.

There are higher requirements for accessibility and punctuality.

In this case, the holding time of large-scale events is fixed, and it is necessary to ensure that the large-scale event participants arrive at the event venue on time before the event begins. Therefore, the effective traffic organization and control of the roads around the event venue are required to improve the intersections and roads that may easily prevent event participants from entering the venue on time. Besides, we are supposed to reasonably set up traffic routes so as to ensure the reliability of the connectivity of the transportation network between the venue for large-scale events and other nodes, the reliability of the traffic capacity of the road network around the venue for large-scale events, and the reliability of the travel time of event participants.

2. The Traffic Flow Characteristics of Large-Scale Events.

   Compared with the conventional traffic flow in the city, the traffic flow for large-scale events has the following particularities.

   (a) The temporal and spatial distribution of traffic flow is uneven, which has obvious high peaks and huge flow.
   (b) The uneven distribution of traffic demand for large-scale events in time and space directly leads to the uneven distribution of traffic flow in time and space. Different from the urban background traffic, the peak traffic flow

during large-scale events is huge, and the task of traffic organization and management is difficult.

(c) Unlike conventional travel, it does not have the characteristics of a balanced traffic flow distribution. When performing conventional traffic distribution, it is generally assumed that travelers are very familiar with the road network, traffic conditions, and traffic organization and management. The conventional travel route selection satisfies the users priority principle, and the traffic flow distribution model adopts a balanced distribution. Compared with regular trips, the participants of large-scale events are not familiar with the road network, traffic conditions, and traffic organization and management between the place of departure and the event venue. They cannot all choose the route with the least travel cost and the shortest travel time, so they do not meet the assumption requirements of balanced distribution.

(d) It has temporal and spatial volatility. The peak time of regular urban traffic flow is often relatively fixed, basically appearing on all road networks simultaneously, and the duration is roughly the same, such as the rush hour. The traffic peaks caused by large-scale events on the surrounding roads of the event venues have obvious temporal and spatial volatility. The traffic peaks gradually spread out and disappear from the event venues like waves along the surrounding main roads over time. Besides, different road sections or intersections will have traffic peaks of different sizes at different time periods.

(e) It has the characteristics of "multi-source single sink" traffic network flow. "Multi-source single-remittance" travel refers to the network travel with only one traffic attraction and multiple sources of traffic. Large-scale events are held at a fixed and unique location, and event participants have different starting points and unique travel destinations, thus forming a "multi-source and single-converging" transportation network.

3. Traffic Organization and Management Characteristics of Large-Scale Events.

(a) Difficulty. According to the traffic demand and traffic flow characteristics of large-scale events, the traffic flow induced by large-scale events is much higher than the normal traffic flow in cities. Conventional urban traffic organization and management can hardly meet the traffic demand of large-scale events. Therefore, the task of traffic organization and management for large-scale events is very difficult.

(b) Complexity. Participants in large-scale events have different priorities, and traffic needs are hierarchical. The transportation organization and management of large-scale events need to ensure that the transportation needs of different levels are met. Therefore, the organization's management work is complicated, and it is necessary to comprehensively adopt various traffic organization measures and management program.

(c) Amorality. The holding of large-scale events is temporary and lasts at most 10 days. The traffic planning and organization and management measures for large-scale events are also temporary. Accordingly, this feature must be considered to minimize the impact on the background traffic.

Conventional traffic management measures are formulated to alleviate traffic congestion caused by the new equilibrium. The difference is that large-scale activities are temporary. Traffic organization and management measures for large-scale activities appear after breaking the original equilibrium state and end when a new equilibrium state is not formed. The aim of the traffic organization and management of large-scale events is to alleviate the traffic pressure in an unbalanced state, which is different from the validity period of conventional traffic management measures. Therefore, the city's conventional traffic organization and management methods cannot be directly adopted in the traffic organization and management of large-scale events.

10.4.2.2 Forecast of Traffic Demand for Large-Scale Events

In order to ensure the rationality and practicability of traffic demand forecast results, the following principles should be followed when forecasting traffic demand for large-scale events.

1. Combining Theory with Practice.

   Traffic demand forecasting for large-scale sports activities does not only concern relevant prediction theory methods to make scientific and accurate predictions but also combines practice, and we try to choose simple and easy-to-understand prediction methods and models on the basis of ensuring prediction accuracy, so that they can be smoothly applied in practice.
2. Systematization and Comprehensiveness.

   The transportation demand of large-scale sports events is an integral part of the city's transportation system, and it is interconnected and influenced with other subsystems of the city's transportation system. Therefore, it is necessary to comprehensively consider various related factors when forecasting traffic demand for large-scale sports activities and conduct comprehensive and systematic research.
3. Quantitative Analysis Combined with Qualitative Analysis.

   The traffic demand forecast of large-scale sports activities lacks directly usable historical data, so it is necessary to combine quantitative analysis methods with qualitative analysis methods to make scientific, reasonable, and accurate forecasts.

10.4.2.3 Traffic Demand Management for Large-Scale Events

Traffic demand management refers to the use of urban land planning, economic means, laws and regulations, information release and other control methods by government departments to adjust the total urban traffic demand, travel structure, and traffic when resources and environment are limited. Its purpose is to achieve a balance between traffic demand and traffic supply. As an effective approach to control urban traffic travel demand, traffic demand management theories and

Table 10.5 Comparison of traffic demand management measures in Beijing, Shanghai, Guangzhou, and Jinan

	Beijing	Shanghai	Jinan	Guangzhou
Traffic control of odd and even numbers	√	√	√	√
Traffic control of license plate end number		√	√	√
"Yellow label vehicles" prohibited	√		√	√
Part of the buses closed	√	√		√
Half-day holiday for the opening ceremony	√	√	√	√
Staggered commuting	√			√
Traffic control of transit vehicles	√			
Improve public transportation security	√	√	√	√
Building construction control	√	√	√	√

measures have been widely utilized in countries around the world since the 1990s, greatly improving the operational efficiency of the transportation system.

During large-scale events, people's travel needs should be considered in the formulation of urban traffic demand management measures, meeting traffic activities services, and minimizing the impact on the original traffic. During large-scale events, urban traffic demand increases sharply, and all the cities need to take traffic demand management measures. In this section, we analyze and study the 2008 Beijing Olympic Games, the 2009 Jinan National Games, the 2010 Shanghai World Expo, the 2010 Guangzhou Asian Games, and other large-scale competitions or expositions. A summary of the comparison is provided in Table 10.5.

In order to ensure the smooth flow of traffic in large-scale competitions or expositions, all the cities have planned to set up the dedicated channels; all the cities have implemented traffic demand management and traffic control measures to ensure the normal operation of urban traffic. As seen above, the measures that can be taken in the management of traffic demand for large-scale events can be divided into three aspects: the first one is to control the total travel demand so as to ensure the traffic demand of large-scale event participants, minimizing the other needs that affect the normal progress of large-scale events; second, adjusting the structure of travel modes and guiding citizens to choose public transportation during large-scale events; the last one is to adjust the travel time and space distribution to promote the equalization of the time and space distribution of traffic volume.

10.4.2.4 Traffic Organization Planning of Large-Scale Events

The purpose of traffic organization includes improving the utilization rate of the road network, eliminating the hidden dangers of road traffic accidents, maintaining the order of traffic operation, optimizing the organization of traffic flow, and ensuring smooth and safe road traffic. The transportation organization planning for international large-scale events is a complex project that requires special planning. The transportation organization workflow is shown in Fig. 10.8.

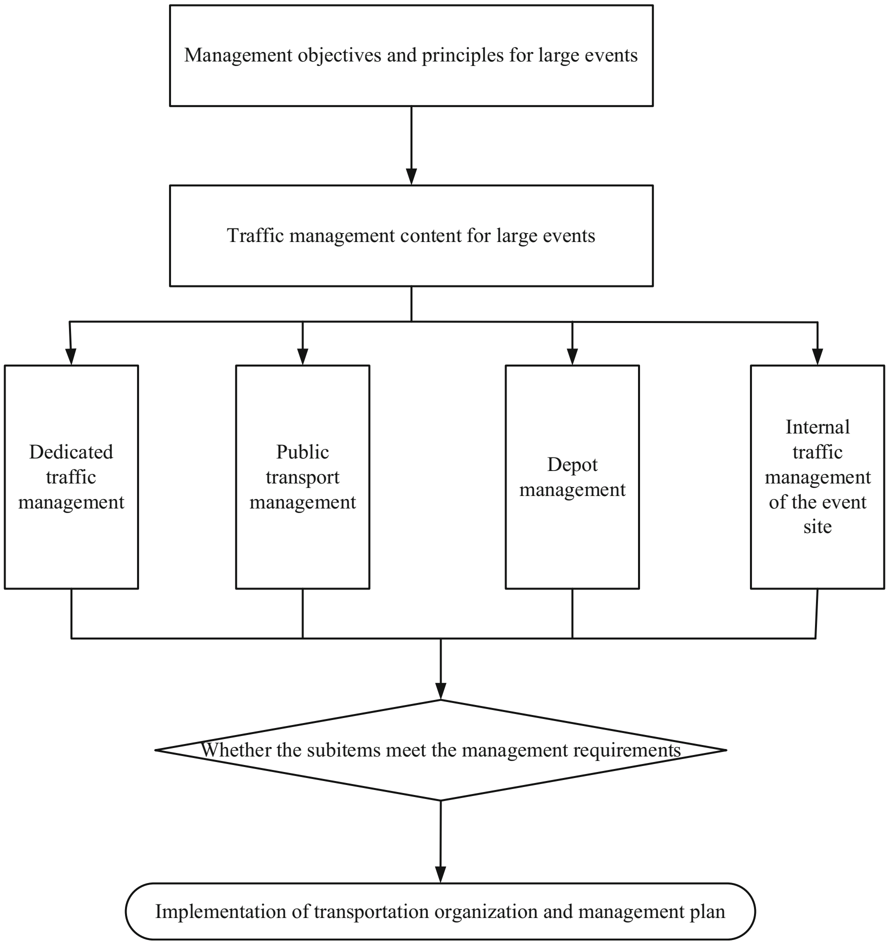

Fig. 10.8 Organization planning process of large-scale event traffic

10.4.2.5 Release of Traffic Information for Large-Scale Events during Large-Scale Events

Temporary traffic organization and management measures will have a certain impact on the daily travel of urban residents. Therefore, it is necessary to release traffic information in a timely manner so that travelers can learn about the latest traffic organization and management measures and choose the appropriate travel mode and travel route. During large-scale events, traffic information can be released before and during the trip of residents.

1. Release traffic organization and management information before residents travel. Television, radio, the Internet, brochures, newspapers, and other means are

utilized to publish traffic information so that residents can understand the various measures of urban traffic organization and management during large-scale events before they travel, and then they choose appropriate transportation modes and travel routes.

2. Release dynamic traffic information during travel. According to the basic data of the city's ITS, various methods such as VMS guidance screen, mobile phone text messages, on-board broadcasting, and on-board navigation are used to release real-time dynamic traffic guidance information to provide travelers with road condition information. Travelers can adjust their routes in time according to the dynamic information obtained during the trip to avoid entering traffic jams.

10.4.2.6 Emergency Traffic Organization and Management Plan of Large-Scale Events

In order to prevent unexpected events affecting the smooth conduct of large-scale activities, it is necessary to formulate traffic emergency organization and management plan for large-scale activities in view of possible major, general traffic events or safety accidents. The following principles should be followed in developing emergency programs.

For large-scale event personnel security, should focus on the protection of international and domestic VIP guests, taking into account other personnel traffic safety. For large-scale activity control areas, emphasis should be placed on the security areas within the activity sites, taking into account the roads and parking surrounding the activity sites.

Strict deployment and improvement of the system. Deploy a large number of police forces in important traffic distribution points, equipped with adequate intercoms and other tools to detect security risks and prevent accidents. In case of an emergency, on-site staff should process and report it in a timely manner to minimize losses as far as possible.

10.4.3 Example: Transportation Organization and Management of the Shenzhen World University Games

World University Games is abbreviated as the WUG. It is a large-scale comprehensive sports event which is only second to the Olympic Games, and it is known as the "Little Olympics." It is hosted by the International University Sports Federation. Its predecessor is the International University Games, which is limited to college students and college students who have graduated not more than 2 years (age limit is 17–28).

The 26th Summer WUG was successfully held in Shenzhen, China, from August 12 to 23, 2011, lasting 12 days. It has a total of 24 competition events and

306 sub-events, the highest in history; more than 10,000 athletes from 180 countries and regions participated in the competition. The registered staff includes four categories with a total of about 21,000 people.

Let's take the Shenzhen World University Games as an example for detailed traffic organization and management system analysis.

10.4.3.1 Traffic Demand Forecasting of Shenzhen World University Games

The demand forecast for special vehicles for registered customer groups during the WUG also includes a four-stage method, as shown in Fig. 10.9.

1. Traffic generation and distribution. Taking into account the number and importance of various service targets such as athletes, technical officials, media, general sports federation officials, and guests participating in the competition, and the number of rooms in the arranged hotel, the number of registered customer groups staying in each hotel is predicted.
2. Classification of transportation modes. All participating members will take special vehicles to the stadiums. According to the traffic service standard, the number of special vehicles produced by each hotel is predicted.
3. Traffic distribution. The traffic needs of the registered customer group are all allocated to the dedicated lane system, and the existing urban traffic model

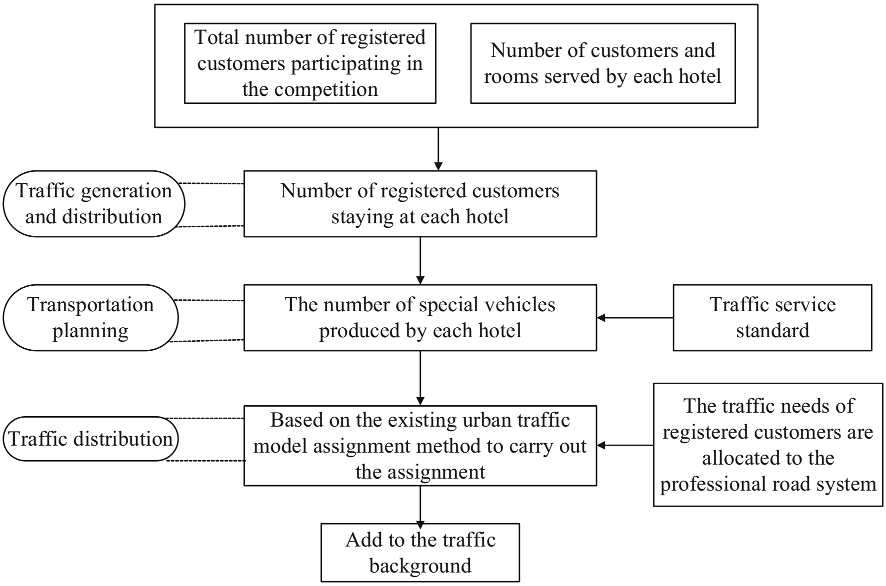

Fig. 10.9 Forecast of dedicated traffic demand for the WUG

allocation method is utilized for allocation and then superimposed on the background traffic.

During the Shenzhen WUG, free public transportation services, which include free rail transit, free regular buses, and some free taxis, will be provided for all registered personnel. They include ticket holders, certificated staff, and volunteers.

Registrants can use public transportation for free if they fail to catch the dedicated shuttle bus or other special circumstances. WUG has about 50,000 certified staff in 8 districts of the city. During this period, about 25,000 volunteers served as language assistants, dispatch assistants, and car assistants to maintain the orderly and efficient operation of the event. Volunteers for the competition live in hotels, school dormitories, etc. in Shenzhen. The number of people in the above three categories is relatively fixed. Those who visit the venues or watch the game can be treated as spectators for traffic organization and management.

10.4.3.2 Traffic Demand Management during the WUG

According to the transportation service needs of the WUG, the background traffic profile of Shenzhen, and the experience of other cities, the following traffic demand management measures have been formulated after comprehensively considering various factors.

1. Holidays for the Opening and Closing Ceremonies.

   According to the residents' travel conditions, we analyze the expected flow changes of different holiday plans based on historical data. Starting the holiday 1 day before the opening ceremony of the Universiade is more conducive to reducing the volume of social traffic on the opening ceremony. Taking all the factors into consideration, the following holiday plan is proposed.

   (a) Scope of holiday. In addition to ensuring the necessary jobs such as ensuring the operation of the city, the city' s government agencies, enterprises, institutions, and social organizations will implement the short vacations which include 4 days in opening ceremony and 3 days in closing ceremony; other social organizations in the city's administrative area can arrange their own arrangements according to actual conditions.

The holiday schedule is shown as follows.
Four days off during the opening ceremony (August 12): August 11–14;
Three days off during the closing ceremony (August 23): August 22–24.
Among them, August 11, 22, and 24 are the days for taking rest, and August 6, 20, and 21 are the days for working.

   (b) Implementation effect. During the holidays, the traffic flow of the road network dropped by an average of about 13%, reducing about 260,000 vehicles on the road. Meanwhile, it will have a certain negative impact on the production and living arrangements of enterprises and citizens.

The specific operation method is shown as follows.

(a) Policy publicity. Based on coordination with higher-level departments, neighboring provinces and cities, and news media at all levels, promotion of temporary traffic management policies for the WUG and holiday policies for the opening and closing ceremonies was carried out in a large-scale and high-density manner. The publicity work of the opening and closing ceremonies and holidays will be assigned to districts and street offices, and high-density publicity will be carried out through the Internet, radio, television, newspapers, and car owners' short messages.
(b) Notice issuance. The General Office of the Municipal Party Committee will issue a holiday notice for the opening and closing ceremonies of the city; all the district governments, neighborhood offices, and neighborhood committees will perform well in holiday notice.

2. The Traffic Control of Motor Vehicles According to Odd and Even Numbers.

(a) Limited travel time. August 4–24, 2011, 7–20 o'clock every day (opening and closing ceremonies extended to 24:00).
(b) Restricted range. The restricted area includes three areas and five roads. The three areas are the original special zone, Bao'an central area and Longgang central area; the five roads are Shuiguan Expressway (including Nanping Express), Qingping Expressway, Bao'an Avenue, Yanba Expressway, and Pingxi Road.
(c) Traffic control plan. All the motor vehicles will run on single-number single-day and double-number double-day driving according to the last Arabic numeral of the mainland-approved license plate number (including temporary license plate vehicles) (single number is 1, 3, 5, 7, 9, and double number is 2, 4, 6, 8, 0).

Identifying via appearance mark and license plate number, the vehicles that do not need to be restricted include: police cars, firefighting, ambulance, engineering rescue vehicles and vehicles of the armed police force performing missions; public transport vehicles, inter-provincial long-distance passenger vehicles, tourist passenger vehicles, large buses, and taxis; vehicles for environmental sanitation, gardening, and road maintenance; urban management, industrial and commercial, traffic, environmental law enforcement vehicles, weather monitoring vehicles, postal and rescue vehicles, and special vehicles for wrecking; vehicles of embassies, consulates and international organizations in China.

As for cars in Shenzhen and Hong Kong: On the day of the opening and closing ceremony (7:00–24:00), we can enter the three areas of the original special zone; Longgang central area, and Baoan central area, Baoan Avenue, Shuiguan Expressway (including Nanping Express), Qingping Highways, Yanba Expressway, Pingxi Road, and other roads are subject to restrictions on odd and even numbers.

As for the trucks in Shenzhen and Hong Kong: According to the principle of "east in and east out, middle in and middle out, west in and west out" that the Shenzhen government and the Hong Kong Special Administrative Region government have agreed and have been implementing vehicles on the main roads are strictly controlled, and permits should be obtained if there is a real need.

Vehicles that need certificates: Dedicated vehicles with certificates issued by the Shenzhen Universiade Organizing Committee; freight vehicles with temporary motor vehicle passing certificates issued by the Municipal Public Security Bureau; motor vehicles to ensure smooth production and operation in the city.

Management and control ideas and principles: Guidance, advice, and duty are directed at all inter-city checkpoints, second-line gateways, and important nodes (expressway toll stations and related nodes in restricted access areas).

- Propaganda Duty Point. Distributing leaflets at this type of duty point to provide explanations for drivers.
- Guiding Duty Points. Propaganda at such duty points through leaflets to guide restricted vehicles to detour.
- Implementation Effect. Reducing about 600,000 vehicles on the road, accounting for 30% of the total number of vehicles, but it will cause inconvenience to citizens' daily travel.
- The specific operation method is as follows.
- Policy announcement. Based on the coordination with higher-level departments, neighboring provinces and cities, and news media at all levels, promotion of temporary traffic management policies for the WUG and holiday policies for the opening and closing ceremonies was carried out in a large-scale and high-density manner. The publicity work of the opening and closing ceremonies and holidays is assigned to districts and neighborhood offices, and the neighborhood offices and neighborhood committees are responsible for all communities so that the publicity work is spread to every household; and high-density promotion is carried out through media such as the Internet, radio, TV, newspapers, and car owners' text messages. Communicating and coordinating with the Hong Kong Special Administrative Region government on the issue of restrictions on transit cars.
- Issuing and filing. The issuance and filing of passes for special vehicles for the WUG; the issuance and filing of passes for vehicles for clearing the port of freight vehicles and ensuring the normal production and operation of the city.
- Investigation and punishment of violations of the law. A fine of 200 yuan and 3 points will be deducted for vehicle owners who go on the road in violation of the regulations, and the automatic license plate recognition system is used to investigate and deal with illegal vehicles on the road, which play the role of electronic police "one police with multiple capabilities" so that the fixed electronic police can carry out red lights, speeding, and speeding. It can also investigate whether the relevant vehicles violate the regulations of odd and even number traffic control at the same time; the police utilize manual video capture to investigate and deal with illegal vehicles on the road.

3. Some buses are stopped.
   (a) The area of stopped driving: the administrative area in Shenzhen.
   (b) Suspension time: August 4–24, 2011, 7–20 o'clock every day (extended to 24:00 on the day of the opening and closing ceremonies).
   (c) Suspension plan: On the basis of the traffic control according to odd and even numbers, on the opening and closing ceremony of the WUG, government agencies, state-owned enterprises, and public institutions will stop 80% of their vehicles, and 50% of their vehicles in the rest of the time. Non-stop vehicles: vehicles holding a special vehicle certificate issued by the WUG Organizing Committee to guarantee the normal operation of the WUG; yellow card buses with more than 10 seats.
   (d) Implementation effect: It plays a leading demonstration role, which has good social significance, but it brings inconvenience to the government's official travel.
   (e) Specific operation methods: Policy publicity, discussions with various units, publicity of the WUG policies, and at the same time, the distribution of official car number plates of each unit is investigated and filed; illegal investigation and punishment, relevant personnel are assigned to the garage of each unit for on-site inspection.
4. Adjustment of Freight Transportation Organization.

   Drawing on the experience of Beijing, Guangzhou, and other cities, Shenzhen plans to implement measures to control transit vehicles during the WUG. Shenzhen City has proposed the goal of building an international logistics hub city. During the WUG, in order to reduce the impact on the logistics industry and at the same time ensure the transportation needs of the WUG, it is considering the implementation of freight detours on the three main passages of the WUG: Shuiguan Expressway, Qingping Expressway, and Longxiang Avenue.

   (a) Detour time: August 4–24, 2011.
   (b) Detour plan. Detour on the day of the opening and closing ceremonies (7:00–24:00): Based on the existing truck restrictions, four measures such as prohibition, restriction, regulation, and detour will be adopted to regulate the driving order, and guide freight vehicles to avoid Shuiguan Expressway, Qingping Expressway, and Longxiang Avenue. Trucks are allowed to bypass Shenhui Road along the alternative road. Except for the opening and closing ceremonies, other race days (7:00–20:00) detour Qingping Expressway and Longxiang Avenue: the detour route is the same as the opening and closing ceremonies; Shuiguan Expressway: it regulates trucks to drive in two outer lanes, depending on traffic conditions, and the rescue lane can be used as a backup lane for freight.
   (c) Implementation effect. Reducing the impact of freight traffic on WUG transportation may also have a greater impact on the freight industry.
   (d) Specific operation methods. Adopting TV, newspaper, radio, and on-site consultations for publicity; port publicity: distributing brochures in the

three port areas of Yantian, West, and Dachan Bay; as for port transit trucks, contacting and coordinating Hong Kong freight industry organizations to provide freight companies in Hong Kong promote with drivers; propagating at toll gates where trucks usually pass. Announcing detour routes in accordance with legal procedures and formulating traffic emergency plans for truck detours during the WUG. On the road, the police used the method of blocking vehicles on the spot to investigate and deal with illegal vehicles on the road.

10.4.3.3 Transport Organization Planning for the WUG

First of all, the WUG' s transportation guarantee and command system will be established. Each dispatch center and transportation service team will be staffed with clear job responsibilities. Then, dedicated transportation planning, public transportation planning, transportation site planning, internal transportation planning of competition venues, emergency transportation organization, and opening and closing ceremonies transportation organization planning are carried out respectively.

10.4.3.4 Summary After the WUG

The Shenzhen Universiade has ended. The WUG Transportation Guarantee has a total of 66,803 vehicle trips, transported 386,478 people registered for the WUG, and the total mileage of vehicles reached 2,931,365 kilometers. There were no safety liability accidents and registered group ride delays and effective complaint incident. This fully realized the overall goal of "safety, punctuality, reliability and convenience."

At this year's WUG, the Shenzhen Municipal Transportation Commission and the transportation industry have invested a total of 9538 traffic security service personnel, investing 2455 various security vehicles, and opening 367 various transportation service lines such as arrivals and departures, competitions, and interviews for 21,000 people. The registered people provide transportation services such as arrival and departure, competitions, training, watching competitions, interviews, exchanges, and opening and closing ceremonies. During the event, the regular public transportation system transported 1,497,900 spectators for free, 9494 buses were operated, and the subway transported 2.066 million spectators for free.

In terms of traffic protection for the opening ceremony, it took only 27 minutes for the athletes to evacuate on-site, and only 22 minutes for the on-site evacuation of the athletes at the closing ceremony; the time for the athletes to the competition and training venues did not exceed the 60 minutes specified by the International Sports Federation, and they all were safe and punctual. The average evacuation time for spectators by bus was 25 minutes, which was 20 minutes less than the promised 45 minutes, and both reached the international leading level. The input of traffic service personnel, drivers, vehicles, intelligent command and dispatch, delivery of vehicles, mileage, delivery service punctuality, and safety rates all set the highest level in previous WUG, reaching or exceeding the international level of large-scale competitions.

During the WUG, after the implementation of the traffic demand management policy in Shenzhen, about 800,000 vehicles were reduced on the road every day. Policies such as reducing traffic on odd and even numbers and prohibiting traffic on yellow-label vehicles, which mainly reduce traffic, have reduced road network traffic flow by about 25%. In addition, the implementation of two small holidays has reduced road network traffic by about 30%. After the establishment of a dedicated channel for the WUG and the implementation of traffic demand management, the service level of the road network has increased by 41.4% compared with the current situation, and the vehicle speed has increased by 42.3%.

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