Parallel Public Transport Management and Control System for Guangzhou Asian Games

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***Abstract*—Public traffic is required for the convenient travel, reducing traffic congestion and accidents, low-carbon, environmental protection, sustainable development, and traffic demand of giant sports and large business activities, etc. For public transport demand of the 16th Asian Games and the 2010 Asian Para Games held in Guangzhou in 2010, based on ACP approach, Parallel Public Transport Management And Control System (PPTMS) for Guangzhou Asian Games had been developed to support management decision of public transport. This system can help public transport managers to improve and enhance significantly the level of public transport management in Guangzhou, from experience-based formulation and manual implementation to scientific computation-based formulation and automatic implementation with intelligent systems, to guarantee the traffic demand effectively during the two Games.**

Keywords-public transport; Guangzhou Asian Games; artificial transportation system; ACP approac; traffic video detection

I. INTRODUCTION

The 16th Asian Games and the 2010 Asian Para Games are the largest international events in Guangzhou, which are an important platform to promote international friendship, regional political, economic and cultural development, and progress on athletic sports, amateur sports and sports industry. There are about 14,000 athletes, coaches and sports officials, more than 7,000 reporters and media personnel, more than 60,000 staff and volunteers, 10 million spectators and tourists in Asian Games, from 45 countries and regions. And, there involves 58 existing game facilities and 12 new sports stadiums, which are located across metropolitan areas. A large number of contestants and spectators make bad transportation in Guangzhou even worse. Safe and effective public traffic management is essential to the success of the two games.

According to Guangzhou intelligent transportation development planning, based on the existing intelligent transportation systems, and with the help of the specific traffic video detection system and parallel traffic management systems created by CASIA (Automation Institute, Chinese Academy of Sciences), parallel public transport management and control system for Guangzhou Asian Games(PPTMS) has been developed. This system can help smooth, safety, efficiency and reliability of public transport during Guangzhou Asian Games. It also can help Guangzhou traffic management and control upgrading from informatization to intellectualization, and also can be used for traffic management and control during Spring Festival period, China Import and Export Fair (Canton Fair), and other major holidays or large commercial activities.

II. PPTMS FOR GUANGZHOU ASIAN GAMES

PPTMS for Guangzhou Asian Games (Figure 1) includes two subsystems, i.e. actual system and artificial system. Actual system includes Traffic Video Detection and Analysis Platform for Asian Games, Public Transportation Security System for Asian Games, Taxi Monitoring System for Asian Games, and the Official Traffic Website for Asian Games. Artificial system includes Artificial Transportation System for Tianhe Sports Center (ATS-Tianhe), Public Traffic Security Assessment System for Asian Games, Taxi Assessment System for Asian Games, and Comprehensive Assessment System for Tianhe Sports Center.

A. Traffic Video Detection and Analysis Platform for Asian Games

Traffic Video Detection and Analysis Platform for Asian Games can detect real-time traffic and passenger flow at stations, main road traffic and road conditions, and improve range and level of dynamic perception of public transport. Based on this platform, traffic data can be tested and analyzed.

B. Public Transportation Security System for Asian Games

Public transportation security system for Asian Games can achieve public traffic service planning, special lines for Asian Games, scheduling management, real-time vehicle tracking and monitoring based on GIS, impact assessment and other service functions. Based on the principle of parallel double-loop control, it can also optimize management of public traffic management, and provide timely and reliable public transport security of the main venues during Asian Games.

C. Taxi Monitoring System for Asian Games

Taxi monitoring system for Asian Games have global monitoring, vehicle location, vehicle tracking, track playback and other basic monitoring functions, and driving curbs for Asian Games, capacity monitoring, area monitoring and other advanced control functions, and other monitoring and search functions such as search taxi in a fixed-point, and vehicle scheduling and induced functions, etc. Based on the principle of parallel double-loop control, it can dynamically predict

This work is supported in part by NSFC 61174172, 70890084, 60921061.

passenger flow, scientifically formulate, evaluate and optimize the induction program under various circumstances, provide drivers with real-time passenger information and road conditions, reduce empty taxis' time for looking for passengers, provide passengers with taxi information, reduce passengers' time to find a taxi.

D. Official Traffic Website

The traffic information website provides traffic information, policy information, match information and weather information for all the audiences, citizens, officers and athletes. The URL of the website is *http://www.gzyyjt.cn/*. Anyone with an internet connection can access the website to get those information and guidance such as:

- How to get Asian Games Stadiums from any place of Guangzhou.
- How to get any place of Guangzhou from Asian Games Stadiums.
- The Taxies distribution of the appointed areas at present.
- The match information in every stadium on every day.
- Important traffic forecast information and guidance service for the public's viewing events and travelling during 2010 Asian Games.

E. ATS-Tianhe

ATS-Tianhe can compare several management programs' results in the same management index system, and a management program's results under different management index systems. The system includes ATS, computational experiments platform, and statics and analysis system.

F. Public Traffic Security Assessment System for Asian Games

Public traffic security assessment system for Asian Games mainly assesses public transport plans in key areas. According to input information of scheduling plans of public transport for Asian Games, program assessment results under different traffic scheduling plans of public transport vehicles can be calculated. Comparing the assessment results with the running public transport scheduling program, decision support for decision makers to optimize the existing public transport scheduling program can be provided accordingly.

Then, the quality and performance of evacuation task can be assessed to provide support for revising and improving the follow-up scheduling program. The assessment indexes include: key regional plan completion rate, gap of actual scheduling security and plan, evacuation plan, etc.

G. Taxi Assessment System for Asian Games

Based on historical data, forecasting passengers' demand, in order to ensure targets (the spatiotemporal proportion of unladen and manned taxis), taxi management plans can be assessed, which include passenger flow forecasting, number, location and time of taxis, whose goals are to assess the spatial and temporal matching of taxis. That is, based on input information and the same assessment index systems, different scheduling results of different taxi scheduling plans can be evaluated to provide decision support for traffic managers to optimize the current taxi scheduling plans.

H. Comprehensive Assessment of Public Traffic for Tianhe Sports Center

Integrated traffic flow and public traffic around Tianhe Sports Center, considering weather, traffic accidents and other conditions, Comprehensive Assessment System of Public Tranffic for Tianhe Sports Center was developed, which can achieve comprehensive assessment of public traffic management programs for managers to provide decision support, including assessment on transport decision, plans assessment of special cases.

III. SOME SUBSYSTEMS OF PPTMS

A. Traffic Video Detection and Analysis Platform for Asian Games

The traffic video detection and analysis platform can detect traffic flow and passenger flow for Asian Games.

1) The detection system of traffic flow videos

Selecting traffic videos from the key areas of Asian Games including the videos of BRT and special network, the online traffic videos captured by cameras are transferred to Guangzhou traffic information command center, and video detector can digitize analog video, process real-time each frame, upload to database server in traffic information platform, and output test results together with quantitative data superimposed on video stream to monitor screen. Through video image processing and intelligent analysis, traffic data, including traffic volume, time share, average speed, traffic density, vehicle type, and queue length can be collected real-time.

2) The detection system of passenger flow videos

The real-time passenger flow videos at bus stations, long-distance bus stations and other places are inputted to Guangzhou traffic information command center after coding and compression. Then, flow video detection system can decode, process and display real-time each frame to count pedestrian number, crowd flow, population density, population parameters and other statistical information. Monitor interfaces configured with parameters changes can adjust system operating parameters, such as setting detection area, direction, alarm threshold, alarm methods. This system can also handle congestion, illegal gatherings and other events, and determine whether there are abnormal behaviors, such as rapid running, assault, fighting, and items left behind, etc. And it can evaluate scene states based on the aforementioned pedestrian detection, tracking, and counting, display test results, and alarm.

B. ATS-Tianhe

Based on ACP approach[13], ATS-Tianhe's architecture is composed of four-layer structure: fundamental component level, data and knowledge level, computational experimental level, and parallel execution level, as shown in Figure 1.

Fundamental component level is the foundation of ATS. It takes basic component designed as program components. Through the interaction of components, components and external interfaces, the system's flexibility and scalability can be fundamentally guaranteed. The related components include

urban planning models, vehicle motion models, population models, staff mental models, road signal control models, etc., which can model traffic behaviors of passengers and vehicles through business process orchestration of component services.

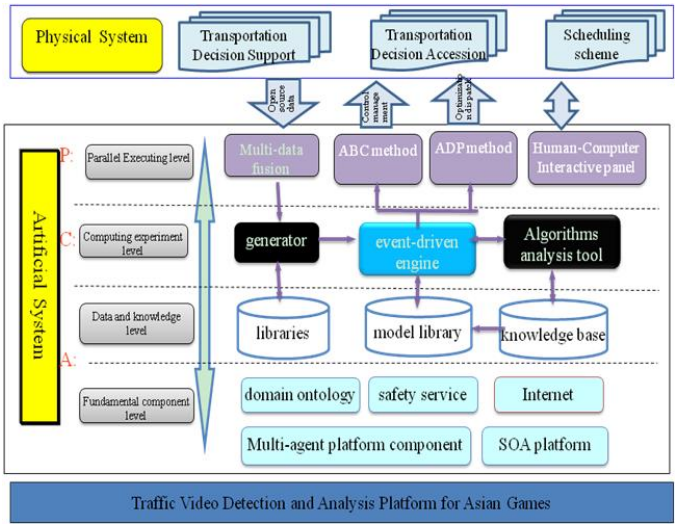


Figure 1. Architecture of parallel transport system

Data and knowledge level is the core of ATS. Its control and management models are denoted as models and algorithms library, and traffic management experience and knowledge are represented by expert knowledge library. Based on these models, experimental scenarios can be provided.

Computational experimental level is the function realization module of ATS, which can build specific traffic scenarios by data and knowledge which are provided by data and knowledge level. It can achieve assessment and decision support of actual traffic control and management programs by experiments design, execution and analysis of traffic control and management.

The main function of parallel execution level is a layer of function display and user interface, which can achieve control and management of actual system through information exchange and feedback process. Its actual system integrates integrated transportation information platform of Guangzhou. Through a variety of front-end analysis tools, video data analysis and processing can be realized. The transport policy plans for Tianhe Sports Center can be evaluated. And scientific, accurate and timely business information and knowledge to form decision can be provided.

1) Construction of ATS-Tianhe

Integrating Guangzhou city maps, traffic maps, weather data, population distribution, scheduling plans of Asian Games and participants' distribution and other data, ATS-Tianhe can be established.

2) Surrounding Environment of ATS-Tianhe

Basic traffic surrounding environment of Tianhe Sport Center need traffic network, public traffic lines, testing equipment, distribution of city resident, rules of public activity, and distribution of private cars. Among them, traffic network, distribution of venues, public traffic lines, testing equipment can be set by GIS in traffic network modules; distribution of city residents, rules of public activity can be set by public modules; and, private cars can be set in car modules.

Distribution of population of ATS-Tianhe includes population distribution around Tianhe Sport Center, sex ratio, age division and ratio, population growth type, travel habits, OD matrix, travel speed distribution and other information.

Vehicle information of ATS-Tianhe is constructed based on traffic data around Tianhe Sport Center, including traffic distribution, car number, private car ownership, vehicle type distribution, and so on.

3) Traffic management of surrounding environment for Tianhe Sport Center

Traffic management of surrounding environment for Tianhe Sport Center can achieve control and management of traffic signal, management of information dissemination, scheduling management of public traffic, and so on.

Signal control program of traffic management of surrounding environment for Tianhe Sport Center includes signal control modules, control methods (phase and time) of every signaler at main intersections.

Management program of public traffic scheduling of traffic management of surrounding environment for Tianhe Sport Center includes number, type, capacity, frequency and stations of every public traffic lines.

Traffic management program of traffic management of surrounding environment for Tianhe Sport Center includes velocity-limitation, limitation according to vehicle type and plate number, and other traffic management program.

4) Environmental influence of traffic for Tianhe Sport Center

Traffic environmental influence for Tianhe Sport Center set up environmental impact on traffic, including weather, large events, accidents, and so on.

Weather environmental impact on traffic can be constructed as different typical weather models according to climate data of Guangzhou. Every model can model a specific typical weather.

Accident environment for Tianhe Sport Center can be constructed as different typical accident models, which can model traffic influence of regular accidents and unconventional emergencies. Accident models can be divided into different types of accidents. Everyone can simulate a kind of specific accident according to general impact and duration time. In implementation, regional effects analysis model of accidents can be defined, and the extent of the emergency and accident levels can be determined based on the occurrence of one or several adjacent individual incidents, to provide emergency management decision foundation making for relevant managers.

The games arrangements for Tianhe Sport Center can be constructed as models of every games held at Tianhe Sport Center including the beginning and ending time, game time, game type, number of seats, participants' number and distribution, etc.

5) Experiment and assessment of traffic evacuation for Tianhe Sport Center

Based on ATS-Tianhe, the experiments of traffic evacuation plans can be designed and simulated to show assessment report by analyzing experimental results, according to traffic evacuation requirements and objectives of Guangzhou Asian Games Main Stadium. Different traffic scenarios can be built in traffic evacuation experiments by selecting variable artificial transportation models, including not only traffic scenarios under normal conditions, but also abnormal traffic environment such as traffic accidents, terrorism attacks, and adverse weather conditions. During assessment process, a variety of traffic parameters in designed traffic scenarios can be counted, summarized, mined, extracted and integrated, to get parameter reports of different traffic scenarios in different model design, and output through intuitive view class model.

Experiment and assessment of traffic evacuation for Tianhe Sport Center can analyze experimental results of ATS, analyze and evaluate similar data collected from actual system, and give results comparison of accrual and artificial systems.

C. Public Traffic Security Assessment System for Asian Games

Public Traffic Security Assessment System for Asian Games can be constructed by combining parallel assessment system with actual application system according to demands of public traffic security assessment of Asian Games.

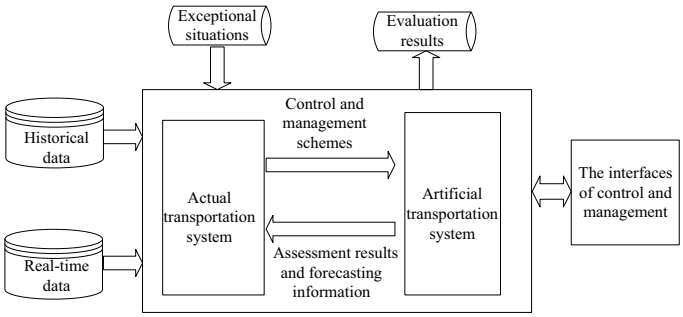


Figure 2. Public Traffic Security Evaluation System

1) Parallel assessment system

Parallel assessment system is to carry out computational experiments of traffic evacuation of Asian Games based on ATS. It can evaluate the implementation of evacuation program and give optimization results, from the perspective of global simulation, considering people, vehicles, roads, and environment, traffic demand, combined with practical application in traffic data, such as transportation decision-making programs, vehicle scheduling program, traffic handling program in special circumstances, and so on. It can also optimize actual application system and prevent accidents in normal circumstances, and carry out emergency management functions to improve emergency management capabilities of public traffic grooming in abnormal circumstances.

ATS receives a variety of control and management strategies and current system state (initial point) from actual system, and verifies feasibility and implementation effect, and assesses effectiveness of program (decision support) by running ahead (prediction). Parallel assessment system can run offline or online. In offline mode, parallel transportation system can provide simulation environment of learning and training where managers can "experience" the implementation of program results before system implementation for traffic managers. In online mode, traffic managers can quickly and effectively grasp traffic running states during the evacuation and take response ahead, using hardware simulation and rolling optimization and combining actual transport system and ATS.

2) Actual application system

Actual application system is to construct Asian Games traffic information services subsystem of, traffic grooming scheduling subsystem and traffic grooming decision making subsystem based on previous data collection and information integration. It can provide traffic information services for Asian Games such as traffic information, traffic policies, traffic control information, vehicle information, and traffic videos. Traffic grooming scheduling subsystem can provide vehicle scheduling program and transportation decision making programs for traffic managers of Asian Games. Traffic grooming decision making subsystem provides traffic grooming decision for traffic managers, including passenger forecasting, vehicle demand forecasting, traffic capacity estimation, congestion analysis, and so on.

D. Traffic Assessment Index Hierarchy

Traffic Assessment Index Hierarchy can be used for the assessment of public traffic security, taxi assessment system, and comprehensive assessment system for Tianhe Sports Center.

Several assessment indexes hierarchy can be constructed which can be used for ATS and also for actual transportation systems.

Assessment indexes of artificial system are divided into 4 types according to different assessment objects, namely assessment indexes based on sections, intersections, traffic networks and activities types.

It can support the establishment of assessment index system, and comprehensively evaluate different transportation indexes.

1) Construction of traffic assessment index hierarchy

Different traffic assessment index hierarchy can be constructed which can reflect different level of assessment of urban transport system, such as traffic smoothness, urban environment, and so on.

For index hierarchy, after selecting indexes, the relative importance degree can be gotten according to expert experimental analysis form the following T-Ck matrix.

Comparison Matrix **W**: where C_i, C_j represent indexes, and W_{ij} represent the importance degree of C_i compared to C_j.

T-CkWeight	C_1	……	C_j	……	C_n
C_1	W_{11}	……	W_{1j}	……	W_{1n}
……	……	……	……	……	……
C_i	W_{i1}	……	W_{ij}	……	W_{in}
……	……	……	……	……	……
C_n	W_{n1}	……	W_{nj}	……	W_{nn}

In **W**, C_j in columns are taken as denominator, and we take 9-scales method proposed by American operational researcher –A. L. Saaty. That is, natural number 1-9 and their reciprocals denote the relative importance degree.

Scale	Definition and explanation
1	The two elements are equally important
3	Comparison of two elements, one element is somewhat important than the other
5	Comparison of two elements, one element is obviously important than the other
7	Comparison of two elements, one element is more important than the other
9	Comparison of two elements, one element is most important than the other
2,4,6,8	Compromise scale between these two elements
$1/W_{ij}$	Reverse compare of two elements

For Comparison Matrix **W**, calculating its eigenvectors, λ_{max} is the largest one, and P is the orthonormal vector according to λ_{max}. The component P_i of P is the single sort weight corresponding to indicators C_i.

a) Orthonormalize each columns of ***W****,* $b_{ij} = \frac{w_{ij}}{\sum_{i=1}^{n} w_{ij}}$.

b) Calculate sum of every row of each orthonomalized column of ***W****:* $Z_i = \sum_{j=1}^{n} b_{ij}$.

c) Vector $Z=[Z_1,Z_2,....,Z_n]^T$ *can be orthonormalized,* $p_i = \frac{z_i}{\sum_{i=1}^{n} z_i}$. *Then, eigenvectors of* ***W*** *is* $P=[P_1,P_2,....P_n]^T$.

d) Calculate the largest eigenvulue of ***W****:* $\lambda_{max} = \sum_{i=1}^{n} \frac{(WP)_i}{nP_i}$, *where* $(WP)_i$ *is the No. i component of WP.*

The Comparison Matrix **W** is based on degree of importance from subjective judgments of experts. When experts are analyzing, the characteristic $W_{ij} = W_{ik} / W_{jk}$ is difficult to be achieved, so to alleviate the burden of experts' analysis, inconsistence judgments are allowed to some extent. Consistency Index $CI = \frac{\lambda_{max-n}}{n-1}$ can control the extent of matrix. When *CI* is larger, the extent of deviation of Comparison Matrix **W** from the consistence is larger. When *CI* is smaller, **W** is closer to consistence.

Generate 1000 n-order matrix (n=1,2,…,15) randomly, calculate their CI.

Order	1	2	3	4	5	6	7	8
Average CI	0	0	0.58	0.9	1.12	1.24	1.32	1.41
Order	9	10	11	12	13	14	15	
Average CI	1.46	1.49	1.52	1.54	1.56	1.58	1.59	

Define *RI* as the average value of *CI,* Random Consistence Index Ratio *CR* is the ratio of CI and *RI*, *CR=CI/RI*.

Consistency check: when *CR<0.1*, Comparison Matrix **W** has an acceptable consistency. When *CR⩾0.1*, the matrix is needed to be adjusted to meet *CR<0.1*, which has satisfactory consistency.

2) Application of traffic assessment index hierarchy

Regular assessment system can be established by traffic assessment index hierarchy. Collecting corresponding index data of an ATS according to assessment system, assessment indexes can be calculated in accordance with assessment algorithm, which can reflect the running effect of ATS. If assessment indexes reflect traffic flow is smooth, the indexes reflect the level of traffic flow situation. If environmental, the indexes reflect the level of environmental effect of urban traffic.

Assessment algorithm has following process: in multi - index assessment conditions, the values can be reflected in the assessment of each single index, and their positive and negative indicators are needed to be orthonormalized. The assumptions are as follows:

- Each index values are directly or inverse proportional simple linear relationship.
- The best result of assessment is the situation where the index has the maximal or minimal value.

Indicator data reflect in forward or reverse goodness or badness of assessment conclusions. For an indicator of positive assessment, its pre-calculation is

$$r_i = \begin{cases} 1 & x_i \geq M_i \\ \dfrac{x_i - m_i}{M_i - m_i} & m_i < x_i < M_i \\ 0 & x_i \leq m_i \end{cases}$$

Similarly, reverse assessment of pre-calculation is

$$r_i = \begin{cases} 1 & x_i \geq M_i \\ \dfrac{x_i - m_i}{M_i - m_i} & m_i < x_i < M_i \\ 0 & x_i \leq m_i \end{cases}$$

Experimental index data of directly or reverse orthonormalizaion are calculated according to their eigenvector matrix in index hierarchy. Accumulating their results, assessment coefficients in index hierarchy can be got.

a) Collect value sequence of each sample period $x_1,x_2,...x_i$.

b) Set directly and reverse relation of an index and maximum M and minimum m.

c) For each x_i, *calculate its pre-calculation* r_i.

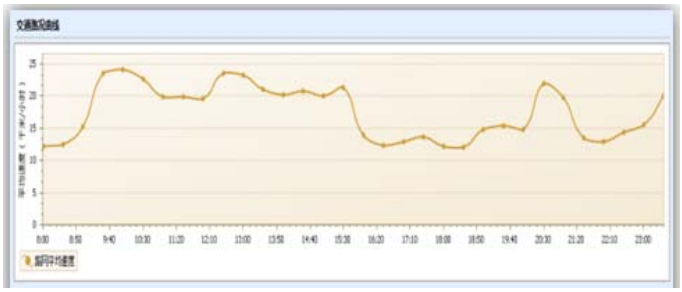
d) For each r_i, *multiple eigenvector* p_i *in its index hierarchy to get the index coefficient,* $E_i = r_i * p_i$.

e) Accumulate all index coefficients to get index coefficient E，$E=\sum E_i$.

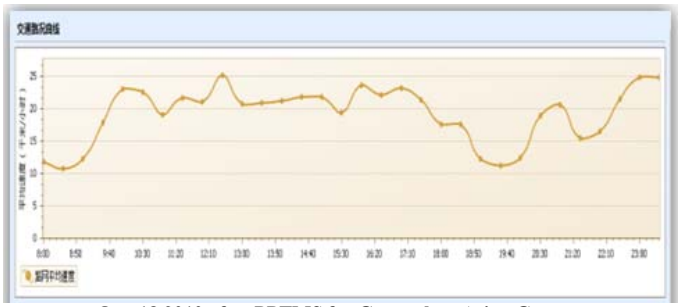
IV. A CASE STUDY

As a case study, we take comprehensive security assessment using the actual data of Oct.11 2010 (Monday, before using the system) and Oct. 18(Monday, after using the system). After using the parallel system, average speed of

network increases from 17.96 km/h to 20.10km/h, and average error of transport capacity match decreases from 22.14% to 20.12% (See Figure 3 and Figure 4).



Oct. 11 2010 before PPTMS for Guangzhou Asian Games



Oct. 18 2010 after PPTMS for Guangzhou Asian Games

Figure 3. Comparison of average speed of road network

时段	需求运力(人)	供给运力(人)	实际载客量(人)	运能匹配度(%)
08:00 ~ 08:30	3332	3114	3371	93.48
08:30 ~ 09:00	3685	3373	3655	91.54
09:00 ~ 09:30	16363	15036	16634	91.88
09:30 ~ 10:00	2053	3015	3265	146.87
10:00 ~ 10:30	5543	4792	5081	86.47
10:30 ~ 11:00	6898	5675	5933	82.28
11:00 ~ 11:30	18815	13228	13525	70.31
11:30 ~ 12:00	13362	10165	10448	76.07
12:00 ~ 12:30	1963	2867	3121	146.07
12:30 ~ 13:00	4471	3699	4019	82.76
13:00 ~ 13:30	2899	2516	2796	86.75
13:30 ~ 14:00	700	940	1032	134.32

Oct. 11 2010 before PPTMS for Guangzhou Asian Games

时段	需求运力(人)	供给运力(人)	实际载客量(人)	运能匹配度(%)
08:00 ~ 08:30	477563	524524	577320	109.92
08:30 ~ 09:00	145967	90291	101300	61.86
09:00 ~ 09:30	128805	100243	108616	77.83
09:30 ~ 10:00	99638	125732	134421	126.19
10:00 ~ 10:30	91109	123313	131329	135.35
10:30 ~ 11:00	256144	210023	219041	81.99
11:00 ~ 11:30	91498	85249	85997	93.17
11:30 ~ 12:00	280357	238703	248830	85.14
12:00 ~ 12:30	165396	112415	115583	67.97
12:30 ~ 13:00	270758	213246	223419	78.76
13:00 ~ 13:30	179067	134032	144540	74.85
13:30 ~ 14:00	137030	118211	127050	86.27

Oct. 18 2010 after PPTMS for Guangzhou Asian Games

Figure 4. Comparison of transport capacity match

V. CONCLUSIONS

PPTMS for Guangzhou Asian Games have improved effectively public transport management level. It can make public traffic managers enhance the level of public traffic management in Guangzhou from experience formulation and human implementation to scientific development and implementation with intelligent systems.

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