Developing Parallel Control and Management for Urban Traffic Systems

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As verified by its successful applications in various cities in China (such as Suzhou and Guangzhou), the Parallel Traffic Management System (PtMS),\(^1,2\) has been accepted as an effective tool for managing and controlling complex urban transportation systems.\(^3,4\) The classic PtMS consist of five major components:

- actual transportation systems;
- artificial transportation systems (ATS);\(^5\)
- traffic operator and administrator training systems (OTST);
- decision evaluation and validation systems (DynaCAS);\(^6\) and
- traffic sensing, control, and management systems (aDAPTS).\(^7\)

Recently, Qingdao (or Tsingdao), another major city in the eastern coast of China, also started building a PtMS—called PtMS-QD—to improve its traffic-management system and alleviate traffic congestion, which is a serious problem that draws significant social concerns. During rush hour, the roads are crowded, and traffic jams occur at many intersections and road sections (see Figure 1).

Qingdao’s situation is different from previous cities’ PtMS implementations. In other cities, the PtMS was built and operated directly on physical transportation systems, where the PtMS also largely acts as the intelligent transportation system (ITS). However, Qingdao is working with the Hisense Group (a major ITS technology and construction company in China) to construct a new, more comprehensive intelligent urban transportation system. This system’s key components include one center, three major platforms, and eight subsystems (see Figure 2). Qingdao has asked us, then, to adapt the PtMS to work in parallel with the structure of Qingdao’s new ITS. Thus, we’ve redefined Qingdao’s PtMS, and created a new structure for the system to provide unique control and management support. This will make the PtMS more versatile, with improved compatibility, so that it can be applied in more scenarios.

Figure 3 shows the framework of Qingdao’s PtMS. In the framework, we redesigned PtMS in parallel with the ITS and physical transportation system in Qingdao. The ITS executes the control and management operations in the physical transportation system in Qingdao; and the PtMS obtains traffic data from the ITS and provides important parallel decision support to the ITS.

PtMS-QD

According to the practical requirements of Qingdao, PtMS-QD is designed to include three subsystems: an artificial transportation system for Qingdao (ATS-Qingdao), a decision evaluation and validation system for Qingdao (DynaCAS-Qingdao), and a parallel execution system for Qingdao (PES-Qingdao).

ATS-Qingdao

The ATS of Qingdao differs from the ATS in previous PtMS implementations, because it includes...
not only the basic traffic simulation system, but also the virtual ITS. This makes the AI system a more complete reconstruction of the transportation reality in Qingdao, and thus upgrades the PtMS’s functionality and service quality. The ITS-combined ATS for Qingdao consists of four parts: the support databases, traffic simulation system, artificial ITS, and 3D visualization platform.

Support databases. The support databases are constructed to acquire and store the huge data provided by the Qingdao Traffic Information Center, so as to support the ATS’s operation. The information required by the ATS can be classified into two categories: first, the basic traffic-related information, such as road infrastructures, traffic network topology, traffic rules, transport facilities, ecological resources, population, and so on; and second, the ITS information, such as traffic control schemes, traffic flow control schemes, traffic guidance strategies, traffic-management strategies, and so on.

A traffic-simulation system. The traffic-simulation system is used to reconstruct the physical reality of Qingdao’s transportation, and to form an artificial microscopic traffic simulation system. The traffic-simulation system includes various functions, such as constructing road networks, generating vehicle routes, selecting travel behavior, monitoring operations, analyzing statistics, and editing schemes and indicators.

Artificial ITS. The artificial ITS aims to reconstruct the ITS’s functions in Qingdao (that is, the three platforms and eight subsystems) based on the traffic-simulation system. By
realizing the artificial ITS, we can perform evaluations and experimental computations for different traffic control and management strategies on the artificial system, and provide parallel feedback or recommendations to the real-world ITS.

3D visualization platform. The 3D visualization platform provides a visual demonstration of the decisions’ potential effects to the managers with a user-friendly interface. We can also use the platform for training staff.

DynaCAS-Qingdao
DynaCAS-Qingdao’s tasks focus on evaluating, optimizing, and training the traffic-management strategies for the Qingdao ITS under different traffic scenarios. In addition, it also has a virtual interface to provide training services to the administrative managers and technical staff in Qingdao. The DynaCAS-Qingdao is composed of three parts: the traffic-management decision evaluation platform, the traffic-management decision optimization platform, and the staff learning and training platform.

Traffic-management decision evaluation platform. Evaluating or testing different traffic-management strategies in a real traffic system can be extremely costly and difficult, sometimes even impossible. The traffic-management decision evaluation platform in PtMS-QD provides offline tests of traffic-management strategies before they’re in operation. The objectives of such offline testing are to validate the traffic-management strategies’ feasibility, evaluate the strategies’ effectiveness, and detect any potential faults or flaws before test runs.

Traffic-management decision optimization platform. With the help of the ATS and high-performance computers, becomes possible to optimize the traffic-management strategies through massive computational experiments. Optimal traffic-management strategies must be derived for different traffic scenarios, different management levels, different management measures, different evaluation effectiveness, and so on.

Staff learning and training platform. This platform provides a virtual environment to train administrative and technical staff for Qingdao’s Transportation Council. New staff can learn the functions of the Qingdao ITS, and simulate the management operations on the platform.

PES-Qingdao
The PES is responsible for linking the decision-support databases obtained from the DynaCAS to the corresponding subsystems of Qingdao ITS, and the subsystems will select suitable traffic-management strategies from the decision-support databases according to real-time measurements of traffic status. After the traffic-management strategies are executed in a real traffic system, the operation results will be collected and analyzed, generating feedback reports to the ATS and DynaCAS. The PES consists of three parts: the decision-support system for administrators, the decision-support system for travelers, and the parallel adaptation platform.

Decision-support system for administrators. One decision-support system is
established to help traffic administrators manage and control the transportation system with a macroscopic view. The decisions in the support databases can be transportation infrastructure-planning schemes, traffic-management policies, traffic-guidance information, traffic-scheduling strategies, traffic-control schemes, and so on. The decision databases are provided to the Qingdao ITS's corresponding real-world subsystems.

Decision-support system for travelers. Another decision support system is to provide traffic information for travelers, helping them make better travel plans. The supporting traffic information contains road works, incidents, congestion, route guidance, travel time, departure time, etc. The information broadcasting devices include websites, cell phones, radios, on-board navigators, etc.

Parallel adaptation platform. Working in parallel with the ITS in Qingdao, the two decision-support systems provide traffic-management decision support for administrators and travel information for travelers. After these decisions and information are executed and broadcast in the real traffic system, we assess the effectiveness. The results generate feedback information to adjust the ATS for a more accurate representation of the traffic dynamics, and update the computational experiments to better support traffic-management decisions.

In future work, we’ll continue perfecting PtMS-QD by observing and analyzing its operating results over a long period of time. Meanwhile, we’ll implement PtMS in other cities in China, so that PtMS-QD can become a good real-world reference case for future PtMS engineering applications.

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