Transit ITS Implementation Guidance

Part 2: Transit ITS Projects in China
Lessons Learned

Prepared for
The World Bank Office, Beijing

February, 2009
Transit ITS Projects in China – Lessons Learned

1. Introduction

The introduction of information technology systems to transit operations throughout the world has evolved considerably over the past few decades. These include systems which improve common business operations such as financial management as well as industry-specific applications such as vehicle location, traffic signal priority and fare collection. The reduction in acquisition cost coupled with the availability of more commercial off the shelf (COTS) product offerings, have resulted in a number of Chinese cities installing transit ITS systems.

The World Bank has participated in the financing of several of these. Given the complexity of these projects and their potential for dramatic transformation of transit operating agencies, it is worthwhile to provide some guidance to staff from transit systems contemplating ITS projects. The World Bank commissioned a series of three papers to assist in this effort. The first is a description of the key ITS applications for transit operations. This second paper reviews a number of previous installations and reports on lessons learned, both positive and negative, in the hope of maximizing the effectiveness of technology in improving transit services. The third is a set of Terms of Reference (TOR’s) for professional services associated with ITS project management to assist in project implementation.

This brief synthesis intends to provide some practical guidance to project sponsors about to undertake transit ITS projects. The source of this guidance was field visits and subsequent interviews with the transit staff at Jinan, Guangzhou and Wuhan. By any measure, these are successful installations which have greatly improved on time performance and the quality of information available to waiting customers. However, in each case, experiences during the development of their respective projects can be helpful to other transit systems in China. The ITS implementation in Guangzhou is very highly regarded among transit systems in China, with about 20 other systems annually either visiting or contacting the transit system to comprehend lessons-learned. Wuhan, which has recently completed installation of their ITS vehicle location system, and is going through some business process transformation is also likely to be regarded in the near future as an exemplary system.

For the purposes of this discussion, transit ITS will refer to a number of industry-specific information and communications technologies designed to improve the quality or efficiency of transit operations. This guidance in organized according to a transit ITS project life cycle from project inception to incorporating the use of ITS in daily business operations.

The specific transit systems are described below.
Jinan

Jinan has a fleet of about 4,000 buses. The company recently (April, 2008) opened a bus rapid transit (BRT) system with two routes. Associated with the BRT service was a range of ITS technologies including a vehicle location system, a revenue processing system using smart cards and a traffic signal priority system. Financing for their ITS system was not through the World Bank.

Wuhan

The City of Wuhan, with financial and technical assistance of the World Bank introduced a vehicle location system in 2008. It operates on 600 buses. The transit system already has an advanced fare collection system. At the time of development of this report, this system was only recently installed. There are no traffic signal priority components to this project.

Guangzhou

In 2006, the City of Guangzhou introduced a transit vehicle locations system as part of sizable traffic engineering and management improvements in the city. The installation was strictly an AVL system, without signal priority or advanced fare collection. The AVL system has been installed on more than 5000 buses out of 8,000 buses in the city. The city eventually plans to equip the entire fleet with AVL equipment. The city’s transit system is operated by a number of contractors which are state owned enterprises. Four of these use the AVL system for bus dispatching. In addition to the on-bard equipment, there are 110 display boards at bus terminals for use in dispatching and customer information and another 200 electronic boards at bus stops.

Based on performance of the system to date, the City plans to expand the installation to the entire fleet. The transit system already had an electronic fare collection system in place and has plans to introduce traffic signal priority in the future. Concerns about the effectiveness of TSP in a highly congested environment have caused the city to be cautious and deliberate in its future plans.

2. Project Scoping and Initiation

The impetus for introduction of ITS systems in transit operations comes from a variety of source. It appears that ITS technology is a marker of a progressive up-to-date transit system and systems who want a reputation of being progressive will invest in appropriate technology. Another pathway is through broader public investments in urban traffic management including advanced traffic signal systems.

We observed some common threads among the agencies in their motivation for initiating their projects. The agencies seemed to be motivated to improve their operation through ITS but had an imperfect vision of how precisely this would be done. This is understandable since it is difficult for a transit operator to imagine operating in a data rich environment when his or her current experiences are entirely in a data poor environment.
Each agency felt that the primary purpose of the system was to improve efficiency through reform of field operating practices, particularly terminal dispatching efficiency. Another benefit cited was improvement in real-time customer information. Guangzhou had a sophisticated motivation for their project, and recognized from the inception that the purpose of the ITS system was to improve the transit system. They described the motivation for system introduction as follows:

- Provide the government and the management departments of the public transit system with decision-making and management support. The data generated from the system is expected to provide a scientific basis for the optimization of the bus route network.
- Strengthen the operation and management of the transit enterprises and increase the operation efficiency of the transit system primarily through alteration of methods of bus dispatching from terminals. Use the ITS system to improve scheduling, monitor the operating performance of buses, understand the patterns of street congestion, analyze operating data from the system to provide transit managers with sufficient information to make operating decisions.

Such a clear articulation of the purpose of the project is important. We have come across instances where the technology itself is looked upon as an objective – not a tool to achieve some set of transit objectives. An alternative perspective for transit technology introduction and consequent transit system improvement would be to initiate these projects as opportunities to renew and reengineer transit systems and to consider technology merely as one of several components to accomplish this transformation. This would be complemented by business process re-engineering, staff training and development and introduction of performance measurement systems. Briefly stated, the problem to be addressed through transit ITS is not that transit operators don’t have ITS, but rather they have opportunities for performance improvement which can be addressed through ITS systems.

This observation is not just a semantic nuance. Transit ITS have the capability of changing transit systems from experience-based enterprises to information based enterprises. However, they sometimes fall short of their potential since the acceptance of the installed technology tends to mark the completion of the project. Normally, transit systems will seek opportunities to use the data from ITS systems as opportunities arise rather than integrate the information into routine business processes.

Developing ITS projects as part of transit system reform will help avoid the acquisition of more ITS components than necessary. Transit ITS might be looked upon as a suite of software products. Much like a software suite of various applications, not all are applicable to all transit systems.

Operators with whom we spoke felt that field visits to comparable cities with mature intelligent transportation systems were invaluable in two main primary areas - developing realistic expectations of ITS in general and how the ITS can be used to improve the quality or efficiency of the transit service. We have found host systems, particularly
Guangzhou to be amenable to such visits. Further, transit systems about to embark on ITS projects would be well served to host visits from staff of agencies with mature ITS systems in order to learn for their experiences.

A final, but difficult to quantify success factor in project development is strong commitment from the transit system executive leadership team. In the cases we observed, the active support of the management including a realistic expectation of benefits and the opportunity to introduce changes in management practices were thought to be the staff to be essential.

### Lessons Learned – Project Scoping and Initiation

1. Define an ITS project not as installation of hardware and software but rather as part of means of transformational change of the transit system to be complemented by other activities such as staff development, business process change, performance monitoring, etc.

2. Field visits to mature installations are invaluable in developing realistic expectations of the value of ITS and possible changes in management practices once these systems are implemented.

3. Initiate ITS projects with a clear articulation of goals and how the system will be used to enhance efficiency or quality of the transit service.

4. Strong support of the transit system leadership team is essential.

### 3. Project Organization and Management

We identified two broad organizational models for ITS project implementation. In Guangzhou, the Guangzhou Communications Commission was the project implementing agency while the contracting agency was the City Center Project Office, a unit of city government charged with implementing externally supported projects. In Wuhan, the transit operator, Wuhan Bus Company, was the implementing and contracting agency. In Guangzhou, since the project was part of a larger transportation and traffic ITS involving extensive communications, the Communications Commission was charged with implementation primarily due to their experience and expertise with wireless communications. The Guangzhou project was initiated prior to the one in Wuhan and there is evidence that Wuhan benefited from the experiences in Guangzhou.

There is no evidence one method is preferable than the other. More important, however, were the similarities in project management between these two cities. Each had a full-time dedicated project manager who led an interdisciplinary team of transit staff managers. In the case of Guangzhou, the project manager had 20 years of information technology experience and 3 years of transit management experience. The Wuhan project manager was comparably experienced.

Each of the two sites (Guangzhou and Wuhan) assembled an implementation team to guide the progress of the technology projects. This was particularly important since each of the transit systems chose to use customized software rather than adapt commercial off
the shelf software. (This is discussed below.) Each system felt that the key success factors were strong information technology management experience on the part of the transit system project manager, active participation by end-user management staff in the development of project scope, specification development and review of prototype systems. In Wuhan, there was a feeling that the software contractor’s limited knowledge of the details of transit operation was not ideal and would have insisted on stronger subject matter expertise on the part of the contractor.

Rather than the development of single agency systems, transportation systems planning should include other agencies as partners. Traffic management systems can be helpful to emergency operations personnel as well as traffic and transit operations. A strong communications infrastructure can be useful in the logistics of other public services. The AVL project is Guangzhou, for example was part of a larger traffic management and control system.

### Lessons Learned – Project Organization and Management

1. Strong project management skills are necessary to lead the implementation of these projects. If custom software is required, there must be extensive information technology experience on the part of the project management team particularly in the areas of reviewing prototype systems, acceptance testing, and parallel operation with current systems during the transition from manual systems to ITS.

2. A dedicated, experienced project manager, who does not have collateral responsibilities is very important. Ideally, they should have both transit management and information technology experience.

3. Technology vendors should be required to have some subject matter expertise on their staff or as subcontractors.

4. Opportunities for multiple agency integration should be sought to spread costs and improve system cost-effectiveness. Traffic signal priority systems, for example, can be quite beneficial to emergency responders.

### 4. Project Specification Development

Specification development for ITS should be left to someone with considerable expertise in this area. In both Guangzhou and Wuhan, a consultant was engaged to assist in the development of technical specifications, a very reasonable decision. In each case, the technical specifications were oriented toward a customized software product for their respective transit systems, rather than adapting pre-existing commercial products to meet their requirements.

The advantage of customization is clear. It is easier to tailor brand-new software to any unique operating practices of the transit system. Further, software built from scratch enables the accommodation of the requirements of each user more readily. Using customized software is not without risks, however. The software development cycle requires extensive, clear requirements analysis, prototyping and testing. This can elongate
the implementation process. A deeper concern is that the staff writing specifications may not have subject matter expertise in transit operations. In that case, the software will likely reflect current operating practices within the agencies, rather than transformational possibilities. Further, the knowledge base of the specification developer will greatly influence the developed specifications. As an example, one BRT system in China, has an AVL system which records (quite well) the arrival times of vehicles at BRT stations. However, the departure times are not noted. This is not a serious flaw. However, it precludes analysis of stop dwell time and further, on time performance is usually determined by stop departure time.

There is no evidence that customizing software rather than modification of existing software greatly impeded the progress of the respective projects. However, each implementing agency recognized the risks associated with this approach. Smaller transit systems, which may not have the depth of qualifications to manage a software customization project, would be well advised to seek solutions which modify existing software rather than develop software systems from scratch. With the more widespread introduction of transit ITS in China, the market for products which require adaptation, rather than origination, is likely to grow.

We observed that some systems chose to procure all ITS components in a single project. This might be motivated by a concern that if certain elements of transit technology are deferred, they may not be compatible with systems already installed. This concern is not illegitimate. This can be avoided by assuring that each vendor be required to provide the tables and field definitions in their installed products. This enables interoperability among systems and enables transit system staff to develop suitable reports for operations analysis after completion of the ITS installation. The requirement that systems be ODBC (Open Database Connectivity) compliant in which data files are independent of programming language is essential.

Lessons Learned – Project Specification Development

1. Project implementing agencies should give considerable thought to decisions as to whether to adapt commercial off the shelf systems or develop entirely new systems. Developing systems from scratch has attendant risks and should be avoided, particularly by smaller transit agencies.

2. Implementing agencies should go to great lengths to assure that installed systems are well documented to enable interoperability with future ITS applications. This can be accomplished by assuring that systems be ODBC compliant- independent of computing languages.

5. Project Procurement

Our review of the installations of transit ITS systems was intended to focus on technical matters. However, a common thread among implementing agencies was the difficulties in acquiring systems which met their technical performance criteria given the perceived complexity of the procurement regulations of the World Bank. We found no
unwillingness to comply with procurement regulations but rather some misinformation which warranted clarification.

Among the most difficult parts of implementation of new ITS systems is structuring a procurement method which meets multiple objectives of integrity and efficiency and also assures that the customer receives the best value for the investment. The procurement environment is complicated by the fact that a typical ITS installation is comprised of computer equipment, software and professional services as well as data and voice communications services between vehicles and fixed facilities. Further, there is considerable investment on the part of vendors in preparing proposals and certain software vendors have established business relationships with certain hardware manufacturers. It is no wonder that implementing agencies find the procurement process quite difficult.

The first step in the procurement process is to develop a procurement plan. It makes the most sense to select a mobile communications vendor first. The specifications for such services are easy to develop and there is a very small set of firms who can provide such a service. The procurement planning should then give consideration to the type of procurement. The first option is a one-step method in which a request for proposals is developed and tenderers are given the opportunity to respond to a set of detailed specifications. The other is a two step process in which vendors are pre-qualified in the first phase and a final selection is made among qualified tenderers in the second phase. Since there is considerable expense in proposal development, the two step method, although slightly elongating the time requirement of the procurement process, has benefits in that vendors have little expense in the first phase and a higher probability of selection in the second phase. This generally increases the pool of qualified candidates from which to choose.

The World Bank has a Standard Bidding document for two stage bidding of IT equipment which has been successfully employed in Bank operations. One of the positive features of the Bank’s two stage bidding process is that the client is permitted to discuss and clarify the details of the technical proposal face to face with the bidder during the evaluation of the technical proposals. It is permissible to request the bidder to make minor modifications to their technical proposal following its evaluation by the client. It is also permissible make general modifications to the technical and commercial requirements of the bidding documents following the outcome of the evaluation of all of the bidders technical proposals.

In a two step process, the role of site visits to mature installations is invaluable. Guangzhou, in particular, has been recognized as an exemplary installation and the transit staff have been very generous of their time in hosting site visits. These visits can help immensely in pres-screening the vendors and their technologies.

Regardless of the procurement method, the second step is to develop an integrated set of specifications for hardware, software and installation services. The evaluation criteria should include price and non-price criteria. The Bank maintains a website with the current standard procurement documents as well as a forum for discussion of technology
Procurement matters. It is generally agreed that a single vendor for all elements of a procurement is preferable than soliciting separate contracts for software and hardware. This diminishes the possibility of shifting responsibility among vendors when inevitable installation problems do occur.

In our review, some organizations which have installed or are about to install ITS systems have expressed a concern that the inclusion of price criteria in selection provides incentives for bidders to provide inferior equipment particularly commodities such as workstations, monitors, servers and routers. This is a misunderstanding of World Bank procurement requirements. Contracting organizations may specify a set of brand name components from a variety of vendors with an authorized service network in place including local capability to provide manufacturer certified repairs. Contracting agencies must also allow for “approved equals” and enable prospective bidders to propose alternatives for agency approval prior to the receipt of proposals. It is important to recognize that this process is not intended to cause the selection of specific manufacturers but rather to assure that the equipment comes from firms with strong business reputations.

Given that in our discussions, the area of procurement is both complex and not well understood, it is important that the Bank Staff provide appropriate technical assistance in the development of procurement processes. This assistance should be early enough in the procurement process to influence the work of technical specifications writers who may not be familiar with Bank requirements in this area.

### Lessons Learned – Project Procurement

1. The regulations of the World Bank concerning procurement impose no obvious constraints on developing specifications which assure a quality installation. However, there is some perception that these regulations impede the ability of contracting agencies to specify products of sufficient quality.

2. The procurement process should not be initiated after completion of the technical specifications but should be done in parallel with their development. Expert assistance in procurement will likely be required in the development of bidding packages.

3. An integrated procurement strategy in which there is a single vendor for both hardware and software is preferred. Equipment suppliers should be suppliers to prime contractors.

### 6. Post Implementation Analysis

An area where ITS have failed to live up to their potential is in the area of analysis of archival data. The primary reasons for this are that post-processing analysis is not explicitly part of the technology work scope and the linkage between the ITS and management improvements is not very sophisticated. This is not limited to Chinese practice - the worldwide experience with using archival data for transit management is weak. In an environment of little data, staff skills in analysis have neither been well cultivated nor highly valued. This is compounded by the fact that software vendors do
not have sufficient industry-specific experience in using technology appropriately to improve transit service.

Fortunately, a body of research in using such data for management analysis is starting to emerge particularly from the US and the Netherlands. The areas where archival analysis of data would be most helpful are:

- Analyzing the distribution of actual round trip route cycle times by time of day to determine the fleet assignment necessary to achieve a specific service frequency,
- Determination of appropriate schedule times between stops to improve on-time performance,
- Making an assessment of the distribution in the time gaps between successive buses on high frequency routes to reduce overcrowding and customer wait times,
- Analyzing the adequacy of layover times for bus operators between successive trips,
- Monitoring on-time departures from the first stop on each trip, a key determinant of overall on-time performance, and,
- Observing speeds and travel time variance between stop pairs to determine sources of delay along routes.

Until more ITS projects are implemented, it would be worthwhile for Chinese research institutions or universities to initiate some research in this area. Further, agencies should consider engaging subject matter experts after ITS implementation.

### Lessons Learned – Post Implementation Analysis

*Using archived data for on-going transit analysis is not very common. There are considerable research opportunities for developing procedures to use of this data in operating and strategic decisions.*

### 7. Estimating Benefits of ITS Installations

We observed very little formal analysis of the effectiveness of ITS systems in meeting stated objectives. There is, however, an abundance of anecdotal evidence of their effectiveness. Transit systems responded that the primary benefits of these systems are:

*Reduction of internal operating cost* – It was universally agreed that AVL systems introduce considerable economies to the vehicle dispatching function at route terminals. The common practice in China is to assign a “starter” at each end of a route terminal to record the arrival and departure times of buses and make tactical decisions concerning bus departure times when buses arrive late at terminals due to traffic congestion. This is quite labor intensive. Transit systems who have invested in AVL systems automatically
One operator expects there will be a reduction in fuel costs with AVL technology. This is particularly important since fuel costs account for about half of transit operating costs in Chinese cities. The expectation is with the ability of transit managers to monitor the operation of each bus (and each driver), drivers will avoid fuel wasting practices such as rapid acceleration and excessive speeding. These assertions, however, are merely conjectures at this point.

For transit agencies which contract services to commercial firms, AVL technology provides a simple auditable means of assuring contract fulfillment since a record of each bus departing from a terminal can be created and compared to the trips assigned to the contractor.

For advanced fare management systems, there is some evidence that using smart cards reduces the transaction time per customer slightly. (Data from the US suggests that this is about 5 seconds per transaction). We do not think there is a large operating cost benefit from the introduction of fare collection systems. However, revenue integrity can be enhanced with such a system. Since fare theft and fraud is difficult to detect, it would be quite difficult to estimate the value of these systems in enhancing revenue integrity.

The number of buses assigned to a route to maintain a specific scheduled interval is a function of the distribution of actual running times on the route. There is no question that better running ties can be established with better running time data. However, it is not unambiguous that this analysis will reduce the vehicle requirement to maintain a schedule. It is possible that existing running times are too tight and that additional buses might be required to assure that the schedule is maintained. In the previous section of this note, we recommended that more research be done in this area since it appears to be a common problem both in China and the rest of the world.

The transit operator in Jinan did implement a traffic signal priority system but discontinued it since it was having no measurable impact on bus travel time or reliability. Traffic signal priority systems are effective only in certain combinations of green and cycle time in the direction of heavy bus movement. In the case of Jinan, during certain periods the traffic cycle time was comparable to the scheduled headway. In such a case, nearly every traffic cycle would request additional green for the heavy bus direction. This is contrary to the design principle of TSP where priority would be requested at only a limited number of cycles.

*Improvement in transit service quality* – Operators cite improvement in transit service quality for two reasons. First, the ability to display the expected arrival times of subsequent buses at bus stops is thought to have some positive effect on how customers
value the service. After the implementation of their AVL system the transit system in Guangzhou experienced an increase in ridership in excess of 10%. It is not clear how much, if any, of this is ascribable to better customer information.

The second category of passenger improvement is the ability to observe and correct “bus bunching” the natural tendency of buses on short headway routes to experience variability in the gap between successive buses. When buses are not evenly spaced and customers arrive randomly, more customer will arrive during wide (longer than scheduled) intervals than short intervals. The excess average delay to customers caused by bunching can be easily computed\(^1\). Since customer wait time is valued more highly than in-vehicle time, this is an area where consumer value can be readily enhanced.

We were unable to find any controlled experiment to determine actual changes in customer wait times with the introduction of AVL equipment. With good data, an experiment can easily be designed to measure this benefit.

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**Lessons Learned – Estimating Benefits of ITS Implementation**

1. Obtaining data to estimate the benefits and costs of transit ITS is difficult. However, the conceptual framework for making the assessment is rather straightforward.

2. The various ITS systems should be evaluated separately to determine estimate their effectiveness.

3. The business case for AVL systems appears to be stronger than for the other systems. It appears that fare collection and traffic priority signal systems can be cost effective under specific circumstances.

4. Granting agencies should consider a prototype benefit cost assessment of one transit installation to explore this matter further.

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\(^1\) The average wait time for evenly spaced short headway buses is \(h/2\) where \(h\) is the headway. If the headway has some random variation, the average wait time is \(E(h)/2 \times (1 + C(h))\) where \(E(h)\) is the average headway and \(C(h)\) is the coefficient of variation (standard deviation/mean) of the headway.