REGIONAL TRANSPORTATION AUTHORITY
TRANSFER CONNECTION PROTECTION (TCP) PROJECT

EXECUTIVE SUMMARY

Prepared by:

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1. INTRODUCTION

The Gary-Chicago-Milwaukee (GCM) priority corridor program has produced a regional architecture which all projects using intelligent transportation systems (ITS) must follow. The program anticipated and includes plans for a regional Transfer Connection Protection (TCP) system. However, a design was not specifically defined. As a result, the RTA is undertaking the design for a TCP system that will be incorporated in future GCM program plans and complement intra-agency TCP systems being planned and/or under development by the service boards.

The RTA's TCP system will help improve service for passengers connecting between the services of two different service boards. This will be done by alerting service board dispatch systems to inter-agency connections that are in danger of being missed. Corrective action can then be considered. For passengers, this will mean reduced waiting time, improved security, and less uncertainty. With TCP service boards should see gradual increases in ridership and revenue, as well as improvements in operating efficiency. While implementation of this system is at best 3 to 5 years away, there are steps each service board can take now to prepare for it.

2. THE INTER-AGENCY CONNECTION PROBLEM

Many public transit users begin their trips each day on the services of one service board, and complete them on the services of another. They follow familiar routines – get off the first vehicle, traverse a terminal, major intersection or station platform, then wait for the connecting vehicle to come.

Most often, this inter-agency connection goes smoothly. When it does not, it is usually because the passenger's vehicle arrives late at the connection point, and the connecting vehicle has already left. Under some circumstances, the second vehicle could have waited if the driver/operator knew that the first one was late. But currently, there is no way for service boards to share this information with one another on a system-wide scale.

Figure 1 depicts a late bus approaching a train station as a train prepares to depart. When a passenger misses an inter-agency connection such as this, there can be many impacts:

? A longer wait time until the next suitable vehicle arrives.
? Feelings of uncertainty, anxiety, anger and frustration.

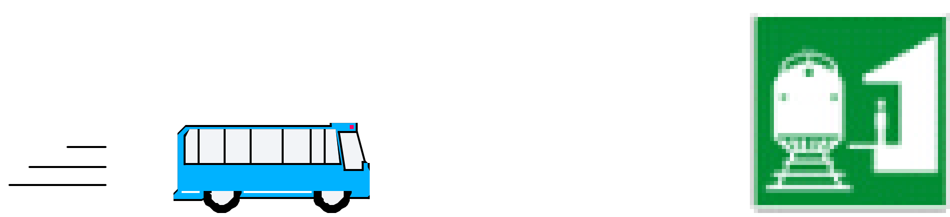

Figure 1: Late arrival at transfer points puts connections at risk.

- A late arrival to work or an appointment; sometimes, a missed appointment and a lost opportunity.
- In some cases, greater risk (real or perceived) of becoming a crime victim.
- The possible loss of choice riders to a competing mode of transportation.

Existing passengers are not the only ones affected. Service boards are also affected by this problem. Impacts to the service boards include:

- Reduced efficiency and additional service disruptions when vehicles are held for connections, but eventually must depart because of other commitments.
- Passengers frustration at missed connections being transferred to service employees.
- Growing political and media pressures to improve coordination at connection points, particularly within the city of Chicago.

Clearly, all parties are negatively impacted by missed inter-agency connections.

3. WHAT HAVE SERVICE BOARDS DONE ABOUT THE PROBLEM

The problem of missed inter-agency connections could be much worse, if not for cooperative improvement efforts by the service boards. CTA, Metra and Pace all participate in efforts to coordinate schedules at major inter-agency connection points, such as suburban Metra stations and city transportation centers served by more than one service board. Thus, when all services are on time, waiting times for frequently used connections should be reasonable and predictable. Because some deviations from schedule are inevitable, each of the service boards are also involved in "on the street" efforts to coordinate service. For example:

- CTA bus drivers on the #33 "Magnificent Mile" route carry Metra schedules and attempt to coordinate their departures with the actual arrival of inbound Metra service at the Western Avenue and Clybourn stations.
- Similarly, when picking up passengers from a Metra connection, Pace feeder bus drivers, with dispatcher approval via voice radio, may hold for late Metra train arrivals.
- Metra personnel at outlying terminals will often provide current train status information to Pace drivers on request. These drivers may also benefit from audio and visual Metra station announcements of delays and estimated times of arrival (ETA).

Despite these efforts, the challenge of systematically identifying endangered inter-agency connections and notifying those who can take corrective action remains. One agency's dispatcher may be able to call another's in order to address an isolated situation if alerted to it in a timely manner by field personnel. But this approach clearly cannot work for larger numbers of connections.

4. WHAT IS TCP AND HOW WILL TCP WORK

TCP is a multi-stage program of computer systems and policies to address missed inter-agency connections. It is believed to be the first effort of its kind in the world. TCP's main goal is to reduce passenger wait times at inter-agency transfer points, by minimizing the number of missed connections.

The TCP system would not be possible without the service boards' individual efforts to develop and implement new Automatic Vehicle Location (AVL) systems and computer-aided dispatch systems for both fixed-route and paratransit operations. It is the AVL system that captures location and status information on transit operations and forwards it to the dispatch system. The TCP gathers that information by a central TCP computer server, connected by high-speed communications links. The TCP examines this information to determine whether any pre-defined inter-agency connections are in danger of being missed. The TCP system will receive continuous 7-day, 24-hour updates of current schedule adherence information from each service board, along with definitions of connections to be automatically monitored and protected by TCP.

Two scenarios will be addressed to describe how a TCP will work. They are 1) automatic protection of a pre-defined Metra-to-Pace connection; and 2) protection of a customer-requested connection between Pace and CTA buses at a suburban terminal. In addition, Figure 2 depicts the high-level architecture for the TCP system.

TCP will be developed and implemented in three stages, with additional long-range enhancements, as described below:

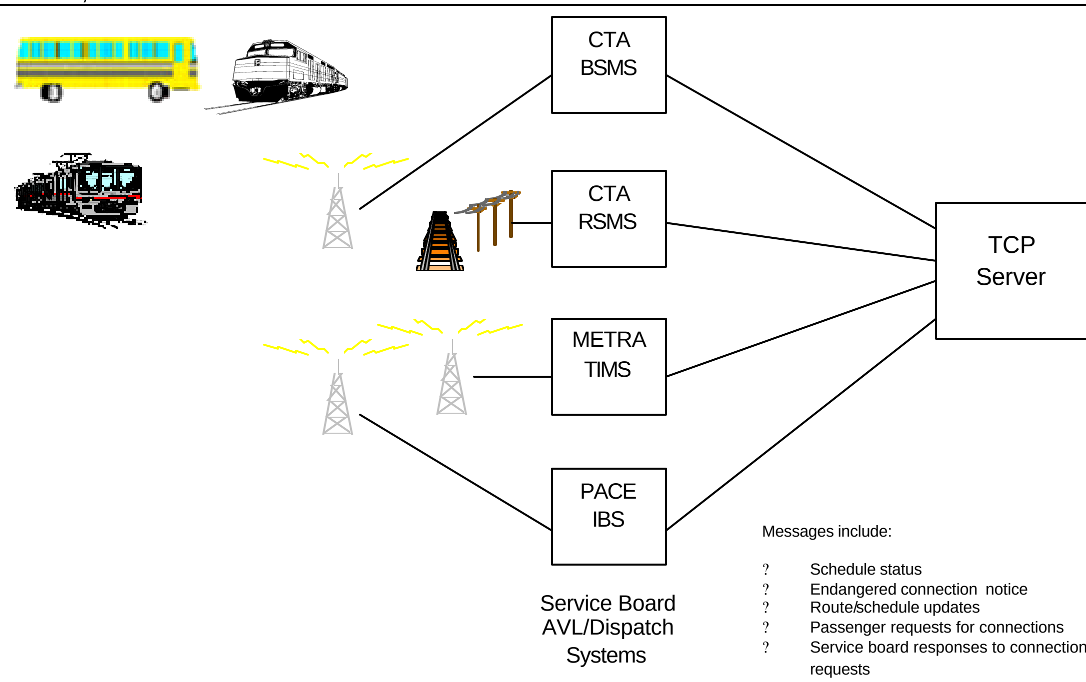

Figure 2: High-level TCP System Architecture

1. **Stage 1 – The base TCP system:** This system will automatically detect endangered inter-agency connections. It will include the hardware, software and networking needed for communications between the service boards' AVL and dispatch systems and a central TCP computer server. This server will continuously review the status of current operations and

identify any pre-defined inter-agency connections that are in danger of being missed. When an endangered connection is identified, the involved service boards will be notified electronically, so that they can consider corrective action.

2. **Stage 2 – Paratransit TCP:** In this stage, the TCP base system will be enhanced to include the contract paratransit operations of CTA and Pace. Passengers will request their desired connection when they reserve their trip. Before the trip or at the time of pickup, the desired connection will be forwarded to the TCP system for protection. TCP will then notify the paratransit dispatch system if the connection is endangered. This option will require modification to contract paratransit operators' AVL and dispatch systems, as well as full networking of those systems with their respective service boards' systems.

3. **Stage 3 – Protection of customer-requested connections:** This extends the base TCP system to include the ability for fixed-route customers to request specific connections and have their request accepted or declined. Both on-board and pre-trip requests will be included. Development of this stage will require programming of on-board equipment to allow entry of the connection request, and a means for visual and/or audio display of responses to requests. It will also require the capability for the other service board to automatically respond to the request.

4. **Additional long-range enhancements:** There are at least two further customer service extensions to the TCP system that could in the future add value for passengers. One is a customer notification option that would allow customers to define their regular trips to the system, then be automatically notified when a connection is endangered. The second is a customer trip completion alternatives option that would enable passengers to request alternative itineraries via transit or other modes (e.g. taxi) for completing their trip if a requested connection is declined.

The TCP system will operate around the clock, seven days a week. It will focus on protecting connections to longer headway routes (over 10 minutes). Specifically, the TCP will focus on:

? Daytime connections to routes with long headways or service only during limited periods.
? Evening, weekend and especially owl service, where most headways are longer, and missed connections mean very long wait times.
? The last trip of the day (or service period), where passengers may be stranded by a missed connection.
? "Near misses", where a short hold of 90 seconds or less would have allowed passengers to successfully make the connection. This avoids passengers arriving at a connection point, only to see their connecting vehicle departing.

5. OPPORTUNITIES AND BENEFITS FROM TCP

The TCP system, when implemented, will provide potential opportunities and benefits at several levels: for the region, for RTA, for the service boards, and for passengers. This section summarizes benefits at each level.

Regional benefits: As inter-agency connections improve, so will the viability of regional public transportation, and thus regional mobility. Also, improved accessibility to regional employment centers will enlarge the pool of potential employees, and support employment initiatives such as welfare-to-work.

RTA benefits: One of the three pillars of RTA's mission is to ensure *coordinated* public transportation for Northeastern Illinois. With TCP, RTA will be able to proactively advance this mission by delivering precisely the information needed to coordinate inter-agency connections.

Longer-term coordination may also enable service realignments for greater efficiency. TCP complements the efforts of the RTA during development of various traveler information systems. The general goal of these systems is to give passengers more and better information prior to and en-route to a destination, thus making public transportation easier to use. An example is the use of visual and audio displays to show current ETA information for routes serving a stop or station. This technology is also known as active transit station signs, and combining it with TCP makes current information available to both the carriers and their passengers. This provides the maximum impact on connection performance and on passenger satisfaction.

In addition, the role of RTA's Traveler Information Center will be enhanced through access to connection status information, and in Stage 3 as the planned contact point for customers to pre-request connections. The TCP system also complements RTA's Regional Signal Priority initiative; both projects will serve to reduce actual passenger travel times from origin to destination.

Service board benefits: First and foremost, overall passenger satisfaction will be improved, leading ultimately to improved ridership and revenue. Also, unproductive holds for connections that never come will be minimized, improving operating efficiency for both fixed-route and paratransit operations. Driver/operator satisfaction will improve with tools to help complete inter-agency connections, and with increased passenger satisfaction. Over the long-term, a mature TCP system may create the opportunity to increase operating efficiency through selected schedule adjustments and equipment reassignment.

Passenger benefits: Passengers using inter-agency connections will experience shorter wait times and fewer late arrivals, as a consequence of more consistent service. This will lead to greater passenger satisfaction with regional public transportation. Also, with the Stage 3 capability for requesting specific connections, passengers will have real information about the status of their desired connection, and thus greater control over their journeys.

6. EXPERIENCE WITH AUTOMATED CONNECTION PROTECTION

While TCP will be the first permanent system for coordinating inter-agency connections, there are a number of past and current connection protection systems worthy of study, both in public transit and in other transportation sectors. This section examines the experience with these systems.

U.S. AVL/Dispatch systems: There are two U.S. transit agencies whose installed AVL/dispatch systems include *single-carrier* connection protection: Ann Arbor, Mich. and Fresno, Calif. Rather than pre-defined connections, these systems currently support passenger-requested connections only. These systems analyze passenger requests, then accept or decline them based on several criteria. According to officials in Ann Arbor, their experience with connection protection has been very positive, as has customer reaction.

A number of North American AVL/dispatch systems with connection protection features are in various stages of development or deployment. These include CTA's Bus Emergency Communication System (BECS) and Bus Service Management System (BSMS), and Pace's Intelligent Bus System (IBS). These systems will provide not only AVL and dispatch but are also planned to provide intra-agency connection protection services.

International experience: Europe has more extensive experience with installations of connection protection systems. One example is the system installed at Üstra, the transit operator in Hanover, Germany. In this system, the dispatch computer analyzes information from the AVL system and identifies endangered connections. If corrective action is needed to protect a connection, the dispatcher is notified of the problem. With dispatcher approval, revised operating instructions are then sent to the vehicle operator via a data message. Similar systems are in operation in more than 25 cities in Germany, as well as in other European cities. None, however, address large-scale inter-carrier connection protection.

Also of interest is a prototype bus-rail connection protection system that operated in Germany for several years and is documented in a 1989 issue of Railway Technology. This system automatically coordinated rail-to-bus connections in two specific situations also targeted by the RTA TCP system. First, the system coordinated off-peak connections to minimize long wait times due to missed connections. Second, the system monitored peak-hour connections to minimize situations in which passengers alighting from a train were able to see their connecting bus or light rail vehicle pulling away from the station. It functioned through a "countdown display" that indicated to the bus driver and passengers the number of minutes until departure, adjusted to conform with the actual arrival of the train.

The Railway Technology article does not mention the city where this prototype system was installed, nor what vendor supplied it. While the system apparently operated successfully for several years, there is no further record of its use or of other installations. However, it serves as a good example of basic connection protection capabilities using relatively unsophisticated technologies.

Passenger airlines: Many U.S. passenger airlines use highly sophisticated software to identify endangered connections and to recommend whether or not outbound flights should be held for inbound connecting passengers. These systems have been refined over many years of experience. Unlike those of public transit agencies, airline computer systems contain detailed information on their connecting passengers, including profitability, and on the alternatives available to each. The success of airline connection protection systems is evidenced by their widespread use at major U.S. airlines, as well as the availability of commercial software being marketed worldwide for this purpose.

Freight railroads: Historically, the majority of freight shipments on U.S. North American railroads have been carried by more than one line-haul carrier. Thus, during the 1980s the industry identified inter-carrier connections as a key improvement area for overall service quality. An industry committee developed standard procedures and responsibilities for handling inter-carrier shipments. Also, just as proposed for RTA's TCP system, the committee identified means for exchanging information on connecting shipments between the carriers involved. Systems for collecting and sharing this information have been successfully implemented at all large North American freight railroads. They have been a factor in the robust growth and profitability of these railroads during the 1990s.

7. POTENTIAL TCP ISSUES AND RISKS

A complex system like TCP, coordinating the operations of several different operating agencies, brings with it issues and risks that will need to be addressed by RTA and the service boards. The primary ones are briefly explored below:

Newness of the concept: TCP marks the first time that automated connection protection has been attempted involving multiple carriers and dispatch centers. Inevitably with a new concept, there will be more kinks to work out, and a higher risk of failure. This will have to be thoroughly addressed by RTA and the service boards through:

? Extensive system testing
? one or more pilot projects

- ? extensive involvement from technical experts, employee groups, customers and other stakeholders
- ? acceptance tests

Policies on holding for connections: The unprecedented availability of information with TCP will make connection policies an issue for each of the service boards. They will need to set decision criteria and operating policies governing when and how they will hold vehicles for inter-agency connections. Each of the situations discussed earlier will need to be examined: daylight service; evening/weekend/owl service; and near misses. Delays to other passengers will also have to be factored in. A start has been made with the documentation of existing service board connection policies as part of the TCP feasibility study. But much additional work will be needed.

Impact on on-time performance: Because holds for connection will increase with the implementation of TCP, service board on-time performance statistics may deteriorate slightly. However, overall service from the customer's viewpoint should improve. One useful approach to dealing with this issue will be the future development of systems that use TCP data to measure connection performance.

Outdated status information due to radio restrictions: This is a complex technical issue faced primarily by CTA and Pace. While AVL systems on vehicles are highly accurate and current, the frequency of transmissions between vehicles and dspatch computers is limited by radio capacity constraints. As a result, the accuracy and freshness of dispatch system information, while adequate for fixed-route dispatching, may not be good enough to support TCP. This is especially true when it comes to the elimination of "near misses", where a deviation of 60 seconds could cause TCP to fail to detect an endangered connection. The same concern may apply to other regional uses of status information from dispatch systems. More study by the RTA is needed, along with efforts by all concerned to maximize the accuracy and freshness of dispatch system information.

Public perception and acceptance: The base TCP system is really a tool to enhance management of service board operations. If it is widely publicized as a way to improve service, then service boards and the RTA may end up defending in the media, if certain connections are still being missed. The result could be negative press for the system and even political pressure to abandon it and seek responsible parties for the failure. To keep this from happening, careful attention must be given to how the system is publicized. In particular, care must be taken to clearly state what the system can and cannot do, emphasizing that there are practical limits on what can be done.

8. HOW CAN THE SERVICE BOARDS PREPARE NOW FOR TCP

There are a series of steps each service board can take to help fully prepare for the future TCP system. They are listed in this section, in priority order.

1. ***Support and participate in regional efforts to integrate ITS technologies***. Promote implementation of a technically integrated and jurisdictionally coordinated transit system across the region. Follow standards that are in line with regional architecture for improved interoperability.

2. ***Institute an agency-wide dialogue about ITS projects. For TCP,*** discuss its impacts, and how best to integrate it into agency plans. Also, assure thorough, thoughtful reviews of TCP project deliverables.

3. ***Review current policies governing inter-agency connections***. Develop policy modifications to support improved connection performance under TCP, as well as any interim improvement measures that may be possible.

4. ***Make sure that AVL and dispatch system design efforts incorporate the requirements of the TCP system*** as they are identified. These include:

   ? Sending service status information to the TCP system.
   ? Automatically processing messages from the TCP system, and implementing needed corrective action subject to dispatcher review.
   ? Supporting GCM architecture requirements for communications between systems, which TCP will follow.
   ? Following open systems principles in all design efforts.
   ? At the appropriate points in the future, supporting the customer- requested TCP system and additional long range-enhancements.

5. At the appropriate point in the future, CTA and Pace need to ***assure that paratransit AVL and dispatch systems are modified to allow participation in the Stage 2 capability for paratransit TCP***. These are some of the changes that will be required:

   ? Networking contract carrier AVL/dispatch systems to service boards. (Progress has already been made in this area.)
   ? Collection of more detailed connection information at reservation time.
   ? The ability to receive ETA changes for connecting services and to update reservations with this information where applicable.
   ? The ability to calculate or accept from the driver updated ETA's at drop-off point.

6. Make sure that necessary on-board hardware will be in place in time to support the customer-requested connection option. This will include on-board passenger displays and driver/operator interfaces.

REGIONAL TRANSPORTATION AUTHORITY
TRANSFER CONNECTION PROTECTION (TCP) PROJECT

TASK 1 REPORT:
NEEDS ANALYSIS

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April 23, 1999

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1 EXECUTIVE SUMMARY

This report summarizes the information developed and findings reached in Task 1 of the RTA Transfer Connection Protection (TCP) Project.

First, project goals and objectives are revisited. Principal among these is improved service to travelers through reduced waiting time and improved consistency of inter-carrier connections. Project stakeholders are then identified, encompassing RTA and its service boards, the travelling public, other governmental agencies, and businesses in the region.

Presented next is a hypothesized set of traveler viewpoints on inter-carrier connections and the potential for TCP. It is believed that the biggest problems perceived by travelers relate to day to day inconsistency in connection performance, failure to make connections when the desired vehicle is still at the transfer point or still visible after departing, and the lack of information about next vehicle arrival at connection points. The first two of these are directly addressed by TCP.

Carrier needs, wants and priorities from the TCP system are addressed next. Several key points emerge from this analysis:

? All three service boards share the viewpoint that the principal benefit from TCP will accrue directly to travelers through improved service
? Pace and Metra both indicate that Metra to Pace connections are their top priority. This opens up the possibility of mutually advantageous interim measures to improve information sharing prior to actual TCP availability.
? CTA voices a strong interest in standardization and mutual agreement by the three agencies on common message sets and database formats.
? Metra sees potential new travelers as key stakeholders in this effort.
? Pace voices a strong concern for ease-of-use and desire for the availability of location-specific status information on specific services.

The report goes on to examine TCP in the context of the regional architecture promulgated by the Gary-Chicago-Milwaukee (GCM) Priority Corridor initiative. TCP is addressed in at least two specific projects under the Integrated Transit System program area. The vision for this program area includes a centralized regional repository for schedule and status information for all carriers, which would support advanced, complex levels of TCP. With respect to the more current capabilities of the GCM Multi-Modal Traveler Information System (MMTIS) and its component Gateway Traveler Information System (GTIS), TCP is implicitly encompassed in the effort, but is not currently part of the explicit functional design for GTIS. Later tasks in this project will determine whether a more formal role for TCP in the GTIS design should be sought in the future.

The report next provides a short primer on how transit service management is performed, and how connection protection fits into this management decision framework. It goes on to explain the downstream impacts of holding a vehicle for connection, which must be considered in any decision: impacts on other passengers, possible missed connections downstream, and potential operational and overtime cost impacts if a vehicle is delayed too long.

Five possible views of a regional TCP system are presented in the next section, as a basis for team discussion about the most desirable approach. These range in complexity from a simple bilateral message exchange approach with limited or no central capability, to a proactive, optimizing central facility that attempts to optimize service quality in its selection of which connections to protect. All views explicitly include support for customer requests for connection. Measures of effectiveness are then proposed for future evaluation of a Phase 2 TCP effort.

The final section presents several preliminary conclusions based on the needs assessment:

- ? There seems to be a clear interest in progressing this project, in that all carriers see the benefit in the concept of having access to real-time status information on each other's operations.

- ? A consensus has formed around the two most advanced system concepts presented. These are *proactive, exception-based TCP*, which automatically notifies the involved carriers from a central server when a connection is protected, and *proactive optimizing TCP*, which goes a step further and chooses which connections to protect on a regional optimum basis. In subsequent tasks, these concepts will be refined and analyzed, leading to a recommended system concept.

- ? There is strong advocacy for standards based interfaces and standard database formats in support of TCP.

2 PROJECT RATIONALE AND GOAL

Each of the Regional Transportation Authority (RTA) service boards has been constrained by lack of information and insufficient communications facilities in its efforts to improve the quality of service to its travelers – particularly reliability. Even when fully adequate service can be provided, it has been difficult to respond to problems which inevitably arise in the course of the day, especially during peak periods. Without comprehensive real time information and/or communications links to operators, dispatchers and street supervision have had to make decisions based on what they can see from their current location, supplemented by second-hand information. Travelers have suffered from the same limited or missing information as they try to navigate through the system to reach their final destination.

The robust growth in recent years of Intelligent Transportation Systems (ITS) technology for public transportation (also known as Advanced Public Transportation Systems or APTS) has created new opportunities for agencies to upgrade their service management and traveler information capabilities. Typical APTS capabilities include Automatic Vehicle Location (AVL), Computer-Aided Dispatch (CAD), and mobile data communications facilities. Each of the RTA service boards has responded to these opportunities with their own automation projects: the Chicago Transit Authority (CTA) with its Bus Service Management System (BSMS); Pace with its upcoming Intelligent Bus System (IBS); and Metra with its upcoming Train Information Management System (TIMS). These projects offer the promise of improved service management, better reliability, better intra-carrier connection performance, and improved traveler information.

At the same time as the above, *regional* initiatives for improved service and information have been gaining momentum. The Gary-Chicago-Milwaukee (GCM) Priority Corridor program has laid out an extensive blueprint for a regional information architecture which will be ultimately be able to support regional intermodal service management. However, today's reality is that, with some notable exceptions, connections *between* the services of CTA, Metra and Pace are coordinated from the standpoint of scheduling, but not on a real time basis. That is, vehicles of one carrier will frequently depart from a connecting point with another carrier without regard to the actual status of the other carrier's operation, unless they can see the connecting vehicle. And, for those connections where operations are intentionally coordinated on a real-time basis, such as Pace feeder buses and Metra commuter rail services, the ability to coordinate is hampered by lack of information.

With carrier and regional initiatives as a backdrop, the rationale for the RTA's Transfer Connection Protection (TCP) project is thus clear: *Real-time coordination of connections between the operations of CTA, Metra and Pace will result in improved service to the traveler.* Further, the sharing between carriers of operational status information can be a major step toward that coordination. Finally, when all carriers have implemented their ITS-enhanced service management systems and can truly process and act upon this shared information, significant improvements in service and traveler information can be expected.

TCP project goals were clearly identified in the RTA Request for Proposal (RFP), and are still applicable today. They include:

- Enhancing the quality of en-route service to customers;
- Improving system productivity and customer satisfaction;
- Enhancing the contribution of public transportation systems to overall community goals (e.g. safety); and
- Expanding the knowledge base of professionals concerned with Advanced Public Transportation Systems (APTS) innovations.

This Needs Assessment task will contribute to all of these goals by establishing a foundation for understanding of the problem, and of the needs and solutions as seen by a variety of stakeholders.

3 PROJECT OBJECTIVES

A number of objectives for the TCP project have been identified. They include:

? Minimizing travel times for transit riders making connections
? Reducing the number of "missed" connections
? Increasing transit ridership
? Improving accessibility to areas and activities attracting connecting passengers
? Improving operating efficiency through coordination
? Allowing for simplification of route structures and/or schedules

In addition, the RTA RFP for this project identified three objectives for the consultant:

? Defining the functional requirements and standard specifications for data exchange between carriers and/or between vehicles to support connection protection.
? Allowing the various transit agencies to include in their AVL/CAD system planning, design and implementation the necessary elements to support inter-carrier connection protection.
? Making recommendations on a deployment strategy, taking regional and intermodal objectives into consideration.

The Needs Assessment undertaken here represents a first step in the development of specifications (Objective 1). It also provides an initial opportunity for carriers to identify what they expect they will need in order to make interagency connection protection work.

4 PROJECT STAKEHOLDERS

In interchanges with the Service boards, and through project team analysis, a number of stakeholders for this project have been identified. They are listed below, along with a brief description of each. These descriptions will also serve as definitions of terms for use in the remainder of this report.

- *Area Chambers of Commerce:* Chambers of Commerce, representing business owners, have a stake in programs such as TCP because they improve employment accessibility for their members.

- *Carriers:* CTA, Metra and Pace. Also may refer to other public or private carriers, but only if so stated. They are active stakeholders in this project because they stand to gain ridership from the improved service it will allow them to provide. They must also integrate this information into their organizations at the same time as many other new systems are being introduced.

  There are a number of specific stakeholder groups within carrier organizations. Some of the most involved are listed below:

  - *Operations Management:* Management and staff directly involved in putting service out to travelers. This includes dispatchers, mobile supervisors, and office based operations management. They must use the information provided by TCP.
  - *En-route service personnel:* For bus operations, this is the bus operator. For rapid rail operations, en-route service personnel are train operators and conductors. For Metra commuter rail, en-route service personnel are locomotive engineers and the train crew – conductor and trainmen. These personnel must execute service modifications in order to make TCP work, and are also a key source of information to the system.
  - *Customer Service:* Each carrier has a customer service unit, although all have different names. Customer service personnel answer various inquiries from current or potential travelers, concerning schedules, routes and fares. They also receive complaints and other information from travelers and from the public at large. They can be a source of information about connection problems, and will play a role in informing travelers of its capabilities.
  - *Marketing:* Carrier marketing groups promote services to current and potential travelers. In particular, they publicize new services and new features, such as TCP.

- *Chicago Area Transportation Study (CATS):* CATS is the Metropolitan Planning Organization (MPO) for the RTA's service area. CATS maintains an Advanced Technology Task Force, which serves to coordinate new or advanced technology initiatives among the various agencies involved.

- *Chicago DOT or CDOT:* CDOT manages a large part of the infrastructure used by the CTA, and has a stake in any initiatives involving regional transportation management.

- *Contract Operators:* All three carriers contract out portions of their services to third party operators, including both mainline and Americans With Disabilities Act (ADA)-mandated services. These carriers typically own their own vehicles and use their own separate, private radio networks for communications. Increased communications capabilities with and between contract carriers will be necessary in order to achieve comprehensive region wide TCP.

- *County DOTs:* County DOTs have an interest analogous to that of CDOT; in some cases they play a role in regional transit hubs.

- *Customers:* Used as a synonym for travelers

- *GCM ITS Priority Corridor:* The Gary-Chicago-Milwaukee Priority Corridor is promulgating a regional ITS architecture for transportation management and information. This project falls under the Integrated Transit System program area of the GCM Corridor Program Plan. While it does not currently appear as a functional requirement in the Gateway Traveler Information System (GTIS) architecture, it is nonetheless expected that TCP will represent an integral part of the regional system.

- *Illinois Department of Transportation (Illinois DOT or IDOT):* IDOT is a funding agency for the GCM program. In addition, the IDOT Department of Public Transit maintains an interest in public transit ITS programs under its jurisdiction, such as this one, and wants to assure that such efforts are standards-based.

- *Municipalities:* While some municipalities may be content to let their COG or COGs represent their interest in a program like TCP, others, especially larger ring communities like Evanston or Oak Park, may see themselves as direct stakeholders. TCP may affect major transfer centers within their boundaries, and may also be perceived as contributing to employer and retail accessibility.

- *Passengers:* Used as a synonym for travelers.

- *Regional Councils of Government (COGs):* These groups, such as the Northwest Municipal Conference and the Lake County Municipal League, are playing an increasing role in shaping transportation policy for their portions of the RTA's service area. They have an interest in any program which has the potential to improve the quality and attractiveness of transit modes.

- *RTA:* Besides being charged with financial oversight of the service boards, the RTA takes an active role in promoting coordination and cooperation among the service boards around advanced technology initiatives. As the sponsoring and managing agency for the TCP project, RTA can be expected to monitor and measure project effectiveness during and beyond the Phase II implementation of TCP. In addition, the RTA is the premier provider of traveler information to current or potential transit users through its Travel Information Center (TIC). The TIC will certainly utilize information from the TCP system in serving callers. In addition, the TIC is a possible focal point for acceptance of telephone requests for connections and for advising travelers how to access and utilize the TCP system.

- *Travelers:* Users of the region's public transportation systems; they stand to draw the greatest direct benefits from TCP
  - *Current travelers:* Those who currently use the system, whether on a regular basis or occasionally
  - *Potential travelers:* Those who do not currently use the system

- *US Federal Transit Administration (FTA):* As a funding source for programs like TCP, FTA is a major stakeholder whose ideas and expectations must be addressed. FTA is also the promulgator along with the Federal Highway Administration (FHWA) of the Interim Guidance on Conformity with the National ITS Architecture and Standards, which needs to be taken into account in the TCP design.

5 TRAVELER VIEWPOINTS ON INTER-CARRIER CONNECTIONS AND TCP: A WORKING HYPOTHESIS

It is easy when embarking on the design of an advanced technology operations support system such as TCP to lose focus on the most important stakeholders – in this case, the current and future travelers using CTA, Metra and Pace services. To be truly successful, the TCP must be responsive to what those travelers perceive to be the problems they face with making inter-carrier connections.

As part of the effort in this task, a set of viewpoints about inter-carrier connections from the traveler's perspective has been hypothesized, addressing these issues:

- What problems with inter-carrier connection protection exist?
- What responses by carriers would be helpful in addressing these?
- How would the traveler view visible technology as part of a solution?

Each is further developed below.

5.1 Traveler-perceived problems with inter-carrier connection protection

The following traveler viewpoints about inter-carrier connection problems are hypothesized (roughly in priority order):

1. Inconsistency from day to day in connection performance, which disrupts plans and can frustrate even dedicated travelers to the point of changing modes.
2. Arriving at the connection point and having the connecting vehicle depart even though you have been seen by en-route service personnel on board. This contributes to the perception that carriers care more about schedules than they do about people.
3. Arriving at the connection point with no vehicle in sight, and no real-time next arrival information. Without information, travelers feel out of control and cannot evaluate their options.
4. Arriving at the connection point and being able to see the already departed connecting vehicle. This is frustrating, and contributes to a perception that carriers do not coordinate their operations for the benefit of travelers.
5. Not feeling safe at the transfer point while waiting for a connecting vehicle.
6. This connection is important to me, but doesn't seem important to the carrier(s).
7. Not knowing at the outset of a trip whether or not a connecting vehicle will be available at the connection point (e.g. night/owl Metra trips and shuttle buses).
8. Having to wait at a connection point in adverse weather conditions – temperature extremes, high winds, precipitation.
9. The connecting vehicle en-route service personnel not knowing that the traveler wants to make a connection. If they knew, perhaps they could expedite the trip and allow the connection to be made.
10. There should be a timed connection at this point but there is not.

If these situations persist over time, the likely results are 1) lost ridership; and 2) negative public perceptions inhibiting potential travelers from trying the affected service.

5.2 Carrier responses travelers would see as helpful

It is hypothesized that travelers would welcome these carrier actions to address inter-carrier connection problems:

- Running service consistently on time (both sides of the connection). If the service were on time, there wouldn't be any problems.

- Reducing waiting time by running more vehicles. However, it is believed that many travelers understand that financial constraints preclude this.
- Holding vehicles for connecting travelers. Airlines do this – why can't public transportation carriers?
- Providing next-vehicle information at the transfer point. This would allow the traveler to evaluate his/her options and give them some control over the situation.
- Providing information about connection status while still on the first vehicle. This might allow the traveler to choose an alternative path to his or her final destination.
- Allowing travelers to notify en-route service personnel that they wish to make a connection at a designated point, and having that information conveyed to the connecting carrier so that they can wait at the connection point. This works well for some Pace-Pace connections today – could it be used on a wider scale?
- Providing or facilitating alternative service if the last vehicle has already departed. This is an integral part of some programs such as the Pace VIP Vanpool program.

Clearly, most of these are not directly addressed by the TCP project. This project primarily addresses providing information to carriers so that they can consider the third bulleted response above: holding vehicles for connecting travelers. Nonetheless, it is useful to remember that there are other useful approaches which could be (and in some cases are being) explored at the same time as TCP.

5.3 Technologies that travelers might see as useful in support of inter-carrier connection protection

Some of the technologies travelers might see as useful are postulated as follows:

- A telephone service to pre-request a connection
- A keypad on the "from" vehicle in the connection which would allow the passenger or operator to enter a request for a specific connection later in the trip
- A display at the connection point with next vehicle information
- A display on board connecting vehicles with next vehicle information

The first two bulleted items could be part of the TCP system design. The other two will most likely play no direct role in TCP (though they most likely will in other related projects). However, it should be noted that in one European system documented in the early 90's, rail to bus connection protection was facilitated by a countdown board at the transfer point which served two purposes. It told bus operators how much longer to hold at the connection point waiting for an inbound vehicle with passengers. It also served as an information sign for travelers already at the transfer point showing them the time left before the bus would depart.

5.4 Validation of traveler viewpoints

The scope of this needs analysis did not include any formal traveler surveys or interviews to validate the above hypotheses. Rather, they are presented as a set of working assumptions agreed to by the project team.

The possibility has arisen that surveys conducted by Pace's Market Research department may shed some further light on these hypotheses. Wilson Consulting will investigate this with Pace and report findings in a task addendum.

6 CARRIER NEEDS, WANTS, PRIORITIES FROM THE TCP SYSTEM

While travelers will be the ultimate beneficiaries of the TCP system, it is the carriers who must both generate and forward the schedule and real-time status information needed. They must also be able to receive the same type of information, and most importantly, integrate it into all aspects of service delivery, including the dispatch center, bus stop and bus cockpit.

Soon after the kickoff meeting for this project, an initial questionnaire was forwarded to CTA, Metra and Pace representatives. Their responses, along with follow-up telephone conversations, reveal that each carrier has a distinct view of the problem and potential solutions. The information gleaned from carriers is summarized in Table 1. The subsequent sections go on to describe carrier responses in these areas:

? Service management structure, capabilities, technologies and plans
? Wants from the TCP system
? Prioritized type of connections the carrier would like to see targeted by TCP
? Benefits expected
? Concerns and obstacles

The carriers were also asked in the questionnaire about TCP-related policies and practices. While their responses in this area are summarized in Table 1, they are not discussed in detail in this report. Instead, they are addressed in detail in the next project task, Task 2, Determine Existing Connection and Transfer Policies.

Carriers also commented on their views of TCP stakeholders; the composite of these can be found in Section 4 above.

Table 1: Recap of Carrier input			
Questionnaire Topic	**CTA information**	**Metra information**	**Pace information**
Current and planned capabilities and associated technologies	Current: *Bus*: Garage dispatch rolls out bus service. Street supervisors make many service decisions based on visual information and telephone calls to control center. Control center uses land line communications with bus supervision, and has two emergency only radio channels. *Rail*: Service managed by control center controllers and terminal-based personnel using signal system and radio communications. Rail Service Management System (RSMS) in place and functioning. There are few formal bus-bus, bus-rail or rail-bus connection protection activities. Rail to rail is based on visual contact of a potential connection by operator. Planned: In the bus area, CP capabilities will come with implementation of the Bus Service Management System (BSMS). It will include automatic vehicle location (AVL), computer aided dispatch (CAD), mobile data communications, and pilot passenger information and traffic signal priority request capabilities In a first stage, bus CP will be implemented, with direction and time of day prioritization, taking into account recovery time and downstream impacts. Next: bus-CTA rail, CTA train-to-train, then connections with Metra. Pace will follow later closer to their bus management implementation. All activities will be without human intervention, though controllers can selectively be notified and override.	All Metra services are controlled by dispatchers using control consoles, voice radio systems, signal systems, and remote switch control. Metra controlled and owned lines are dispatched at Metra facility – 15th & Canal. Contract for service lines are dispatched by contract carriers at remote sites (e.g. UP – Omaha; BNSF – Ft. Worth). Radio contact with train crew is used for information update. Currently, any TCP-related activities are performed via telephone and live dispatcher. There is proactive coordination during emergencies or service interruptions. Customer information is currently provided via message boards at outlying stations, and monitors at downtown stations, all connected via wireline data links. Information is generated by staff at dispatch who key in information as received from the train crews. Future plans include an AVL-based Train Information Management System (TIMS). This system will capture location data from trains, along with text messages from on-board personnel. It will support a system operator at the Metra Control Center, dispatchers, Passenger Service Representatives, operating personnel, and the traveling public. It will drive station displays, on-board stop announcement displays, and other public information facilities. The specified system should provide basic status information necessary for TCP, but does not explicitly include any provisions for TCP support. Metra recently issued a procurement for a pilot implementation of this system.	Pace uses a multi-channel two-way radio system to support the dispatch function, which is decentralized at each Pace division. Overnight, dispatch is consolidated at South Division; drivers sign off with their dispatcher and sign on with the South Division dispatcher using the appropriate radio channel. Contractors use separate private radio systems and frequencies; there is no direct bus to bus communications possible in these cases. All connection protection is done bus operator-bus operator. Pace has outlined future plans in a recent RFP for specifications development services for its Intelligent Bus System (IBS). The system will include AVL with schedule adherence and exception reporting capabilities via radio data communications. It will also explicitly support intra-Pace and inter-carrier CP. Most likely this will continue to be bus operator-bus operator for Pace-Pace connections. The methodology for supporting inter-carrier CP is still to be determined.

Table 1: Recap of Carrier input			
Questionnaire Topic	**CTA information**	**Metra information**	**Pace information**
TCP policies and practices	CTA policy covers trains on adjacent tracks. CTA rule book addresses bus connections: "Operators must wait a reasonable length of time for passengers to transfer from approaching trains or buses from another route, allowing more time in owl periods and on routes where there is a long headway." At certain points, a rail supervisor may use PA system to instruct a train to wait for a connecting train. No arrangements are in place for connection between agencies.	Metra's first priority is safety; subject to this, every effort is made to accommodate passengers making connections to Metra services. There are no routine efforts to coordinate connection protection with other carriers.	No blanket policy. Connections are made within reason between Pace mainline routes. Repetitive connections become "established" with regular operators initiating the communications daily to assure connection. Regular practice at satellite (pulse or "hub and spoke" operations is to wait for late arriving vehicles up to two minutes – five minutes for last trip (more if dispatcher authorizes). Connections from Pace operated to contractor routes may be done visually but there is no formal communications. Pace mainline routes which intersect a Metra line will wait to pick up passengers if visual contact is made with the train. Feeders have more flexibility to wait since this is their primary purpose; however if there is typically bi-directional traffic on the route, its flexibility is limited. Information on train status is occasionally obtained via request to dispatcher, or conversation with train crew at station. A few CTA train stations have train arriving indicators which are also useful; or, visual contact is used if possible.
Want from system	Standardization of message sets – TCP. Catalyst for interagency efforts on this strategy. Agreement on parameters for designating a vehicle meet as TCP eligible. Carrier database compatibility.	Better link-ups, coordination of schedules, and handling of contingencies which arise.	Improve passenger satisfaction (and service) via improved connections. Expand ability to receive information from other carriers to facilitate this process. Would like dissemination of info at following levels: dispatcher to specific bus; dispatcher to all buses. Automated notification to operators vs. inquiry driven; location-specific real-time information by mode about specific services – e.g. when will train 327 arrive at Highland Park? A system that is user friendly to operators and supervisors. A demonstration period with limited test area for evaluation. A basic system which can be upgraded or enhanced later as mastered by operators.

Table 1: Recap of Carrier input			
Questionnaire Topic	**CTA information**	**Metra information**	**Pace information**
Prioritize types of connections	1. Intra-CTA connections for all but short headways 2a. CTA Bus/Rail to Pace Bus – long headway or last trip 2b. Pace Bus to CTA Bus/Rail – long headway, owl, last trip 2c. CTA Rail – CTA Rail – short headways 3. Intra-CTA – other short headway connections 4a. CTA Bus to Metra Rail -- long headway or last trip 4b. Metra Rail to CTA Bus/Rail – long headway or last trip	1a. Metra to Pace bus 1b. Metra to CTA bus 2a. Metra to Pace ADA paratransit 2b. Metra to CTA ADA paratransit	1. Metra – Pace (all) 2. Pace division – Pace contractor/paratransit ** 3. Pace contractor/paratransit ** – Pace division 4. Pace contractor – Pace contractor 5. Pace – Pace (first /last bus) 6. Pace – Pace (long headways) 7. CTA Rail – Pace 8. CTA Bus – Pace 9. Pace – Metra 10. Pace – Pace ADA paratransit ** refers collectively to all Pace paratransit services
Need from WC, RTA, others?	Well organized and clearly stated carrier requirements.	Not sure yet.	Information about the system being designed: how it will operate, impacts on personnel, what information will be available, etc. Also want to know expectations of Metra protecting connections from Pace (i.e. holding trains in some cases).
Benefits expected	Regional, seamless trips across carriers with minimal and predictable wait times. On CTA, more attractive service for 2, 3 or more-vehicle trips due to reduced and predictable waiting times at transfer points. Improved security. May be able to maintain comparable overall service levels with slightly fewer runs/busses. Analysis of passenger requests for connections should allow modifications for improved service.	Improved connections	Availability of information on connecting modes to allow assessment of a potential connection. Ability to determine vehicle location and respond to passenger inquiries regarding status of service. Improved passenger safety.
Concerns/obstacles	Ability to get agreement on standards between 3 service boards. Absence of implemented AVL and control systems at this time. Absence of state of the art scheduling software. Patience needed to deal with trial and error in order to get first generation working products. Willingness to search out and accept off the shelf products rather than starting from scratch will be critical.	None at this time	How will the system improve the working conditions of the operators? How will the operation affect personnel requirements?
Stakeholders	RTA, Pace, CTA, Metra, regular customers, tourists, chambers of commerce, ITS America, ITS Midwest, GCM initiative, IDOT, CDOT, county organizations.	CTA, Pace, Metra, potential new customers	Passengers first. Then bus operators, division personnel, contract operators, travelers in region.

6.1 Chicago Transit Authority (CTA)

Contact: Ron Baker, General Manager Control Center and CI Task Force

Service management structure, capabilities, technologies and plans:

Facilities and communications*:* CTA has a modern Control Center for both bus and rail operations at its 120 N. Racine facility. Radio communications is available to rail operators and supervisors and on a very limited basis (emergency only) with bus operators. Telephone is used for other communications.

Bus: Garage dispatchers, street supervisors and bus controllers all play a role in service management and decisionmaking. Garage dispatchers roll out service, and decide how to deal with bus or driver shortages at roll out. Most other service decisions are made by street supervisors who are either stationary at a high volume point or are mobile and travel to problem areas. Street supervisors must work primarily with what they can see, what bus operators tell them, or through land line or cellular calls to one another or to bus controllers. Bus controllers, located at the Control Center, are a central point of communications for bus service management, as well as the focal point for all emergency or contingency communications using the two CTA radio channels dedicated to emergency use only. They will contact police or fire as needed when receiving a silent alarm or radio call, and will also notify supervisors who can respond to the problem. Controllers can also coordinate responses to service problems.

Today, there is no automated dispatch system in place to assist bus controllers and supervisors in managing service. However, CTA is well into an effort with Orbital Sciences Corporation to develop, furnish and install a state of the art Bus Emergency Communications System (BECS) and Bus Service Management System (BSMS). BSMS will include automatic vehicle location (AVL), centralized computer aided dispatching (CAD), traffic signal priority request, active bus stop signs, connection protection and other features. The general philosophical approach of the system is that workload on the bus operator is to be minimized, and decisions made without human intervention wherever possible. In addition, the existing bus controller and street supervisor positions will inevitably see some changes in their processes for managing service, due to the central availability of so much more information than is available on the street today.

Rail: Rail service is managed by a combination of terminal and tower-based supervisory personnel and Control Center-based power controllers. Radio communications is available from trains to the power controllers at the Control Center. Terminal based supervisors can communicate face to face or via public address system with train operators while they are in the station. Power controllers can cut power to sections of a line in case of an emergency. Switches are controlled locally at terminals, via automatic interlockings, or in emergency or contingency situations manually.

Power controllers also have available to them a Rail Service Management System (RSMS). This system tracks train location, status and schedule adherence. It identifies class of train, highlights deviations from schedule, and flags trains whose schedule deviation exceeds their recovery time at the end terminal before starting their next trip.

Connection protection capabilities and plans: CTA currently has few formal bus-bus, bus-rail or rail-bus connection protection activities. Some rail-bus connections are facilitated by station lights which indicate to bus operators that a train is present. One Metra-CTA connection is managed by CTA operators using Metra timetables. CTA rail-CTA rail connections may be coordinated by a terminal supervisor, if present, using the public address system to communicate with operators. Also, CTA rules require train operators on adjacent tracks in the same station to co-dwell long enough to assure connections are made.

Connection protection plans will proceed with the implementation of the BSMS. It includes capabilities for both intra-CTA and inter-carrier connections, all without human intervention (though controllers can selectively be notified and override). In a first stage, bus connection protection will be implemented, with direction and time of day prioritization, taking into account recovery time and downstream impacts. Next in succession will be: 1) bus-CTA rail; 2) CTA train-to-train; and 3) connections with Metra.

Connection protection with Pace will follow later on a mutually agreed-upon schedule taking into account the progress of Pace's service management automation.

CTA also sees the handling of customer requests progressing in stages. Initially, operators will respond to passenger requests only with schedule information on the connecting service. Next, operators will begin providing actual status information for connecting service. Finally, operators will be able to provide all of the above, along with a confirmation that the request has been received and that every attempt will be made to hold the connecting service.

Wants: The CTA is looking to the TCP project effort to be a catalyst for interagency efforts on transfer connection protection. Also, it looks to the project to bring about standardization of message sets used for TCP, carrier database compatibility, and interagency agreement on parameters to be used to designate a connection as eligible for connection protection.

Priorities: The CTA's priorities for types of connections to be covered can be organized into four groupings, with priorities from 1 (highest) to 4 (lowest). These are summarized in Table 2 below:

Priority	**Connection Type**
1	All intra-CTA connections for all but short headways
2	CTA (bus & rail) to/from Pace Bus – long headway or last trip
	CTA Rail to CTA Rail – short headways
3	Intra-CTA – other short headway connections
4	CTA to/from Metra – long headway or last trip

Table 2: CTA priorities for connection protection

Benefits: The CTA sees the primary benefits from TCP accruing to the traveling public. Multi-carrier trips will be more predictable and more "seamless". Long CTA trips with one or more connections will be more attractive as well due to reduced, predictable wait times, once CTA has implemented this function internally. Also, when regional TCP is fully implemented, it may be possible in a few situations on selected routes to make slight reductions in the number of scheduled runs necessary to maintain the target level of service.

Finally, CTA expects that the capture of passenger connection requests will provide valuable data for planning of schedule/route modifications for improved service.

Concerns: CTA has several concerns about this project, which are summarized below:

? It may be difficult to get all three service boards to agree on standards to support TCP
? The lack of installed service management systems at this time will complicate the design of TCP
? The lack of state of the art scheduling software may also be a problem
? Patience will be needed during the development and testing process; trial and error will be required in order to get to a first generation working product
? It will be critical to have a willingness to accept off-the-shelf products rather than starting from scratch.

6.2 Metra

Contact: Barry Resnick, Metra Project Manager, ITS

Service management structure, capabilities, technologies and plans: All Metra services are controlled by dispatchers using control consoles, voice radio systems, signal systems, and remote switch control. Metra controlled lines are dispatched at the Metra dispatch facility located at 15th & Canal in Chicago. Contract-for-service lines are dispatched by contract carriers at remote sites (e.g. UP – Omaha; BNSF – Ft. Worth). Radio contact between train crews and dispatchers is used to report any service problem and issue revised operating instructions. Currently, any service coordination between Metra services and those of CTA or Pace is performed by the dispatcher via telephone. There is proactive coordination during emergencies or service interruptions.

Customer information is currently provided via message boards at outlying stations, and monitors at downtown stations, all connected via wireline data links. Information is generated by staff at dispatch who key in information as received from the train crews.

Metra's first priority is safety; subject to this, every effort is made to accommodate passengers making connections to Metra services. There are no routine efforts to coordinate connection protection with other carriers.

Metra's future plans include an AVL-based Train Information Management System (TIMS). This system will capture location data from trains, along with text messages from on-board personnel. It will support a system operator at the Metra Control Center, dispatchers, Passenger Service Representatives, operating personnel, and the traveling public. It will drive station displays, on-board stop announcement displays, and other public information facilities. The specified system never explicitly mentions TCP as a supported capability. The basic status information it collects and ETA's it calculates are, however, two of the key building blocks for such a capability. Metra recently issued a procurement for a pilot implementation of this system.

Wants: Metra looks to the TCP system to help facilitate better link-ups between carriers, better coordination of schedules, and better handling of contingencies as they arise.

Priorities: Metra's priorities for connections to be protected under TCP are summarized in Table 3:

Priority	Connection Type
1	Metra to Pace
2	Metra to CTA bus
3	Metra to Pace ADA paratransit
4	Metra to CTA ADA paratransit

Table 3: Metra priorities for connection protection

Benefits: Improved service to travelers through better connections are the primary benefit area seen by Metra.

Concerns: Metra has no concerns about the project at this time.

6.3 Pace

Contact: Dick Brazda, Department Manager, Operations Planning

Service management structure, capabilities, technologies and plans: Pace bus operations are dispatched at the division level. Information and instructions are conveyed by voice radio contact between dispatchers and bus operators. A analog trunked voice radio system provides adequate capacity for these communications, as well as for direct bus operator to bus operator contacts. There is presently no computer-aided dispatch or other automated real time service monitoring. Overnight, dispatch is consolidated at South Division; bus operators sign off with their dispatcher and sign on with the South Division dispatcher using the appropriate radio channel. Pace contract operators use separate private radio systems and frequencies; there is no direct bus to bus communications possible in these cases.

Pace efforts at intra-Pace connection protection are focused at the bus operator level. Regularly assigned operators know where passengers wish to make connections; or, a passenger may request a connection from the operator. In either case, the operator initiates communications with the "to" bus in order to coordinate a meet at the transfer point. If the "to" bus has to take a delay in order to protect the connection, that operator must request and receive approval from their dispatcher. For connections between a Pace operated bus and a contractor operated bus, direct radio communication is not available, so visual connection protection only is used.

At outlying Pace transit hubs with coordinated schedules, known as "pulse points", it is regular practice for operators to wait up to two minute for late arriving buses – five minutes for the last trip. Longer delays must be authorized by the dispatcher.

Pace's inter-carrier connection protection efforts are based mostly on visual contact. Pace mainline routes which intersect a Metra line will wait to pick up passengers if visual contact is made with the train. Feeders have more flexibility to wait since this is their primary purpose; however if there is typically bi-directional traffic on the route, the flexibility is limited. In some cases, the Pace operator may request Information on train status either through the Pace dispatcher, or by talking with Metra personnel at the station, if any. Also, a few CTA train stations have train arriving indicators which are also useful; otherwise operators rely on visual contact.

Pace has outlined future plans in a recent RFP for specifications development services for its Intelligent Bus System (IBS). The system will include AVL with schedule adherence and exception reporting capabilities via radio data communications. A limited dispatcher interface to view exceptions and deal with emergencies is envisioned in the initial phase; computer aided dispatch is a future desire. IBS will also explicitly support intra-Pace and inter-carrier CP. Most likely this will continue to be bus operator-bus operator for Pace-Pace connections. The methodology for supporting inter-carrier CP is still to be determined.

Wants: Overall, Pace hopes to improve traveler satisfaction through TCP. The TCP system would facilitate this by giving Pace access to operational status information from other carriers. Pace would then want to make this information available to a specific bus or to all the buses under a dispatcher's control.

More specific Pace desires include:

- Location-specific real-time status information for specific runs/trains – e.g. when will train 327 arrive at Wilmette?
- Automated information delivery versus manual inquiry-driven information delivery
- A system which is user-friendly to dispatchers and bus operators

Priorities: Pace's priorities for connection types to be addressed by TCP are as follows:

Priority	Connection Type
1	Metra to Pace (all types)
2	Intra-Pace – linking contract operators with Pace divisions and each other
3	Intra-Pace – first/last bus and long headway routes
4	CTA Rail to Pace
5	CTA Bus to Pace
6	Pace (all types) to Metra
7	Intra-Pace – Pace operated routes to Pace ADA paratransit

Table 4: Pace priorities for connection protection

Benefits: Pace expects that TCP will provide both operational benefits and improvements for travelers. Pace dispatchers and bus operators will have information to allow them to make better assessments of the viability of a connection. Travelers will be able to get information on the status of connecting services if the system is set up to provide it to the bus operator. Also, passenger safety and security should be improved due to reduced waiting times at transfer points.

Concerns: Pace's only stated concerns about the TCP project concern people impacts. First, Pace is concerned that any such system should improve the working conditions for operators rather than making things more complex. Second, Pace is concerns about any implications the system may have for staffing levels.

6.4 Key points from the carrier perspective

A review of the information gathered from each of the service boards yield these key points:

- All three agencies support the TCP concept, and agree there is a need for interagency coordination for improved connection performance.
- All three share the viewpoint that the principal benefit from TCP will accrue directly to travelers through improved service: better connections (reduced waiting time), more consistent connections, and improved safety/security due to the reduced waiting times.
- Pace and Metra both indicate that Metra to Pace connections are their top priority. This suggests that effort might be concentrated there once the infrastructure is in place at both carriers. It also suggests some potential for mutually advantageous interim measures to improve information sharing prior to actual TCP availability.
- All three agencies indicate that there is little or no *routine* coordination of operations to protect inter-carrier connections, beyond that done at the connection point by operators or supervisors who are on the scene. However, the agencies have well-established lines of communications for coordination in case of emergencies, service interruptions, inclement weather.
- CTA's bus service management vision emphasizes a central approach to dispatch and connection protection, with no human intervention required in the connection protection decision (there is provision for dispatcher override). This is in contrast to Pace, which is not pursuing extensive automation of the dispatch function in the short term, relies entirely on the bus operator and dispatcher to make the decision, and has expressed a concern were there to be headcount increases associated with the TCP project.
- CTA voices a strong interest in standardization and mutual agreement by the three agencies on common message sets and database formats. The agency is concerned about how difficult it will be to conclude this process successfully, as well as about the absence today of most of the automated pieces which need to be in place for it to work, such as AVL/service management systems and state-of-the-art scheduling systems
- Pace voices a strong concern for ease-of-use and desire for the availability of location-specific status information on specific services.
- Metra sees potential new travelers as key stakeholders in this effort.

7 THE REGIONAL PERSPECTIVE: TCP IN THE CONTEXT OF THE GCM/GTIS ARCHITECTURE

7.1 The GCM/GTIS Architecture Vision for Transit

The GCM Corridor Program Plan lays out a 20-year plan for the coordinated implementation of ITS projects and technologies. Within this program plan, 132 projects are categorized into seven program areas. One of these, the Integrated Transit System, is defined as the program area to integrate the status and schedule systems of the transit operating agencies for use by the transit operators and the public within the GCM Corridor. Over the long term, this program envisions dynamic management of transit operations to facilitate connections between routes and modes. The information and capabilities it provides will also enhance the individual capabilities of transit management systems with the GCM Corridor, such as those of the RTA service boards.

The Integrated Transit System program area is to be progressed in a series of phases. The first phase calls for development of an automated public information service covering transit schedules. It is designed to obtain information from computerized scheduling packages used by individual transit agencies, and to support the integration of schedules and routes from all transit services in the GCM Corridor. It will utilize or be closely integrated with the RTA's Itinerary Planning System (IPS), currently being used to provide trip plans to travelers in the RTA service area. Concurrently during the first phase, advanced vehicle management systems are being developed or planned by each of the major bus transit agencies in the GCM Corridor. These systems will include automatic vehicle location and schedule adherence monitoring capabilities, along with the necessary communications infrastructure. systems.

The second phase of this program leverages integrated schedule information and carrier vehicle management systems to support a new integrated transit information system based on actual location or schedule status. This integrated and distributed system is envisioned as providing transit users and operators with complete information about the schedules, routes, and status of all transit systems in the corridor. The information developed and processed by this system will be available to transit operators through their vehicle management systems. It should be capable of supporting the requirements of TCP.

A subsequent phase of this program will support the development and expansion of transit management systems in each metropolitan region within the GCM Corridor. Transit management systems are needed in regions where significant transit demand requires advanced techniques to efficiently supply service.

The last two phases of this program area include the development of parking management systems to promote transit and ridesharing and the development of neighborhood on-demand automated transit.

Also related to the overall transit vision for GCM is the Multi-Modal Traveler Information System (MMTIS), envisioned as the major source of traveler information for all modes across the entire region. As the central element of the MMTIS, the Gateway Traveler Information System (GTIS) collects dynamic and static transportation data from distributed transportation management systems throughout the Corridor via various regional hubs. Besides collecting, organizing, and redistributing transportation related data on the national highway system and strategic regional arterials for transportation applications within the Corridor, the GTIS is also expected to provide real time information about transit operations, which could support TCP unless and until a dedicated regional transit hub is established.

7.2 How TCP Fits Into the GCM/GTIS Architecture

Today, TCP is primarily reflected in the program plan and architecture via individual projects. In addition to RTA's TCP project, a new connection project was recently added to the Integrated Transit System program area. The *GPTC/Hammond Connection Protection* project will deploy a connection protection program for public bus services operated by Hammond Transit and Gary Public

Transportation Corporation. This project will be extended to interface with other transit agencies, such as CTA, Pace, and South Shore Transit, who provide or connect with service to Northwestern Indiana.

In addition, TCP is implicitly included in the program plan and architecture to the extent that it helps support the intended goals of traveler information systems and transportation management systems in the GCM Corridor. These goals include improved public travel safety through reduced waiting times, and increased transit system productivity.

While the current GTIS design includes a link to CTA's Bus Service Management System (BSMS), referred to in the design as the CTA's Transit Management System (TMS), this link is principally concerned with collecting information on incidents or major transit disruptions. Currently, these data are relayed by bus operators to CTA dispatchers via 2 way radio. However, under BSMS, bus operators will report incidents via a preformatted message from the on board driver interface. The incident report will be time, date and location stamped based on the on board AVL capabilities of BSMS. Such incident reports will be stored in an Oracle database at the CTA Control Center, and extracted for the Gateway by a PC serving as a DSI (Data Source Interface). Location information will be retained to assist the DSI in converting the event to a suitable LRMS (Location Reference Message System) geo-referenced profile for use at the Gateway.

While this same link, or analogous ones with the other carriers, could be used to support collection of TCP information, TCP is currently not explicitly included as a functional requirement in the GTIS system architecture design. As the TCP design progresses during subsequent tasks, serious consideration will be given to whether TCP should be explicitly incorporated as a functional requirement in the future design of the next generation of GTIS.

8 SERVICE MANAGEMENT AND TCP

What are the basic tools and information used by transportation operators to manage service? What, specifically, is involved in managing connections? What are the downstream impacts of protecting a connection? How, then, based on all the above, does one decide whether or not to protect a connection?

In the following sections, each of these questions is examined, and some basic answers presented. Taken together, they represent the context of a connection protection system within an overall transportation service management framework.

8.1 What is Service Management?

Service management is the process by which transportation operators execute their current operating and service plans. It encompasses or is linked to every process involved, from the check-in of operators or other en-route service personnel and the mechanical release of vehicles into service, to ongoing monitoring of performance against the plan, to the check-in of the personnel and equipment at the end of their day's work.

Service management is often used as synonymous with operations management. At the ultimate level of service management, however, a key distinction emerges. True service management, it may be argued, involves managing for optimal service ***from the viewpoint of the traveler***. Thus, an operating and service plan might be executed at a very high level of quality, and yet from a global viewpoint, there might have been a net improvement in service from the traveler viewpoint if one or more of the carriers had deviated from their plan in selected situations, as response to problems elsewhere. Connection protection, as detailed below, is one of these circumstances. It thus represents a logical extension to or enhancement of a carrier's service management efforts.

How do carriers manage service? In reality, all scheduled services are managed in a similar fashion. The core concept involves an operating/service plan made up of many individual scheduled services over the routes served by the carriers. Carriers know when individual vehicles are supposed to be at predetermined points along their routes. These points can either be passenger stops, or other points used strictly for tracking purposes (in bus service these are known as "timepoints"). The carrier uses whatever means are available – communication with the en-route service personnel, monitoring by street supervisors, station or tower-based personnel, an automatic vehicle location (AVL) system with mobile data communications, or a combination of the above – to determine where the vehicle stands relative to schedule. Then when a late vehicle is noticed (or one of a dozen or so other *service impacting events* occurs) management personnel may select and implement a corrective action (*service restoration action*). This cycle is repeated countless times during the day as service impacting events occur.

It should be noted that vehicle operators play a major role in service management themselves. Besides seeing and reporting events which may impact service, they can take action within the limits of their authority to make up time when late, or hold at a stop if they are early.

There are several variations of the standard scenario above which should be noted. First, for vehicles operating at close headways (e.g. 3 minutes) on a route, carriers may switch to maintaining even headways (spacing) rather than keeping every vehicle on schedule. Second, while many services operate on a grid basis, some operate on a "hub and spoke" basis similar to that employed by airlines, with many routes converging on a single point known as a **pulse point**. Third, commuter rail operators such as Metra and its contract operators control the tracks they operate over, as well as other traffic which may be competing for use of the tracks. Thus, they must also manage their trackage as an integral part of service management – assuring safe separation, providing windows for maintenance crews, and delaying some trains to make way for others. The latter is important to our discussion because if a commuter rail operator had to delay one of two trains due to an unscheduled problem, it could take the impact on connections into account in making that decision if that information were available on a real time basis.

8.2 Transit connections and connection protection: definition of terms

A connection is a situation where two transit routes intersect in some fashion at a given point, and one or more passengers wish to switch from one of the routes to the other in order to continue their journey. In the above scenario, the vehicle from which passengers are alighting is the **"from" vehicle**, and the vehicle they're transferring to is the **"to" vehicle**. From a planning standpoint, if passengers only make the connection in one direction at a given point, it is referred to as a **one-way connection**, whereas if passengers make the connection in both directions, it is **two-way** or **bi-directional connection**. Thus, in a bi-directional connection, each vehicle is both a "from" vehicle and a "to" vehicle.

Transfer time is the amount of time necessary for connecting passengers to alight, move between vehicles, and reboard. Note that this time varies not only with the number of passengers, but by location and also potentially by direction. It can be affected by weather, darkness or traffic volume. Note also that for persons with disabilities or limited mobility, transfer times may be much higher.

A **near-miss** is a situation where connecting passengers arrive at the connection point only to see that their vehicle has just departed. From a quality of service standpoint, this situation should be avoided wherever possible. Often this can be accomplished with only a short hold by the "to" vehicle. For each connection point, it is desirable to define the length of time after departure that a vehicle is visible from that point. This value, sometimes referred to as "courtesy hold time", will be referred to here as **near-miss avoidance time**. It is used in system calculations about whether or not to hold a vehicle for a connection. This value may also vary by location, direction, time of day, weather, or darkness.

The process of managing transit connections in an attempt to ensure they occur in a timely fashion is known as **connection protection**. This is most easily facilitated by ITS technology on board vehicles and at control centers, but can be successfully accomplished by visual coordination or via two-way voice radio systems as well. Schedule coordination is also critical to the effort. Pace currently uses two-way radio communications between operators for its internal (Pace to Pace) connection protection efforts.

The principal means of protecting a connection is holding the "to" vehicle until the "from" vehicle arrives at the connection point and passengers can make the transfer. The instructions for such a hold would indicate that the "to" vehicle a was to hold for a connection, and would indicate a **maximum hold time** beyond which the operator was not to hold without approval form the dispatcher.

Finally, despite all the above terminology, it's useful to remember that from the customer's standpoint, a successful connection involves the connecting vehicle being at the transfer point, either when they arrive or within a short **waiting time**. Scheduled waiting time is a function, among other things, of the headway on the "to" route. The carrier's goal in connection protection is not only to assure that the connection occurs, but to do so while keeping waiting time to a minimum.

8.3 How does connection protection fit into the service management decision framework?

Connection protection is most appropriate to consider in situations where the "to" route has long headways, and there are not synchronized schedules with overlapping standing times at the transfer point. It is also very appropriate as an aid to service coordination at pulse points. It may also be considered for shorter headway routes as a service enhancement strictly to alleviate near-misses.

Incorporating connection protection into transit service management introduces an additional layer of complexity into the process. Instead of simply trying to keep a vehicle on its schedule, the process must now take into account connections along the vehicle's route, looking specifically at the current status of potential "from" vehicles. If a "from" vehicle is late, while the "to" vehicle is on time, the connection can be considered *endangered*.

Once the system (or a manager) has made such a determination, a decision is required as to the action required. Can the "from" vehicle be expedited by running express or through signal priority request? Should the "to" vehicle be held until the "from" vehicle arrives and its passengers can complete their transfers? If so, what is the maximum hold time? Factors directly relevant to the decision include:

- How late the "from" vehicle is
- How many passengers will be making the connection
- The near-miss avoidance time at the connection point
- Downstream impacts of holding the "to" vehicle, including passenger delays and the possibility of exceeding the "to" bus's turnaround time, which could impact vehicle availability and operator overtime.

Downstream impacts of holding the "to" vehicle are discussed in the next section.

Finally, the above discussion has implicitly assumed that a single operating entity had full control over both the "from" and "to" vehicles. When this is not the case, such as for inter-carrier trips, an external source of information is needed to support the decision process. That is the role which the TCP project is designed to fill.

8.4 Downstream impacts of holding for connection

Downstream impacts of holding a vehicle for connection fall into two categories. First, the vehicle may end up running late for the remainder of the current trip. This will make all the current travelers late. Further, being late may cause some travelers to miss connections later in the trip. The impact of this will be increased wait times, or at worst the need to make alternative arrangements for travel to their final destination(s).

Second, the vehicle may use up its *recovery time* at the end of the trip, and be late departing for its next trip. (Recovery time is an interval built into the end of each trip but the last, which serves as a buffer if the vehicle is behind schedule, and as a "breather" for the en-route service personnel.) If the vehicle is indeed late in departing for its next trip, again all those passengers are delayed, and some may miss connections. In addition, the carrier may incur overtime if the en-route service personnel are ultimately late in finishing their day's work. Also, late-arriving vehicles may impact the overnight maintenance cycle, possibly even affecting the following day's equipment availability.

8.5 Optimizing the application of connection protection

The preceding discussion has made it clear that holding a vehicle to protect a connection may cause downstream impacts which can propagate through the carrier's network, and those of its connecting carriers. Thus, when making a decision about protecting a connection, all predictable downstream impacts should be considered.

In the ideal world, with perfect information and appropriate decision support systems, the option would be selected which minimized the total door-to-door travel time (including all connections) of all impacted travelers in the network. However, the data and computational requirements of such an approach mean that with existing technology, initial implementations of regional TCP will have to be less ambitious, using a more limited set of variables, and sometimes relying on averages or historical information. For example, a first generation system might explicitly consider the tradeoff between cumulative time savings for the connecting passengers on the "from" bus, and cumulative delay for passengers currently on the "to" bus, as well as impacts on the held bus's turnaround time and operator overtime. It would make assumptions about the number of passengers affected and the extent of their delays based on default values derived from historical data and field observations. Its decisions about what to hold and how long could be implemented automatically or made subject to dispatcher review and override, depending on the carrier's philosophy and preference.

An additional consideration is the regionwide implementation of other ITS components or capabilities which may affect bus service, such as traffic signal priority. If signal priority were standardized and integrated across the region, and vehicles were appropriately equipped, then the design of that system would need to be explicitly taken into account in the development of requirements for the TCP system.

In subsequent tasks, this project will explore these decision criteria in more detail, and formulate the specific ones to be employed in a deployed regional TCP system.

9 SEVERAL POSSIBLE VIEWS OF A REGIONAL TCP SYSTEM

9.1 Description of possible TCP system approaches

The discussion above, as well as the expressed needs and priorities of the RTA service boards, suggest several characteristics of any successful regional TCP system:

- It would support the decisionmaking of carrier operations managers
- It would make available location-specific, real time status information on specific services – i.e. by train number or route/run number
- It would employ standard message sets for transfer of information, and standard database structures for storing it
- It would interface with carrier CAD/AVL systems (although some information might be available via manual inquiry to carriers still working toward automation)
- It would accept as input customer requests for connection, either pre-trip or once on board the "from" vehicle.
- It would support tracking connection performance on a regional or more detailed basis.

With the preceding as a backdrop, what would differentiate alternative approaches to a regional TCP system? Four differentiating factors identified so far are:

- Does the TCP system incorporate central schedule and operations status databases, so that regional performance measurement can be done?
- Does the TCP system provide status information automatically to carriers (as opposed to requiring an inquiry)?
- Does the TCP system monitor connection status and identify endangered inter-carrier connections?
- Does the TCP system actually perform local or global optimization in determining which exception conditions to report to carriers?

As a starting point for discussion, five possible views of a regional TCP system have been identified as a starting point for discussion. They are differentiated according to the four criteria above. They are:

1) Bilateral message-based TCP: This approach to regional TCP would require each carrier equipped with AVL/CAD systems to support a set of standard inquiries. Carriers would electronically receive, process and reply to inquiries about service status from other carriers. (Or, alternatively, carriers could ship predetermined status information to each other – either predetermined times and services, or on an exception basis driven by predefined criteria.) Carriers would forward interline requests for connections from customers to the "to" carrier. Monitoring of performance could only be done on carrier systems. Functionality of the TCP system itself would be limited to switching messages between carriers, and possibly providing some context or content editing of inquiries. This is the most decentralized approach.

2) Inquiry-based TCP: Under this approach, carriers equipped with AVL/CAD systems would constantly update a central database of operational status information, which could be hosted at a regional transit hub. Individual carriers could make inquiries to the central database in order to get specific status information they require on other carriers' connecting services. TCP would edit inquiries against the schedule database and other reference files, then respond with the requested information. It would also be able to monitor regional performance. This approach still leaves all responsibility for determining required information and requesting it to the individual carriers. Carriers would still forward interline requests for connections from customers to the "to" carrier.

3) Repetitive notification TCP: This approach is similar to inquiry-based TCP, except that in essence the inquiries are canned (predefined) and automatically executed on a repetitive basis as requested by the carrier. Another way to look at this is that the carrier sets up a "profile" of desired information, then receives it automatically based on a predetermined schedule.

4) Proactive, exception-based TCP: This is a much more centralized and ambitious approach. The TCP system would continuously monitor real-time status information from all participating carriers against schedules, and attempt to identify predetermined connections that are endangered. Customer requests for connections would be received by or forwarded to the system, and also monitored for endangered status. Upon identifying an endangered connection, the system would send a notification message to the carriers involved, including the latest status on the involved vehicles. If desired, it could continue to transmit information at regular intervals to update status until the connection was made or missed. (Or, carriers could then revert to inquires for as-needed updates.) Performance monitoring would also be supported on this system. This would be a processing-intensive solution, but would conserve bandwidth by only transmitting information when needed and not requiring an inquiry to do so.

5) Proactive, optimizing TCP: This is the most complex and ambitious of the approaches presented here. Under this approach, all functions included in proactive, exception-based TCP are included. In addition, the system would examine groups of potential connections at a local and or regional level to try to pick a set of protection actions which will minimize the sum of overall transfer times, if possible weighted by the average or actual number of passengers involved. Exception reports would then be issued to carriers only for those situations where connection protection is part of an optimal solution.

The key differentiating factors of these alternative views are shown in Table 5 below.

Alternative View of TCP system	Central schedule and operations status databases required	Predetermined status info automatically provided	Proactive notification of endangered inter-carrier connections	Optimization of connections selected for protection
1) Bilateral message-based TCP	No	No	No	No
2) Inquiry-based TCP	Yes	No	No	No
3) Repetitive notification TCP	Yes	Yes	No	No
4) Proactive, exception-based TCP	Yes	Optional	Yes	No
5) Proactive, optimizing TCP	Yes	Optional	Yes	Yes

Table 5: Differentiating factors for alternative views of the TCP system

9.2 Direction for TCP design efforts

Initial comments from the RTA and the service boards indicate that all are in agreement that the desired solution falls into the category of alternatives 4 and 5 above – those with the most advanced capabilities. RTA and the service boards also gave clear direction that the chosen approach must support the handling, acceptance and processing of customer requests for connection. In the tasks which lie ahead, these system views will be refined into one or more distinct system concepts. They will then be evaluated in light of relative advantages and disadvantages in order to arrive at a recommended system concept.

10 MEASURES OF EFFECTIVENESS FOR A REGIONAL TCP SYSTEM

Project measures of effectiveness are used to determine whether a project has met the expectations of its sponsors in terms of cost, service, revenue/ridership, and other factors. Well defined, consensus measures of effectiveness are correlated with clear, workable goals, objectives and benefits. Measures of effectiveness, like objectives, must be objectively measurable.

The project team reviewed project objectives (section 3) and benefits (section 6), and developed a preliminary set of project measures of effectiveness. These are summarized, along with corresponding objective(s) or benefit(s) and data collection approach, in Table 6 below.

Project Objective/Benefit	Measure of Effectiveness	Data Collection Approach
Minimizing travel times for transit riders making connections	1. Reduction in average actual traveler waiting time at TCP-covered connection points. 2. Improvement in consistency of traveler waiting time at TCP-covered connection points.	1. Field data collection through observation – before and after 2. Use of system-collected data to look at changes in available time for connection.
Reducing the number of "missed" connections	1. Percentage of requested connections made 2. Percentage of scheduled connections made 3. Improvement in satisfaction for riders using selected connections covered by TCP	1. Before data only available via field observation. After data only by surrogate measurements. Customer reporting would be required for positive knowledge. 2. Before measurement exceedingly difficult or impossible. After figures are inferred from system data. Precise measurement very difficult. 3. Before and after measurement using field traveler surveys at connection points. Could possibly be done with a single survey after implementation.
Increasing transit ridership	Increases in ridership over selected connections covered by TCP	Merged CTA and Pace data streams from use of AFC cards could be used for before and after measurements for intra-and inter-carrier connections for these two carriers. Otherwise/in addition, carrier ridership over involved routes would be measured.
Improving accessibility to areas and activities attracting connecting passengers	Same as above, for routes serving selected trip generators.	Same as above, for routes serving selected trip generators.
Improving operating efficiency through coordination	Bus miles/bus hours to serve covered routes	Before and after data from carrier measurement systems.
Allowing for simplification of route structures and/or schedules	Actual carrier rescheduling or route changes.	Survey carriers after 6 months of system operation to determine changes facilitated by TCP system.

Table 6: Proposed Project Measures of Effectiveness

Measures of effectiveness will be revisited after draft specifications development as part of an overall review. They should also be revisited and updated if necessary when and if the project progresses to Phase II.

11 PRELIMINARY CONCLUSIONS

Based on interaction with the carriers, there seems to be a clear interest in progressing this project. All carriers agree that there is need for a regional initiative around connection protection, and that there are significant benefits to be had from the sharing of real-time status information in order to better coordinate inter-carrier connections.

Initially, no clear consensus emerged out of one-on-one discussions concerning the particular approach which should be taken to provide TCP capabilities. However, in the project team's review of the five options presented above, there was a clear consensus that the TCP system should have at minimum the capabilities and architecture associated with Alternative 4, Proactive, Exception-based TCP. The team wanted to see more specifics about how Alternative 5, Proactive, Optimizing TCP, would work before passing judgement on it. This will be available at the design concept document stage of Task 6, *Draft Functional Requirements*.

CTA strongly advocates standard message sets and database formats. Since they have taken the lead in AVL service management systems development in the region, and are designing for inter-carrier connection protection, it will be useful to learn more about their efforts during Task 4.

The current GCM/GTIS architecture and plans include some specific connection protection projects, and do envision advanced management capabilities which could easily encompass regional connection protection. Nonetheless, there is a lack of detailed definition at this time, presenting an opportunity through this project to positively influence the design of future generations of GCM/MMTIS/GTIS capabilities so that the needs of carriers and travelers are well supported.

11.1 MEMORANDUM

To: Angela Johnson, P.E., RTA Project Manager
From: Lawrence B. Wilson, Wilson Consulting
Subject: Transfer Connection Protection: Task 2 findings
Synopsis of Existing Carrier Connection Policies
Date: FINAL – May 25, 1999

This memo summarizes findings from our review of existing connection policies at each of the three RTA service boards: CTA, Metra and Pace. After describing the task approach immediately below, it explores key findings and common threads for the carriers' respective connection policies, practices and procedures.

12 Task approach

In our task 1 carrier questionnaire, we asked each carrier questions about their current connection polices, practices and procedures. For this task, we used those responses along with our team's knowledge of the carriers' operations to develop draft connection policy statements for each carrier. We forwarded these to the carriers, received their comments verbally or in writing, and incorporated them into revised connection policy statements. These statements are attached to this memo for ready reference.

This revised version of the findings memo also incorporates some changes suggested in UIC's comments. Specifically, more detail has been added about connections involving paratransit. This entailed additional discussions and reviews with paratransit staff at both CTA and Pace. Each carrier has approved the updated version of its summary policy statement. However, the summary of findings has *not* been reviewed by the individual carriers.

13 Standard practices, little formalization of policies

All three carriers had some standard practices concerning management of connections. However, the only formal mainline service policy brought to our attention was the CTA's requiring that connections be made between trains in a station on adjacent tracks. CTA operating rules for bus operators also make explicit statements about the handling of connections based on visual contact.

Connection practices for both CTA and Pace contract paratransit operators provide for a somewhat higher degree of protection. When waiting for a connecting passenger, the contract operator's driver waits at least five minutes for arrival of the connecting service, then may coordinate with the dispatcher where practicable for additional wait time in order to protect the connection.

None of the three carriers guarantee any connections between mainline services, either intra-carrier or inter-carrier. In addition, at least some of them make explicit disclaimers in their literature. Metra makes an explicit statement in many of its timetables that connections are not guaranteed. Pace includes a statement on its timetables disclaiming responsibility for the impacts of delays or missed connections.

14 Management of the connection process

Visual coordination is used by all carriers to protect mainline connections at selected points. That is, if the operator of a departing vehicle sees an arriving vehicle or passengers from it desiring a connection, that operator may extend dwell time at the connection point in order to accommodate connecting passengers. In an extension of this concept, connections from CTA rail to bus are facilitated at some points by street level "holding lights" which indicate a train is in the station.

The use of operator-operator or operator-supervisor voice communications to manage mainline service connections is done only an intra-carrier basis, and for the most part only by Pace. (Pace has adequate communications facilities to support operator to operator communications, while CTA and Metra do not.) CTA does manage some rail to rail connections at points where supervisors are present using the station public address system (PA).

Pace is the only carrier to explicitly involve the passenger in management of mainline connections. Passengers on Pace routes may request a connection with other Pace services from a Pace bus operator. The operator then uses voice radio to ascertain the status of the desired service (the "to" bus), either directly with the operator or through the dispatcher. If the connection is endangered, and the "to" bus needs to hold at the connection point, the dispatcher must approve.

Connections involving paratransit services are managed differently. Because paratransit services involve reservations and scheduled pickup and dropoff times, the customer must inform the contract carrier of his or her desire to make a connection and of the most convenience connection point. Contract carriers then manage by 1) setting pickup or dropoff times to dovetail with scheduled service times or with connecting paratransit service; and 2) directing drivers to wait at pickup points in order to protect connections.

15 Intra-carrier connection policies and practices

CTA policies and rules require mainline bus operators, as well as rail operators on adjacent tracks, to dwell at stops long enough to allow passengers to make connections.

CTA Special Services riders connect with CTA mainline services only in cases where mainline service disruptions cause a Special Services client to have to complete their journey with a Special Services contractor. This is really not a connection, but rather a substitution of service. There are no Special Services – Special Services transfers.

Pace mainline operators are given the latitude to extend their dwell times when visual contact is made with a connecting vehicle in order to allow passengers to make connections. In addition, frequently voice radio is used to protect regular connections or passenger-requested connections.
Also, at outlying Pace hubs, operators routinely hold two minutes for late arriving buses, and may wait up to five minutes with supervisory approval.

Pace ADA paratransit services trips sometimes require connections if they cross service area boundaries. There are no formal policies or practices governing these connections.

Most Metra to Metra connections are made at downtown terminals, where the management goal is to make departures on schedule. At a few outlying points where connections are made between different lines (e.g. Clybourn (UP North and Northwest lines), Western Avenue (Milwaukee District lines) and River Grove (Milwaukee District West Line and North Central Service)), dwell times may be extended to protect connections if visual contact is made with a connecting train.

Inter-carrier connection policies and practices

Metra-Pace, Metra-CTA and Pace-CTA mainline connections at selected points are protected based on visual contact between vehicles. CTA bus operators on the #33 route, which takes Metra passengers from outlying stations to North Michigan Avenue destinations, use train schedules as a guide and will often wait for a late arriving train. Pace drivers of shuttle or feeder services that serve Metra stops often do the same thing; in addition, they may speak to local Metra station personnel if available, or radio their dispatcher to request that he or she contact Metra for status information.

CTA and Pace paratransit operations afford a higher degree of connection protection than do fixed route services. This is primarily due to the intrinsically higher level of service generally associated with paratransit: door-to-door service with scheduled pickup and dropoff times conforming to the passenger's requirements. Under the current system, paratransit customers desiring a connection must notify the carrier of the desired connection and transfer point. Also, if the connection is between the paratransit services of CTA and Pace, the passenger must make two reservations; the second carrier's pickup time is then calculated from the first carrier's projected dropoff time. This coordination at reservation time sets the stage for a smooth connection.

CTA and Pace operational practices with respect to inter-carrier paratransit connections are very similar. For pickups of connecting passengers, operators wait at a connection point for about five minutes after scheduled pickup time – the same as for any other passenger. Then, if the passenger has not appeared, operators contact their dispatcher, who may try to get more information on the status of the connecting service. If the vehicle is found to be arriving in a short time, then the vehicle may be held when practicable in order to protect the connection.

16 Overall CTA policy on connections

CTA's effective overall policy on connections can be summarized this way:

1. Operators and supervisors attempt to hold vehicles for connections when they are both at the transfer point or can be seen approaching it. Details on specific situations are outlined below.

2. CTA generally does not protect connections between its mainline or paratransit services and those of other carriers. There are two exceptions – see "CTA connections with other carriers" below.

3. CTA does not guarantee any connections.

17 Management of the connection process

In the case of mainline bus and rail connections, formal CTA policies and rules apply to all operators and are implemented by them.

At rail system points where supervisors are present, they may also implement connection protection which goes beyond stated policies and rules, based on information available to them. For example, a rail supervisor may hold a departing train for passengers from an arriving one even though that train is not yet visible, if he or she knows it will actually be arriving shortly.

Communications of supervisory decisions on connection protection is done over the public address systems at specific rail stations. Existing radio communications with mainline bus operators is extremely limited and typically is not available for this purpose.

18 Intra-CTA connections

Rail to rail: CTA policy is that rapid transit trains on adjacent tracks at a stop will wait a sufficient period of time to allow persons desiring a connection to make one. In addition, at certain points where a supervisor is present, he or she may use the station PA system to instruct a train to wait for a connecting train.

Rail to mainline bus, mainline bus to mainline bus: With respect to bus connections, the CTA rule book states: "Operators must wait a reasonable length of time for passengers to transfer from approaching trains or buses from another route, allowing more time in owl periods and on routes where there is a long headway."

There are also "holding lights" in use at Orange Line and certain Blue Line stations, both for passenger convenience and operational coordination. These lights illuminate when a train is entering the station. Buses serving the station are to hold for passengers when this light comes on while they are in the station.

CTA Special Services uses contract operators to provide the CTA ADA paratransit service. All of these operators serve the entire CTA service area. As a result, Special Service customers do not have to transfer to get to any destination in the CTA Special Services service area.

Connections between CTA Special Services and CTA mainline services seldom occur. Passengers who are able to get a reservation for a Special Services trip will normally take their entire trip that way; ADA customers using mainline services generally use them for their entire trip. However, if there is a major service disruption on the mainline service and a Special Services customer using that service is stranded, Special Services will sometimes arrange for a special pickup to complete the passenger's trip. Under these circumstances, the Special Services contractor's driver would wait for the passenger at the transfer point.

19 CTA connections with other carriers

CTA has no overall arrangements in place to protect connections between its mainline services and those of other agencies. However, at points where CTA buses and Pace buses connect, drivers may apply the same criteria for connection protection as they do for CTA bus to CTA bus connections. In addition, there is one route where CTA drivers coordinate their departures with Metra train arrivals. This is the #33 Mag Mile Express, a weekday morning-only route which serves the Western Avenue station on the Metra Milwaukee District North and West Lines, and the Clybourn station on the UP North and Northwest Lines. CTA drivers have copies of the Metra schedule and are aware of scheduled train arrival times. In some cases they will hold for delayed Metra trains as long as this will not seriously impact later trips.

CTA Special Services connections with the mainline services of other carriers are not centrally coordinated. The Special Services contractor's driver will wait for these passengers at pickup points for five minutes after the scheduled pickup time, just as they would for any other passenger.

CTA's handling of connections between CTA Special Services and Pace ADA paratransit is as follows: When desiring a transfer from CTA to Pace services, the customer must call both carriers for a reservation, advising each that a transfer from one to the other is desired, and specifying the transfer point from a published list. The customer gives CTA's estimated dropoff time to Pace as a guide to the appropriate pickup time.

The Special Services contractor's driver normally drops off the passenger at the transfer point rather than waiting with the passenger for the arrival of the other vehicle. The demand for trips is such that the driver needs to drop off the passenger and move on to serve another trip as expeditiously as possible. When slated to receive a connecting passenger from Pace ADA Paratransit, the Special Services contractor's driver will wait for the normal five minutes after the scheduled pickup time. Then, if the passenger has not arrived at the transfer point, the driver contacts the contractor's dispatcher for additional information and instructions. If the dispatcher is able to ascertain that the connecting vehicle will be arriving in a short period of time, he or she may authorize additional wait time in order to protect the connection.

20 Overall Metra policy on connections

Metra's effective overall policy on connections can be summarized this way:

1. Metra relies on its connecting carriers to wait for its trains as connections are made from Metra to the other carrier.
2. Metra en-route service personnel always place safety as a first priority. Subject to that overriding consideration, they are authorized to increase station dwell times within reason in order to wait for passengers trying to make a connection, particularly those who may need additional time to traverse the distance involved.
3. Metra makes every effort to accommodate connecting passengers, but as is the case with all three service boards, does not publish any connection guarantees.

21 Management of the connection process

The operation of Metra trains on a particular line is overseen by Metra or contract carrier dispatchers. They assign track occupancy and balance competing demands for use of the line. Actual movement is regulated by train signals visible to the locomotive engineer.

Any significant deviation from schedule is a cause for communications between the locomotive engineer and the dispatcher. Once apprised of the situation by the locomotive engineer, the dispatcher will take corrective action if necessary, and will also initiate the process for informing passengers and the riding public of any delays.

When a train is dwelling at a station, the locomotive engineer will not start up again without a signal from the conductor. The conductor thus has the discretion to extend the station dwell time within reason in order to accommodate connecting passengers.

22 Intra-Metra connections

Most connections between Metra trains take place at or between downtown Chicago stations; these are not generally coordinated. At outlying points where connections between different Metra lines are made, en-route service personnel may use visual coordination to protect connections. For example, some passengers connect between the UP North and Northwest lines at Clybourn. If personnel on an outbound train preparing to depart Clybourn see an inbound train arriving on the other line, particularly at rush hour, they may choose to extend their dwell time in order to allow passengers to make the connection.

Other points where such coordination may occur are at Western Avenue (Milwaukee District North and West lines), and River Grove (Milwaukee District West line and North Central Service).

23 Metra connections with other carriers

Metra generally relies on connecting service operators to protect connections from Metra trains to connecting services. With respect to connections being made to Metra services, safety is the top priority; subject to this, Metra will make every attempt to accommodate connecting passengers.

24 Overall Pace policy on connections

Pace's effective overall policy on connections can be summarized this way:

1. Mainline bus operators may attempt to hold vehicles for intra- or inter-carrier connections on the basis of visual contact at or near the transfer point. They may also choose to initiate radio communications with other operators to coordinate connections. Outside of "established" regular connections, connections may be made upon request of the passenger.

2. Connections between Pace ADA paratransit vehicles are protected to a limited extent. Drivers may wait 5 minutes for the connecting service, then call the dispatcher, who may authorize a further wait based on information from the connecting carrier.

3. Pace does not guarantee any connections.

25 Management of the connection process

Mainline connection protection normally only occurs when efforts are initiated by the driver, either based on a one-time or standing (recurring) customer request.

Dispatcher assistance may be required should there be no contact made with bus-bus communications, as in some radio coverage problem areas. In this case, the communications link would operate as bus-dispatch-bus.

Dispatcher approval via voice radio is required in order for a mainline operator to deviate substantially from schedule in order to protect a connection.

26 Intra-Pace connections

Pace bus to Pace bus: On mainline or "grid" routes, reasonable connections are made. At satellite ("Pulse" or "hub and spoke") operations, regular practice is to wait up to two minutes for the arrival of a late bus – this may be extended to five minutes for the last trip or if the dispatcher authorizes it.

Connections between Pace mainline service and contractor-operated routes (without Pace radios) are made only on a visual basis.

Pace contracts with private operators to provide ADA paratransit service. A single operator is contracted to provide the ADA paratransit service in a given county, or large part of a county. Passengers can travel between different Pace ADA paratransit service areas, if they are adjacent. Transfers are usually required for passengers wanting to cross service area boundaries. In order to arrange travel between adjacent areas, a passenger must call the different providers/dispatchers from each area and schedule a trip.

As there are few such trips, there are no special arrangements in place to protect connections between Pace mainline service and Pace local dial-a ride or ADA paratransit services.

27 Pace connections with other carriers

Pace makes every effort to protect connections from Metra trains. This is usually done visually, or by the bus operator querying Metra operations staff if any are present at the station. In some cases the bus operator may contact the dispatcher, who in turn contacts Metra to determine the status of a particular run.

There is no predetermined hold time for buses waiting for Metra connections. The shortest holds are when the bus also serves downstream passengers or there are other significant downstream impacts. This is typical of non-feeder routes that happen to serve Metra stops. For feeder runs where the downstream impact is minimal (e.g. no reverse commuters to pick up and bring back) then buses can be held longer. Special efforts are made to protect the last trips of feeder buses. These are held as long as reasonably possible. Under special circumstances (e.g. major train delays), extended hold times may be possible.

Similar efforts are made at a handful of CTA rail points where there are visual indicators of approaching or in-station trains. Connections with other CTA rail points, as well as with CTA mainline bus service are handled visually on an ad hoc basis, much as connections with Pace contractors are.

Connections between Pace ADA paratransit and the paratransit or mainline services of CTA or Metra are protected to a limited extent. Drivers for Pace ADA paratransit services who are to pick up connecting passengers may wait at the connection point for 5-10 minutes after the scheduled pickup time. They will then contact the dispatcher for further instructions.

REGIONAL TRANSPORTATION AUTHORITY
TRANSFER CONNECTION PROTECTION (TCP) PROJECT

TASK 3 REPORT:
REVIEW INDUSTRY PRACTICES AND EXPERIENCE

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EXECUTIVE SUMMARY

This report reviews experience with connection protection in the transit industry, as well as in two other industries with more advanced technology for operations support: freight railroads and passenger airlines. It also reviews national and regional ITS standards pertaining to transit operations management. The goal of these reviews is to identify lessons learned that are applicable to the TCP project effort.

The report begins with a review of other industries' experiences. The *freight rail industry* has reshaped business processes for better management of interline connections, and developed integrated data exchange messages that support those processes. The freight rail experience suggests that while full sharing of relevant data is a necessary condition for effective connection management, the critical success factor is actually the ability of participating carriers to manage according to the new business processes *on a consistent basis*.

The *passenger airline industry* faces connection management issues at major hubs very similar to those faced by transit agencies: whether to hold outbound flights for delayed incoming passengers. At one major U.S. airline, these decisions are made at system control centers, except for the largest hubs, where the connection protection decision is made at an airport-based management center. Airlines consider many of the same criteria as transit agencies, including the number of passengers making the transfer, potential passenger delays on the "to" vehicle, the transfer time between gates, and downstream assignments for the aircraft and crew. Extensive data on connections is made available to decisionmakers along with decision support tools strictly designed for connection management. In general, airline experience points toward making intra-carrier connection decisions centrally, just as most other operational decisions are. However, it also suggests that *inter*-carrier connections be viewed as the responsibility of the "to" carrier, with the support of fully shared operational status information between the service partners.

The review of U.S. transit experience with connection protection is next. The team identified two operating agencies where intra-carrier connection protection is included in an installed AVL/SD system: Ann Arbor, MI and Fresno, CA. Both use the same technology: it supports passenger requests for connection, but not predefined connections. Passenger requests are either accepted or declined based on an analysis by the dispatch system. Among systems in predeployment stages, the Chicago Transit Authority Bus Service Management System (BSMS) design calls for support of both intra- and inter-carrier connection protection, but the specifics of how this will be done are still unclear. No systems were identified where inter-agency transit TCP is currently being practiced with computer assistance.

The U.S. Transit experience provides several important insights. In terms of technical system design, it is important to consider a maximum wait time threshold beyond which the system will not accept a connection request. Also, definitions of predefined connections will be more robust if they are identified only by "to" route, and the dispatch system is allowed to locate the appropriate vehicle on that route. U.S. experience also indicates that for larger systems, it is essential to offload most of the connection protection decisionmaking from the dispatcher based strictly on the volume of events he or she would have to work.

The absence of any computer-assisted inter-agency connection protection in the U.S. is an indication of the difficulty of the problem being faced in the TCP system design. Specifically, there are significant service and accountability issues raised when customer requests for inter-carrier connection protection are incorporated in the design. As a result, the philosophical approach of the TCP system design will need to be revisited in Task 6, Draft Functional Requirements. There are problems with each option available for supporting this function, although the preferable one is forwarding requests to the "to" carrier for a response. At the very least, this function should first be implemented only on a trial basis in the later stages of the TCP project.

Next, the review of international transit systems presents four examples of past, current and planned installations of connection protection or related technologies. Of these, two are full-blown transit

AVL/SD systems installations, and two are specialized connection protection installations. Sites include London (Ontario) Transit, Üstra Hanover, Bologna, Italy, and an unnamed German site. None, however, directly address inter-carrier connection protection on a macro scale. The main insight from this review is a concern raised in an interview with an industry consultant about the viability of connection protection when the AVL/SD system is based on an exception reporting architecture. Such systems provide reduced location accuracy at the central site directly related to the threshold tolerance for schedule deviation selected. The results may be accurate enough for the dispatcher's purposes in maintaining service on a route, but not to support inter-carrier connection protection where a 2 or 3 minute tolerance could cause false alarms and unexpected missed connections. This issue will be explored further in Task 5, Integrate with AVL & SD Systems.

A review of national and regional standards efforts and their relevance to the TCP project is provided. Both the NTCIP (National Transportation Communications for ITS Protocol and TCIP (Transit Communications Interface Profiles) standards and guidelines are reviewed. They both conform to the requirements of the National ITS Architecture, and have elements specifically applicable to the TCP project. In particular Transfer Connection Protection is specifically referenced in the draft TCIP Transit Control Center (CC) standard. However, none of the specific messages required to support it have yet been defined.

The report wraps up with a summary of findings and conclusions.

EXPERIENCES OF OTHER INDUSTRIES

It seems appropriate to begin the review with two other transportation industries that have employed advanced technology and communications to improve connection performance. The *North American freight rail industry* relies heavily on intercarrier connections to provide the majority of its service, and is thus faced with challenges in information sharing and operations coordination. *Passenger airlines* rely to a great extent on hub operations where thousands of passengers must make time-sensitive connections every day. They manage these situations with the aid of extensive computer support, including advanced analytics to allow the impacts to be evaluated before a outbound flight is held for connecting passengers or allowed to depart without them.

The remainder of this section looks at the experiences of each industry, along with their applicability to the Transit TCP system design.

North American Freight Railroads

Interline Service Management **is a North American freight rail industry initiative to better serve connecting shipments. It relies on a set of defined business processes for handling such shipments, enabled by customized Electronic Data Interchange (EDI) transactions. Each shipment has a primary responsible carrier, known as the *prime contractor*. The system provides for full information sharing and coordinated business processes, not on advanced analytics for decisions-making. The system has been a qualified success; the biggest challenge has been *individual carriers managing through the ISM business processes on a consistent basis.***

North American freight movement by rail has been characterized by a high percentage of "interline" shipments, involving more than one rail carrier. Thus, close cooperation is necessary between carriers to meet customer expectations for service and information quality. This requirement led North American rail carriers to become early adopters of electronic data interchange (EDI) for the support of business processes. As early as the late 1960's – early 1970's, automated status information was being generated by rail carriers and printed on teletype machines in shipper offices. Around the same time, the first formatted railroad-to-railroad business messages were instituted for accounting purposes. By 1990, carrier-carrier and carrier-customer EDI represented the industry norm, and was thoroughly integrated into business processes.

As railroads looked for further service improvement opportunities in the late 1980's, it became clear that the *management of intercarrier connections* represented a major service quality improvement opportunity area. In response to this, through its trade group the Association of American Railroads, the industry instituted a program for *Interline Service Management (ISM)*. This program defined a series of processes for the seamless handling of interline shipments, and leveraged the EDI infrastructure already in place to support the execution of those processes. Implementation of this concept on a trial basis began in the early 1990's; today the program has been implemented in varying degrees on all the largest North America rail carriers.

ISM processes encompass:

- service commitments on an origin to destination basis
- execution of service plans to meet those commitments
- monitoring of individual shipments to detect possible problems
- problem resolution
- post-trip analysis to identify patterns or recurring problems needing to be addressed
- customer access to status information

Participating carriers must implement computer support for these processes on their various operations management computer systems. Standard message sets support the exchange of status information, as well as estimated time of arrival (ETA) and estimated time of interchange (ETI) updates. While some status information is maintained centrally, it is carefully segregated from sensitive, proprietary commercial information. Virtually all commercial or proprietary information is maintained on carrier systems, and synchronized among carriers via standard messages. This includes information on customer identities, nature of shipments, and specific service commitments made to those customers. Some industry standard reference files that support the processes are also maintained centrally.

Central to the ISM program is the concept of a *prime contractor* for each system. For each shipment, one carrier, usually the originating one, takes primary responsibility for monitoring status across all carriers, instituting corrective action, and keeping the customer informed. Customers have one point of reference, although they may contact other carriers if they choose. Responsibilities of each party are clearly defined in ISM business processes.

The ISM system does not rely on sophisticated analytic models for identifying endangered connections, either on a central level or at individual carriers. It relies entirely on intercarrier communication with timely updates when status changes. Individual carriers must use their own operations management systems to respond to the information and institute any corrective action needed.

The ISM program has been a qualified success. From a technical standpoint, the reference files and message sets have proven mostly adequate to support the business processes. Numerous carriers are participating on a significant percentage of their traffic. The main limitation has come from the varying capabilities of individual carriers to manage according to the ISM business processes on a consistent, real-time basis. This is due in no small part to:

1. The large number of shipments requiring monitoring.
2. The difficulty in formulating effective problem resolution while minimizing impacts on other shipments.

The resultant missed commitments have caused loss of goodwill and in some cases lost customers

Comparing the railroad ISM challenge with that of transit TCP yields both similarities and differences. A strong similarity is that in both cases, the decision to hold an outbound trip for a late inbound one is based on whether the benefit from doing so outweighs the adverse downstream impacts. Another is that electronic information exchange is a prerequisite for large scale intercarrier coordination. A third is that recurring problems with a particular connection will eventually lead to the loss of customers.

The primary difference between the rail ISM and transit TCP cases is that shipments are not people! Thus, they are not in and of themselves averse to en-route delays because of uncertainty, weather or security. (Shippers may monitor en route transfer delays electronically at chronic problem points, but are primarily concerned with overall transit time goals being met.) Shipments also cannot "request" connections from vehicle operators; all connection management must be done strictly between the local or systems operations control centers off the carriers involved. Finally, the physical time to accomplish the transfer of a shipment from one train (inbound) to another train (outbound) is measured in hours or even days, as opposed to a few minutes in the case of transit passengers.

Taking both the similarities and differences into account, there are several "lessons learned" from the railroad ISM experience that are applicable to transit TCP. They include the following:

? Bilateral cooperation without centralized monitoring can be an effective tool for managing connections. However, it requires an agreed upon set of business processes, standardized message sets, and a high degree of proficiency from each carrier in adhering to both on a consistent, real time basis.

? Over time, as customer trust levels rise, the need for detailed real time customer information may diminish. However, in the initial stages of a service improvement effort, customer information is critical in order to achieve buy in and increase confidence.

- ? The exchange of status information is a necessary, but not sufficient condition for service improvement. The information must be continuously monitored, and timely and effective corrective actions must be taken. *The big challenge is in consistently managing operations according to the ISM business processes.*

- ? The maximum effect cannot be achieved without post audit of results and adjustment of operating plans/schedules.

Passenger Airlines

The operations of major passenger airlines tend toward a high degree of central control, because of their complexity, service sensitivity, and the high costs of assets involved. Extensive status information and sophisticated analytic tools, widely available, help make this possible. At major hubs on American Airlines, the only operational decision reserved for local management is that of whether to hold outbound flights for inbound connecting passengers. Local hub managers have access to detailed information on inbound connections, gate-to-gate transfer times. They are constrained by a maximum hold they can take without central control approval. For transfers from/to code share and regional partners, the "to" carrier has full autonomy in determining whether to hold; all parties have full status information to support their decisionmaking.

American Airlines controls operations from its System Operations Control Center (SOCC) at DFW Airport, Texas. Decisions make there include how to respond to weather and mechanical delays, how to position crews and equipment, and whether/when to cancel flights.

One frequent operational decision passenger airlines must make is whether to protect passenger and baggage connections by holding outbound flights for late inbound ones. Information used in making this decision -- or any other decision involving delays or cancellations – is made based on a number of factors, including:

- ? Number of passengers, by class of service
- ? Length of hold required
- ? Next assignment for the crew
- ? Next assignment for the aircraft
- ? Passenger transfer time from arrival gate to departure gate
- ? Number of passengers on board the "to" aircraft who will be delayed
- ? Downstream connections of other passengers that may be affected

On American Airlines, the SOCC makes connection protection and aircraft hold decisions for all but the largest hubs, such as DFW and Chicago-O'Hare. At these locations, there is a local tower management team empowered to make the connection protection/aircraft hold decision, subject to maximum hold times (e.g. 20 minutes). American has gone this direction because local management at these locations has access to virtually all the relevant information the SOCC does, but is in a better position to take local factors into account such as gate assignments and availability, and the feasibility of ground shuttles to speed connecting passengers to their outbound flights.

American uses sophisticated analytic tools in support of the connection protection decision. These models are based on the relative costs and benefits of the hold/no hold decisions, taking into account all the criteria listed above.

Like most major airlines, American also faces connection protection issues with service partners: code-share airlines, and owned or affiliated regional carriers. American's regional carriers are all company owned, and have their own operations control center at DFW near the SOCC. Management in the two centers consult each other around major operational issues. However, the connection protection decision is not usually a subject for consultation: it belongs to the "to" carrier. The same is true with code share partners. In both cases, the carriers exchange all the relative information on passengers and operational status, but the “to” carrier makes the hold/no hold decision. The decisions may be subject to post audit and review between service partners. In addition, in unusual or emergency situations, operations managers from both service partners will regularly confer over the phone or in person to coordinate activities, including holds for connection.

A passenger airline-transit comparison with respect to connection management yields many more similarities than differences. Operations at an airline hub and a transit hub (pulse point) are quite similar. For both, the hold decision involves the “from” vehicle
ETA, the transfer time at the transfer location, the number of passengers affected, and the downstream impacts on equipment and crew members. Due, however, to the high value of air travel and the extraordinarily high value of airline assets, passenger airlines have already heavily invested in sophisticated information systems and decision support tools, including tools which specifically address connection protection decisionmaking. This means that carrier dispatchers have full information about who is making connections, and exactly how long it should take them to get from their arrival gate to their departure gate. Also, airlines have the option of speeding passengers to connecting flights with company shuttle vehicles; this is seldom possible for larger transit agencies, although it is done routinely by certain smaller agencies.

The most useful insights for the transit TCP case from the airline example seem to relate to management control structure:

? Central management controls all intra-carrier connection protection decisions, except for those at the largest hubs, where local management equipped with full information and decision tools are given the prerogative

? *Inter-carrier connection protection is not controlled centrally.* Instead, full information sharing is practiced, with the “to” carrier empowered to make the hold decision. This is even true where there is common ownership of the carriers.

? Carriers do consult in person or by phone when special circumstances require close coordination in order to maintain service quality

U.S. TRANSIT EXPERIENCE

Connection protection has been practiced with operator-to-operator voice radio communications for a number of years. Computer assisted connection protection as an integral part of carrier SD systems is a very recent phenomenon, with only two such systems operating in the United States. Nonetheless, there are lessons to be learned form the U.S. experience to date.

Transit TCP Without SD Systems/Data Communications

The majority of U.S. transit properties doing connection protection today do so with voice communications between the operators of the involved vehicles, and where necessary the dispatcher. Pace's approach, described in an earlier task report, is typical. When a passenger requests a connection, bus operators initiate voice contact with connecting vehicle operators to inform them and determine whether the connection is endangered. Holds at the connection point must be approved by the dispatcher. The same method is used by operators for regular connections even when a specific request is not made.

Practices similar to these are understood to be widespread in the industry, especially with smaller transit agencies. Since they require timely voice communications between all parties, agencies with serious constraints on voice communications capacity generally are unable to do anything beyond coordination based on visual contact.

No effort was made in this study to identify specific agencies outside the RTA service area who are presently using voice communications for connection protection.

Transit TCP using SD Systems/Data Communications

In discussions with vendors and other industry professionals, we identified only two U.S. transit agencies currently doing connection protection with an automated scheduling/dispatch (SD) system: Ann Arbor (MI) Transportation Authority, and Fresno (CA) Area Express (FAX). In addition, a similar system is in testing in Stockton, CA. All these agencies are using AVL dispatch systems provided by Rockwell Corporation, Cedar Rapids, IA.

The Ann Arbor and Fresno systems both work the same way. Connection protection is triggered when a passenger makes a transfer request. The bus operator enters the transfer request with the desired "to" route, using the on-board driver interface. The dispatch system receives and processes the request. It selects the appropriate vehicle on the "to" route, then determines whether the connection can be made based on the position and schedule adherence of that vehicle. In so doing it takes several constraints into account: 1) the "to" route headway, which determines how long the passenger would have to wait without intervention; 2) a preset maximum hold time for holding vehicles for a connection; and 3) a preset maximum passenger wait time (requests for connections which will result in wait times longer than this are not accepted). It then determines whether or not to accept the request, and notifies the requesting operator of the result. It also informs the operator of the "to" vehicle, and issues operating instructions (e.g. "hold 2 minutes at transfer point").

Dispatcher oversight of the connection protection process is also available. The dispatcher can override the system's decision on whether or not to accept a transfer request. He or she can also override the system's choice of specific vehicle on the "to" route.

The system currently does not allow for predefined connections to be protected. However, Rockwell representatives indicate that that capability would not be too difficult to add.

The Chicago Transit Authority (CTA) Bus Service Management System (BSMS) currently under development is also intended to include functionality for protecting both requested connections and predefined ones. However, at this point it has not been determined exactly how this will be done; significant modifications to Orbital's basic system may be required. It is expected that more information will be developed on this in Tasks 4 and 5.

Finally, brief mention should be given to the RFP for AVL/SD systems issued by Raleigh, NC in early 1998. This specification included intercarrier connection protection for three separate carriers in the Raleigh area, both fixed-route and paratransit, who already coordinate operations and protect connections using traditional methods. They are said to have a connection success rate in excess of 95%. Since each of the three carriers are under separate control and have separate dispatch centers, the RFP addressed the connection protection requirement by specifying the use of transfers printed on board buses based on transfer requests given to the bus operator. The transfer information was to be used to notify the operator on the "to" route, and also to be saved by the scheduling system of the from and to carriers.

The Raleigh approach, essentially involving data interchange between separate dispatch systems but no central function, is beyond anything offered by the market today. It also covered a total of only 57 vehicles among the three carriers. Apparently for these and other reasons, Raleigh received no responses to its RFP. This design has therefore apparently been tabled for the time being.

We were unable to identify any situations in the U.S. where interagency connection protection was being done with information technology support.

Lessons for Transit TCP

Several important insights can be drawn from the information developed on current and planned U.S. systems for intra-carrier --connection protection. First, the Ann Arbor experience points out the importance of establishing a maximum acceptable passenger wait time for "accepted" connections. For example, if a customer requests a transfer to a route which is operating on time, but where the next vehicle will be arriving at the transfer point 45 minutes after the customer arrives, should the connection request be accepted? Accepting a request like this would seem to be endorsing a low service level. It is likely that the TCP design will need to include such a maximum time, beyond which the customer is still given connecting ETA information, but the request is not accepted.

Another insight concerns support of predefined connections. The Ann Arbor/Fresno/Stockton system architecture accepts a request for a transfer to a "to route". The dispatch system then figures out the appropriate "to" vehicle. This approach is robust in the face of operational disruptions on the "to" route. It suggests that where predefined connections are protected instead of or as well as customer requested connections, they should be defined in terms of "to routes" rather than specific runs.

The third insight relates to the role of the dispatcher. None of the installed or planned systems place the primary burden for evaluation and acceptance of a connection request on the dispatcher, even with expert systems assistance. Rather, the system itself takes the primary responsibility, with the dispatcher having overview and override capabilities for use in contingency situations.

The fourth concerns the fact that no system so far has attempted to protect customer-requested connections involving multiple carriers and SD systems. The question must thus be asked concerning the TCP system: if its design includes customer requests and the function of approving or declining them, where will this decision be made? At the transit TCP hub? At the "to" carrier's SD system? Or, will passenger requests be allowed, but with no mechanism for approval?

Let us examine this point more closely:

? If the approval decision is to be made at the TCP hub, then a customer commitment is being made without direct involvement of the carrier responsible for fulfilling it. As well as increasing the chance that the commitment cannot be met, this approach relieves that carrier of accountability for downstream service impacts which might ensue.

? If the approval decision is made by the "to" carrier, a more complicated communications path is involved. This increases the possibility that there will be a delay in responding to the passenger's request. This is not desirable in a situation where the customer will need a prompt response to their inquiry, or boarding delays may result while the passenger waits. Nor should it be implemented at the same time as a basic capability for protection of predefined inter-carrier connections.

? If passenger requests are supported, but there is no formal acceptance or decline, customer satisfaction is not likely to be high. The only difference between this situation and simply providing connecting service ETA information on request is that the passenger knows their request is recorded. But without any specific response, after a few missed connections disillusioned customers may stop making requests.

This issue will need to be revisited in Task 6, Draft Functional Requirements. The project team's preliminary view is that customer-requested connections would be recorded at the TCP server so they could be tracked if they are not already predefined. However, the approval/declination process will need to explicitly involve the dispatch computer of the "to" carrier. Communications delays will need to be evaluated as they arise, and addressed as a technical problem needing solution.

Finally, the fifth concern involves the lack of options presented for customers whose connection request is declined. Such options might include alternative routings, scheduling of a paratransit trip if available and applicable, or dispatching a taxi. We are not aware of any transit carrier doing this today, with the exception of transit-sponsored vanpools such as the Pace VIP program. In addition, there are many policy-level questions that would need to be worked out. Nonetheless, the TCP design should envision such a possibility. We will revisit this in Task 6 as well.

INTERNATIONAL TRANSIT EXPERIENCE

The use of information technology for transfer connection protection is more widespread outside of the United States. It is part of a broader trend toward what is termed "intermodality" – or seamless transportation across carriers and modes. European vendors such as TransTec and Siemens have installed or are in the process of installing a number of SD systems with this capability.

This section will briefly examine four examples of past, current or planned installations that include connection protection capabilities, then identify insights from these experiences that are applicable to the design of the transit TCP system.

The German ASS system

A pilot system for rail-to-bus connection protection from the mid-1980's, ASS is documented only in a journal article. However, it provides important insights into the base components required for successful connection protection.

The earliest recorded use of information technology for connection protection found in research for this task is documented in a Railway Technology International 1989 article entitled "Ensuring Rail and Bus Connections". Referred to by the acronym ASS, the system's purpose was to coordinate rail to bus connections in two specific situations. First, the system coordinated off-peak connections to minimize long wait times due to missed connections. Second, the system monitored peak-hour connections to minimize situations in which passengers alighting from a train were able to see their connecting vehicle pulling away from the station.

This system was installed in a pilot installation in Germany at an unnamed location. It consisted of a circa-1986 system computer with links to a railroad signal/dispatch system and to a "countdown" display for buses at the transfer point. The system worked in the following fashion:

1. At a predetermined interval before a bus's scheduled departure from the transfer point, the system would automatically query the railway dispatch system to determine the status of the incoming train and its ETA at the station. (It is not clear whether the railway computer or this system calculated the ETA.)

2. The system would then determine whether the connection was endangered. During off-peak periods this meant a long wait time for the next bus; for peak periods it meant only that the passenger would be able to see the bus pulling away.

3. For endangered connections, the system computer would determine whether or not the bus could be held to make the connection without exceeding a predetermined maximum hold time.

4. The system drove a "countdown display" showing the time until the departure of the next bus. This display served both for passenger information and for operator instructions. If the connection was going to be made, or the bus was not going to be held to make a connection, the countdown would reflect minutes to the scheduled bus departure time. If the bus were to be held, the countdown would reflect minutes to the actual bus departure time.

Dispatchers had capabilities to monitor health of the system computer and displays and to change the functions of the displays. However, the dispatcher apparently could not view what the displays said, and could only alter the instructions by disabling or resetting the display.

The project team was unable to locate any record of where this pilot installation was located, whether it was made permanent, or whether the technology was expanded to additional locations. Nonetheless, this system is a useful illustration of what was possible even more than a decade ago in terms of small-scale intercarrier computer assisted connection protection.

London, Ontario, CANADA

The only other installation identified in North America, the London, Ontario system is based on European technology from Siemens. It is said to cover both predefined and customer-requested connections. It is still in testing; completion is projected for later in 1999.

As of April, 1999, London Transit is in integrated testing of its new SD system. Final testing is planned for June, 1999. This system is said to include protection of both customer-requested and pre-defined connections. The system vendor is Siemens/Häni Prolectron. Niacad, Ltd. consultants are assisting London Transit in design, specification, procurement and implementation oversight.

In the Siemens system, customer-requested connections are initiated by the bus operator pushing a button on the driver interface, then entering the route number. The dispatch system determines the appropriate “to” vehicle, and whether or not the connection can be made. It then informs the requesting bus of the decision, and issues any necessary instructions to the “to” bus.

Predefined connections are managed in a similar fashion, except that the system identifies endangered connections on its own, determines whether corrective action is necessary, and issues necessary operating instructions. In essence, it is as if a customer requested each such connection on a daily basis.

At London Transit, this system will replace the current system of attempting to protect customer-requested connections using only a capacity-constrained voice radio system.

Wilson Consulting tried to determine specifically how predefined connections are identified in the route database of the London system, but was unable to do so in conversations with either London Transport or Niacad personnel.

Üstra Hanover

Other European vendors also offer some elements of connection protection in their systems. The system installed at Üstra, the transit operator in Hanover, Germany, supports primarily predefined connections. Similar systems are said to be operating in many European cities, most based on beacon (signpost) AVL systems, which can provide a high degree of location accuracy at key transfer points.

TransTeC is the systems and consulting affiliate of Üstra Hanover, the transit operating agency in Hanover, Germany. The TransTeC BON system is an integrated software suite installed at Üstra and other European operators.

The BON system supports transfer connection protection. Precise location is obtained through the use of infrared beacons (signposts) or GPS to verify/correct odometer readings, which are the primary source of location information. The system supports protection of predefined connections at the dispatch computer level. If corrective action is needed to protect a connection, the appropriate action is selected and communicated to the operator automatically via a data message. Our understanding is that customer-requested connections are not supported, in line with a philosophy that a well-defined and well-executed operating plan, with frequent scheduled connections, is sufficient to provide good service.

The Teleride, Inc. TeleDispatch system, offered by the U.S. TransTeC subsidiary TransTeC America, provides for protection of predefined (“scheduled”) connections as well. It is said to automatically detect at the dispatch computer level when a connection is endangered, and to automatically institute corrective action within predefined parameters. In the case of marginal connections at or near the maximum tolerance for wait times, the situation is automatically presented to the dispatcher for resolution.

VIVALDI Demonstration: Bologna, Italy

While not strictly a connection protection application, the VIVALDI project in Bologna, Italy, includes extensive plans for customer information support at bus-rail transfer points. Estimated Time of Arrival (ETA) information is to be displayed for both modes. This project is typical of many being undertaken in Europe that use multiple approaches to improve "intermodality". Future plans for enhancement to connection protection are not known; however, results from this project in terms of ridership, revenue and customer satisfaction should be interesting to watch.

With financial support from the European Commission (EC), the CONCERT Project (COoperation for Novel City Electronic Regulating Tools) encompasses eight demonstration projects, each in a major city in a different EU member state. Each project focuses on one or more approaches to improving "intermodality", or seamless transportation across different transport carriers and modes.

The VIVALDI project (Viable Integrated Payment VALidation via Demonstration of Intermodality) is focused on integration of bus, rail and parking services in the Bologna, Italy region. The main focus of VIVALDI is on seamless payment through sharing of various existing and new fare media. However, an important component of the program is integration of information from rail and bus operations.

Rail and bus operations in the Bologna northern corridor are already highly integrated from a schedule standpoint. Plans for VIVALDI are to set up integrated displays of ETA information covering both rail and bus at key transfer points. While this does not directly address connection protection, it does address a number of the traveler-perceived problems with connections identified in Task 1 of the TCP project.

The projected schedule for implementation of VIVALDI is not known at this time. Nor is it known whether there are plans to got to the next step of coordinated operations management and connection protection. However, the project should be useful to watch for its impacts on revenue, ridership and customer satisfaction.

Lessons for Transit TCP

? If there is a common theme to these diverse stories, it is that information is at the heart of efforts to improve connection performance both within and between the services of individual carriers. European systems pursued, and continue to pursue, passenger information at major trip origin and transfer points ahead of more advanced operations integration functions such as connection protection.

? The ASS system potentially represents a viable *small-scale* approach to rail-bus connection protection. It is, however, a standalone, parameter-driven system without links to the bus dispatch system, and thus unable to take into account downstream impacts of a vehicle hold.

? Discussions with the Niacad consultant raised another interesting point not covered in the above discussions. Any centralized connection protection functionality, whether intra- or inter-carrier, requires a high degree of location accuracy in order to be successful. This means not only that accurate AVL systems are needed, but that the control center must be frequently updated with accurate information so that its information is nearly as accurate, if not as accurate.

This requirement leads to the possibility that exception-based systems, which are adequate for telling dispatchers when there's a problem, may not be able to support centralized TCP. This is because the actual error at the central site is potentially the sum of 1) the AVL system error, and 2) error equivalent to the tolerance for reporting schedule deviation. For example, if the schedule deviation tolerance before reporting back to the control center is three minutes late, the bus may be 2.5 minutes late, and the control center will still think it is on time.

The implications of this insight for the TCP project and service board AVL systems will be explored more closely in Task 5, Integrate with AVL & SD Systems.

REGIONAL/NATIONAL STANDARDS RELEVANT TO TCP

This section reviews regional and national standards efforts to which the TCP system will need to conform. (Conformance will be limited by the fact that many of the specific relevant standards are yet to be developed or are currently under development.) First, it addresses the National ITS System Architecture and related standards, including NTCIP and TCIP. Next applications of the National ITS System Architecture and standards to the GCM Gateway Traveler Information System are reviewed. Finally, there is a discussion of applications of the National ITS System Architecture and standards to the TCP System.

Overview of National ITS System Architecture And Standards

National ITS System Architecture

The U.S. DOT Joint Program Office on Intelligent Transportation System (ITS) coordinated the development of a national system architecture for ITS, and promulgated consistent, coordinated standards that support interoperability among the architectural systems, subsystems, and components.

The National ITS Architecture defines the components of the surface transportation system, how they interact and work together, and what information they exchange to provide 30 ITS user services. These 30 user services have been identified by the ITS community as part of the National ITS Program to guide the development of ITS. A key requirement for development of the National ITS Architecture was that it includes the transportation functions necessary to provide the 30 user services.

The National ITS Architecture provides a common structure for the design of intelligent transportation systems. It is neither a system design nor a design concept. What it does is to define the framework around which multiple design approaches can be developed, each one specifically tailored to meet the individual needs of the user, while maintaining the benefits of a common architecture. To maximize the potential of ITS technologies, system design solutions must be compatible at the system interface level in order to share data, provide coordinated, area-wide integrated operations, and support interoperable equipment and services where appropriate. The National ITS Architecture provides this overall guidance to ensure system, product, and service compatibility/interoperability, without limiting the design options of the stakeholder.

The architecture defines the functions (e.g., gather traffic information or request a route) that must be performed to implement a given user service, the physical entities or subsystems where these functions reside (e.g., the roadside or the vehicle), the interfaces/information flows between the physical subsystems, and the communication requirements for the information flows (e.g., wireline or wireless).

In addition, the National ITS Architecture identifies and specifies the requirements for the standards needed to support national and regional interoperability, as well as product standards needed to support economy of scale considerations in deployment.

National Transportation Communications for ITS Protocol (NTCIP)

The principal national standard with regard to the Intelligent Transportation Systems is the National Transportation Communications for ITS Protocol (NTCIP). The primary objective of the NTCIP is to provide a communications standard that ensures the interoperability and interchangeability of traffic control and ITS devices. The NTCIP is the first protocol for the transportation industry that provides a communications interface between disparate hardware and software products. The goal of the NTCIP effort is to not only maximize the existing infrastructure, but also allow for flexible expansion in the future, without reliance on specific equipment vendors or customized software.

NTCIP development began in 1992 when users of traffic signal controllers began to request that manufacturers standardize their products. In 1993, the Federal Highway Administration brought users and manufacturers together with software developers of NEMA (National Electrical Manufacturer's Association) and Model 170 controllers. This meeting resulted in a working committee sponsored by NEMA with members from all types of traffic signal controller manufacturers to signal system developers. The first version of the NTCIP was developed in December 1995 and provided a standard protocol for traffic signal systems.

An NTCIP Steering Committee was formed in May 1995 with representatives of ITS users, designers, and developers from public, private, and academic sectors to guide the NTCIP efforts. In September 1996, a consortium was founded by the American Association of State Highway Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and NEMA, and was awarded funds by the FHWA to further develop the NTCIP. This consortium replaced the NTCIP Steering Committee and was renamed the NTCIP Joint Standards Committee. There are currently six representatives from AASHTO, ITE, and NEMA. The NTCIP Joint Standards Committee is in charge of developing additional elements of the NTCIP and coordinating with related ITS and communications standards efforts in the U.S. and internationally.

The NTCIP is actually a family of standard communications protocols used for data transmission within and between Intelligent Transportation Systems. The standard covers both the "how" and "what" of data communications, i.e., both the transmission rules and the format and meaning of standardized messages transmitted using those rules. Where possible, the NTCIP is based on existing standards in the telecommunications and computer industries.

The NTCIP aims to do for transportation systems what the Internet has done for communications between general-purpose computers: it will help enable interoperability and interchangeability between devices and between systems from different manufacturers. It can provide more choices, more flexibility, and the ability to coordinate the operation of adjacent devices and systems.

The NTCIP offers increased flexibility and choice for agencies operating transportation management systems. The NTCIP will support and promote interjurisdictional coordination by enabling communication with adjacent controllers that are owned by different agencies and may be from a different vendor. Basic monitoring and signal coordination functions can then be facilitated. Additionally, for closed loop signal systems, two masters of different vendors and/or jurisdictions can communicate with each other to provide coordination.

Another benefit of using the NTCIP is that it includes the ability to communicate with a mixture of device types on the same communications channel. Equipment of different types and manufacturers can be mixed on the same communications line. The communications network is usually the most expensive component of a transportation management system. If a master signal controller and a variable message sign are in close proximity, the master could send messages to be displayed to the sign controller using the same communications channel as the traffic signal controller.

Within the NTCIP, there are various profile classes defined:

? A - Connectionless
? B - Central direct to field
? C - Connection oriented
? D - Undefined
? E - Center to Center
? F - Alternate Center-to-Center

Note that the Class B Profile is the only Class Profile that has been standardized to date.

Class A is a suite of protocols allowing the connectionless transmission of data packets over a medium that does not require a permanent connection between two devices. The Class A Profile suite of protocols will use the Transmission Control Protocol (TCP) as its Network Layer protocol to guarantee delivery or signal when a message cannot be delivered correctly. The NTCIP Class B Profile defines a set of communication protocols to be used in field devices and their management systems that are part of an Intelligent Transportation System. The profile provides for exchange of information between a primary station and each secondary station on a particular communications channel or subnet. Class C is a profile providing connection-oriented services similar to the data transmission within the Internet. It will utilize the Simple Network Management Protocol (SNMP), the TELNET, and the File Transfer Protocol (FTP), which are well tested and implemented within the Internet and Intranet networks. The Class E Profile specifies the suite of protocols that allows for center-to-center communications. The specification of this Profile is in a very preliminary stage and its development will probably take several years. Another NTCIP compatible and NTCIP-compliant method for center-to-center communications has been introduced. The introduction of a Class F Profile took place in December 1996, but the information regarding this proposed standard development effort has not yet been specified in writing.

Transit Communications Interface Profiles (TCIP)

The Transit Communications Interface Profiles (TCIP) project was initiated in November 1996. It was funded by the U.S. Department of Transportation's Joint Program Office for Intelligent Transportation Systems, and developed by the Institute of Transportation Engineers (ITE) in cooperation with the Federal Transit Administration (FTA), the Federal Highway Administration (FHWA), and the American Public Transit Association (APTA).

TCIP is a standards development effort designed to provide the interface structures that will allow separate transit components and organizations to exchange data. The standards development effort was organized to define the information and information transfer requirements among Public Transportation Vehicles (PTVs), the Transit Management Center (TrMC), transit facilities, and ITS centers; identify physical and data link requirements; develop required message sets; establish liaison between ITE and other Standard Development Organizations (SDOs); and coordinate with those SDOs on the development of related standards.

Importantly, the standards development effort produced a comprehensive set of TCIP interface requirements that when fully implemented, will allow effective and efficient exchange of data used for ITS user services, and transit operations, maintenance, customer information, planning and management functions. The standard provides for interfaces among transit applications, which will allow users to communicate data among transit departments, operating entities such as emergency response services, and regional traffic management centers.

The Transit Communications Interface Profiles domain covers the data needs of the functions related to the support of public transportation operations, service, and planning. This includes all input and output data needed for the following business areas: 1) Fare Collection (FC), 2) Scheduling/Runcutting (SCH), 3) Passenger Information (PI), 4) Incident Management (IM), 5) Vehicle On-board (OB), 6) Transit Control Center (CC), and 7) Traffic Management (TM). Other business areas that support or cut across the definitions of these business areas include Spatial Representation (SP) and Common Public Transportation Data (CPT) elements and messages.

The National ITS Architecture and the IEEE Data Dictionary and Message Set Template are two of the major efforts that facilitated coordination between transit (TCIP), and other centers and subsystems within the National Architecture. TCIP addresses the transit-specific data interfaces defined in the National Architecture and adheres to the requirements specified. TCIP's primary goal is the definition of data interfaces to both transit-related applications and the National ITS Architecture data flows. TCIP will be developed by addressing data flows as identified within the National ITS Architecture to the extent possible. Interfaces needed for other transit-related applications that have not been addressed will also be identified.

The TCIP development effort is expected to augment the information management area of NTCIP with transit-related information and message formats that facilitate the exchange of transit information among operations centers, transit vehicles, and the infrastructure. The TCIP will provide additional NTCIP Class Profiles or subsets of existing and planned Class Profiles, and the necessary bridges for information transfer from legacy transit systems to advanced information systems developed conforming to the National ITS Architecture. The main focus of TCIP is the development of message formats to exchange transit information in a standardized manner.

Vehicle Area Networks

Standards are being developed for interfacing ITS devices on transit vehicles. Currently, three different standards are being applied across the United States. These are described briefly below.

SAE J1708 / J1587: The Society of Automotive Engineers (SAE) develops recommended practices to be used for the automobile industry, including transit vehicles. SAE maintains an ITS program office to develop and promote ITS standards, not just at the national level but also internationally.

Recommended Practice J1708, and most likely J1587, is already being used as a "quasi" standard within the transit industry for the setup within the transit vehicles. It is anticipated that J1708 or a modified deviation will be the basis for the Vehicle Area Network (VAN) standard. The transit community strongly recommends that the J1708/J1587 standard be used for the design and procurement of transit ITS.

LonWorks: LonWorks technology is a general-purpose control networking technology developed by Echelon Corporation. LonWorks technology is designed to enable various devices to communicate across a range of media in a control network. A LonWorks technology control network utilizes the LonTalk communication protocol fully implemented in silicon and available as Neuron Chips, manufactured by Motorola and Toshiba.

Besides the LonTalk protocol, the Neuron Chip performs most of the control functions, which add distributed intelligence and inter-operability to network devices. In addition to the Neuron Chips, LonWorks technology provides transceivers to couple Neuron Chips to the network devices and communications media, bridges to connect separate communications media in the LonWorks network, and network management and diagnostic equipment.

VDV-300 IBIS: The Verband Deutscher Verkehrsunternehmen (German Association of Public Transport Operators - VDV) has developed VDV Standard 300 - Integrated on-Board Information System (IBIS). This is the VDV's own specification for a vehicle area network. The VDV-300 specification, released in January 1992, was designed as a recommendation for data processing and transmission of data in public transportation vehicles.

The VDV standard specifies a modular design with interchangeable devices. It specifies a protocol software design along with hardware operations and connections, including a central vehicle area network control unit.

Dedicated Short Range Communications (DSRC)

Dedicated Short Range Communications (DSRC) consists of short-range communications devices that are capable of transferring high rates of data over an air interface between mobile or stationary vehicles and normally stationary devices that are either mounted to structures along the roadway or are hand-held. The National Architecture program recognizes the need for DSRC systems for those specific applications that require a close physical interaction between the vehicle and the roadside infrastructure. Transit has been identified as one of the candidates to utilize DSRC as a primary communication technique or mechanism.

Automated Vehicle Location (AVL) Systems

The application of AVL within the transit industry is one of the most beneficial applications in ITS technology implementation. It enables transit managers to manage transit vehicles in real-time with reference to the roadway network and the planned schedule.

There are many AVL systems in use in the U.S., provided by a variety of vendors. However, none is based on an open architecture or industry standards. Instead, they are largely proprietary, although they may support a small number of SAE J-1708 interfaces for add on components. As a result, integration with other systems such as transit TCP or a regional transit management center will be an expensive proposition.

The TCIP standards under development have embraced the SAE J-1708/J-1587 family of standards for bus on-board device identification and parameter identification, as part of the Standard on On Board Objects (OB). Further, the Standard for Control Center Objects (CC) covers both messages within the transit control center, and messages in both directions between the vehicle and the control center. Once these message sets are fully defined and approved as standards, vendors can start to incorporate them in their system revisions. This will lead several years down to standards-based, open architecture systems that will be more easily integrated with regional management centers and with each other.

Applications of National ITS Architecture and Standards to GCM Gateway

The Gary-Chicago-Milwaukee (GCM) Corridor is one of the four corridors originally selected by the US Department of Transportation (USDOT) for the deployment of Intelligent Transportation System (ITS) initiatives. The GCM Multi-Modal Traveler Information System (MMTIS) Project involves a large number of ITS-related tasks. The Gateway is the central element of the GCM MMTIS. The Gateway System is an integrated information system that serves the information needs of operating agencies and travelers within the GCM Corridor. The Gateway collects dynamic and static transportation data from the distributed transportation management systems via their respective regional hubs throughout the Corridor. The Gateway complies and coordinates this data to create a corridor-wide source of transportation information. The Gateway collects, processes, distributes, and presents this information directly to various operating agencies (through their respective regional hubs) and to travelers within the GCM Corridor (through Information Service Providers and the Internet).

The Gateway System will be developed to serve several purposes in the GCM Priority Corridor as the Corridor Hub of the MMTIS. The primary responsibility of the Gateway System is to collect, organize, and redistribute all transportation-related data on the National Highway System and Strategic Regional Arterials within the Corridor. In addition, the Gateway System will be multimodal, and collecting and distributing transportation related data from a variety of transportation modes. The other main objectives of the Gateway will be to provide the communications infrastructure for cooperative control of traffic surveillance and control devices by traffic management agencies within the Corridor.

In order to collect information from sources throughout the Corridor, the Gateway will be connected by a Corridor wide electronic network together with regional hubs within the three states and with all appropriate ITS data sources. A multi-phased implementation is proposed for the Gateway system. The Gateway development under the current contract is the initial phase implementation. The primary difference between various phases is the number of data connections to the Gateway and the communication medium. The current Gateway Project will design and implement automated connections with the Chicago Transit Authority (CTA); these will be only for support of incident management. CTA is the only data source in the Transit area in the current phase of the Gateway System.

The Gateway Traveler Information System (ITS) will be designed in relation to the ongoing development of National ITS technologies and system architecture evolution. The GCM Corridor Multi-Modal Traveler Information System Project (MMTIS) developed the overall ITS architecture for both interconnected ITS elements and isolated elements. The Gateway architecture addresses the interconnected ITS elements only, since the non-interconnected elements are not considered as a major factor in determining data flows, system interfaces, etc. A mapping of Gateway/MMTIS to the national ITS Architecture has been made in the process of the Gateway design.

In order for the GCM system to achieve interoperability and joint control of field devices, it is necessary to provide seamless transactions between heterogeneous hardware and software systems. In the development of the Gateway System, every attempt has been made to utilize existing national or regional standards. In this manner the Gateway System will be able to interface not only with both existing and emerging transportation systems within the corridor but also with other regional systems throughout the country and with mobile devices (pagers, in-vehicle devices) which can roam throughout the U.S.

Two NTCIP message structures will be very important to the GCM ITS System: Class B and Class E. Class B protocols include those for actuated signal controllers, dynamic message signs, environmental sensor stations, highway advisory radio, freeway ramp meters, video camera control, and traffic sensor stations. Class E protocols will cover communications between transportation operations centers, which are referred to as center-to-center communications.

In building the message structures for field devices, the NTCIP precisely defines the data to be exchanged for each field element (actuated signal controllers, dynamic message signs, and environmental measurement devices). For center-to-center communications, the NTCIP also needs to define the data to be exchanged. So far, there are four categories of data streams where definitions are being developed: Traffic Coordination, Event Notification, Data Sharing, and Regional Command Distribution. Traffic Coordination messages will allow the traffic management centers in different jurisdictions to coordinate operations. Event Notification messages will allow different jurisdictions to learn about events close to their borders that may impact their operations. Data Sharing messages allow various agencies to collect and distribute transportation system data. Regional Command Distribution messages make it possible to coordinate the activity of multiple traffic management centers by issuing commands at a regional level. All four of these categories are pertinent to the GCM ITS System.

The Gateway makes use of Common Object Request Broker Architecture (CORBA) as its primary center-to-center communication protocol. This is one of the two alternatives currently being developed by the NTCIP Committee.

Applications of National ITS Architecture and Standards to TCP

Figure 1 is an overview of the proposed high-level TCP system architecture. In this system, there are two types of communication systems – internal communication (vehicle to management center) and external communication (center-to-center communication). The vehicle to management center communications include: 1) the communications between CTA transit vehicles and the CTA Control Center, 2) the communications between Metra trains and Metra's Dispatch Center, where the new Train Information Management System (TIMS) will be housed, and 3) the communications between Pace transit vehicles and Pace divisional dispatch centers (here represented as a single entity). A Transit Server will work as a hub to collect transit information from the CTA Management Center, the Metra Management Center, and the Pace Management Center. Using center-to-center communication, this Transit Server will interact with the Gateway Server directly. It is expected that the TCIP profiles will apply for the above communications.

Figure 2 shows the TCP internal communication architecture. In addition to the regular AVL data flows shown, passenger connection requests will be forwarded from the vehicle to the control center. Responses to requests will be returned from the control center to the requesting vehicle. This internal diagram does not reflect the subsequent flow of requests and responses to the Transit Server and if necessary to other carrier management center systems.

A number of the TCIP profiles will be directly applicable for the TCP system. The Transit Control Center (CC) Profile, which covers messages between vehicles and control centers, specifically incorporates Transfer Connection Protection as part of its scope. However, the TCIP program has yet to identify specific messages to support the function. Nor is any mention made of customer-requested connections and the messages associated with them. The TCIP program leadership has expressed an interest in dovetailing a standards development effort with this project if funding can be secured.

This would mean that messages identified by the RTA, its service boards and consultants as part of this project would actually serve as the basis for TCIP profiles covering the transfer connection protection area.

Other TCIP business areas are also expected to include elements and messages relevant to the TCP project. These include Scheduling/Runcutting (SCH), Passenger Information (PI), Vehicle On-board (OB), Spatial Representation (SP), and Common Public Transportation Data (CPT).

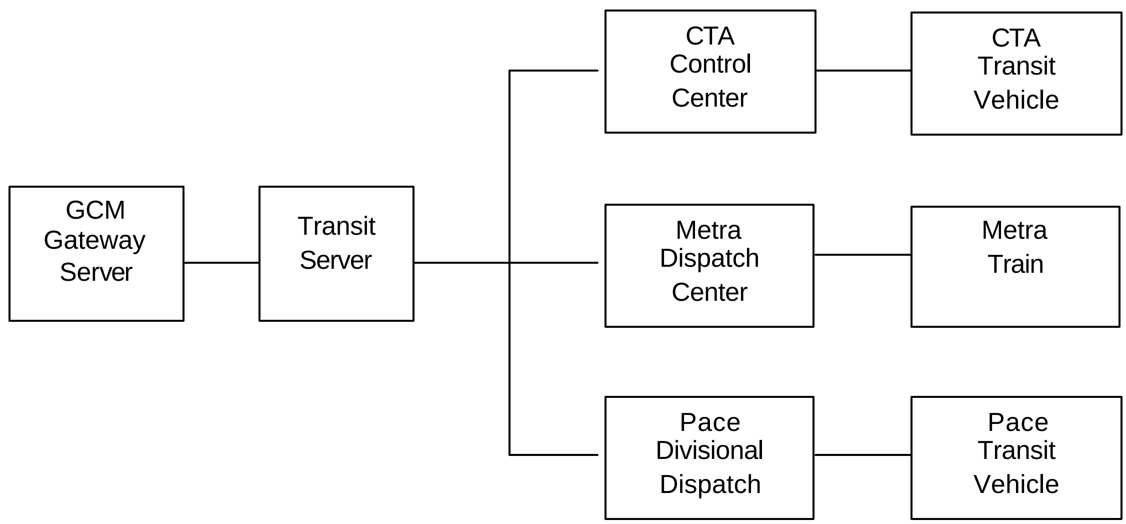

Figure 1. TCP System Architecture Overview

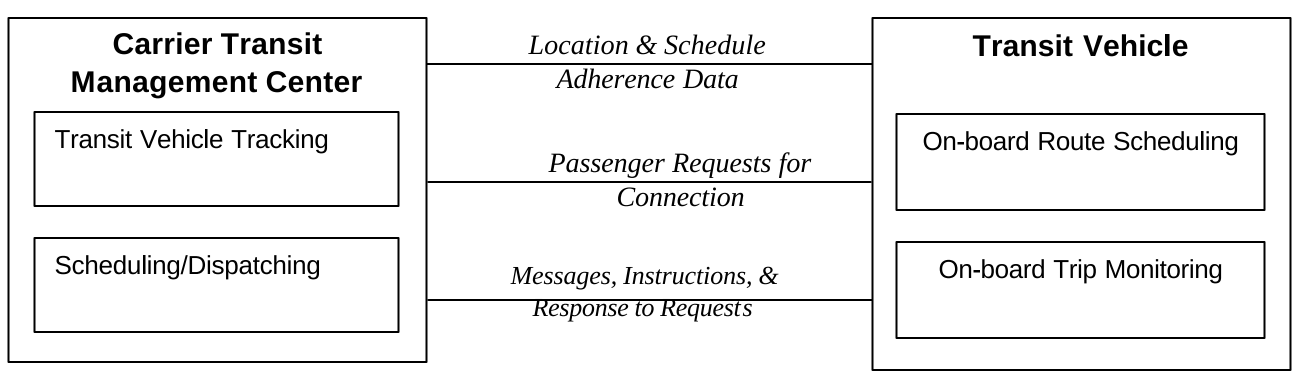

Figure 2. TCP Internal Communication Architecture

SUMMARY OF FINDINGS/CONCLUSIONS

Key findings and conclusions from this study are summarized below:

- Electronic information exchange is a necessary, but not sufficient, condition for system success. The major challenge is managing through the business processes that support connection protection on a consistent basis.

- Designating a party with primary responsibility for intercarrier trips is important from the standpoint of tracking, follow-through, accountability and customer interface. The alternative is finger-pointing instead of customer service.

- Post audit of intercarrier trips is necessary for maximum benefit, so that chronic problem areas can be identified and operating adjustments made.

- A maximum allowable wait time should be defined for “accepted” passenger connection requests.

- The definition of predefined connections should be based on “to” route, not the specific “to” vehicle. This is a more robust approach in the face of service problems.

- For a large system, dispatcher review of all connection requests is infeasible. Therefore, computer-based decisions with the opportunity for dispatcher review and adjustment are a necessary part of a connection protection system design.

- There are significant service and accountability issues raised if the TCP system is to support customer requests for intercarrier connection protection. As a result, the TCP system design approach will need to be revisited in Task 6, Draft Functional Requirements. There are problems with each option for supporting this function; the preferable one is forwarding requests to the “to” carrier for a response. At the very least, this function should only be implemented on a trial basis later in the project.

- European efforts at improving “intermodality” have been focused more on improving passenger information than on actual connection protection. RTA’s current approach of progressing passenger information solutions as well as the connection protection functionality is very sound and should be continued.

- Both the NTCIP and TCIP standards have elements specifically applicable to the TCP project. In particular, Transfer Connection Protection is specifically referenced in the draft TCIP Transit Control Center (CC) standard. However, none of the specific messages required to support it have yet been defined.

- There is the potential that exception-based AVL/SD system architectures may not provide sufficient location accuracy at the control center/dispatch computer to support intercarrier TCP. This will be addressed in Task 5, Integrate with AVL & SD Systems.

REGIONAL TRANSPORTATION AUTHORITY
TRANSFER CONNECTION PROTECTION (TCP) PROJECT

FINAL TASK 4 AND 5 REPORT:
INVENTORY EXISTING SCHEDULING/DISPATCHING SYSTEM
INTEGRATE WITH AVL AND SD SYSTEM

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December 14, 1999

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EXECUTIVE SUMMARY

This report covers two tasks from the RTA Transfer Connection Protection (TCP) project. Task 4, Inventory *Existing Scheduling and Dispatching Systems,* involves a review and cataloging of each service board's planned or under development AVL/SD systems. Task 5, *Integrate with AVL and SD System,* provides for a review of where service board systems do and do not comply with the requirements of TCP and of relevant national and regional ITS standards.

The report first reviews the functional components of AVL/SD systems that are relevant to the design of the TCP system. These include automatic vehicle location (AVL) capabilities, an on-board processor, a driver interface, mobile data communications, a vehicle area network connecting all on-board devices, computer-aided dispatching (CAD), monitoring of schedule adherence, on-board passenger information displays/announcements, a scheduling system electronically linked to the CAD system, passenger counting or load estimating, and connection protection.

The report next reviews requirements for compliance with national and regional architectures and standards, including the National Transportation Communications for ITS Protocol (NTCIP), the Transit Communications Interface Profiles (TCIP), and the Gary-Chicago-Milwaukee (GCM) Priority Corridor system architecture. In general, while these standards and architectures provide for connection protection functionality similar to TCP, there are few if any specifics in place. All the service boards can do at this point is to stay current with these efforts, and to follow open systems principles in system design.

A brief review of special issues relating to paratransit is presented. For paratransit, pick-ups from connecting carriers can be managed by updating pick-up times in accordance with updated estimated time of arrival (ETA) information provided by those carriers. For drop-offs it would be required for the carrier to supply updated ETAs while en route to the transfer point. In addition to AVL/SD system modifications, changes to paratransit reservations systems would be required to allow recording of more detailed information on desired transfers.

A detailed review of service board AVL/SD functionality follows. A table is provided with design details of four service board AVL/SD systems: the CTA Bus Emergency Communications System (BECS)/Bus Service Management System (BSMS); CTA's Rail Service Management System (RSMS); Metra's Train Information Management System (TIMS); and Pace's Intelligent Bus System (IBS). A brief narrative summary of each carrier's system(s) is then provided. Only the CTA's RSMS is currently fully operational. The CTA BECS/BSMS is currently being installed, while a contract was recently awarded for Metra's TIMS. Pace is currently developing specifications for IBS. In general the service boards' AVL/SD system designs include most of the customary capabilities that will be required to support TCP.

The last two sections of the report review each carrier's AVL/SD system in light of TCP functional requirements and national and regional ITS architecture and standards. The principal required action is for ongoing tracking by RTA and the service boards of developments in GCM, NTCIP, and TCIP. Developments in the RTA Active Transit Station Signs and Parking Management Systems projects will also be relevant. Regular tracking of developments in these areas will allow the RTA and service boards to incorporate more specific requirements as they are developed.

Among other specific requirements:

? Service boards need to continue to adhere to open systems principles in their design and procurement.

? System designs should incorporate relevant "object definitions", specifying data elements and message sets, from NTCIP and TCIP.

? Service board systems planning should begin to take into account the additional functionality, processing power, and center to center communications traffic that will be required for TCP.

? The TCP system will require a higher degree of location accuracy at each service board's central site than may be required for routine service management. More specific requirements will be developed later in this project. Service boards need to be aware of this potential requirement, although there may be little they can do about it due to the significant region-wide shortage of radio frequencies necessary to provide greater accuracy.

? CTA should coordinate its schedule for adding a rail operator interface to the RSMS with the TCP deployment schedule.

? Service boards with paratransit operations need to take into account the unique requirements for paratransit participation in TCP, as outlined above. These include reservations systems enhancements to permit more detailed connection information to be collected; real time updates of pick-up times based on connecting service ETAs, and reporting of paratransit ETAs for trips where a connection is required at drop-off.

INTRODUCTION

This report covers two tasks from the RTA Transfer Connection Protection (TCP) project. Task 4, Inventory *Existing Scheduling and Dispatching Systems,* involves a review and cataloging of each service board's planned or under development AVL/SD systems. Task 5, *Integrate with AVL and SD system,* provides for a review of where service board systems do and do not comply with the requirements of TCP and of relevant national and regional ITS standards.

In order to meet this requirement, this report first reviews the functional components required of AVL/SD systems in order to fully support TCP. It then recaps from Task 3 requirements for systems to be in compliance with national and regional standards. It also briefly recaps special issues associated with paratransit systems.

The report then presents a detailed inventory of the fixed route AVL/SD systems of each service board. A summary table is provided, followed by recaps of each service board's functionality.

A TCP support and standards compliance review of each carrier's system is presented next. The report then concludes with a summary of findings and required actions.

CARRIER AVL/SD SYSTEMS FUNCTIONAL REQUIREMENTS

Support of TCP

Each RTA service board is planning, procuring or implementing some form of automatic vehicle location (AVL) systems, as well as integrated scheduling and dispatch (SD) systems. If the service boards are to support the TCP system, there are a number of specific functional components required of their AVL/SD systems. There are also some additional components that are desirable for support of future enhancements.

This section defines the components and functionality of AVL/SD systems, and indicates whether or not they are required for carrier participation in TCP.

Automatic Vehicle Location (AVL)

For support of TCP, carriers must have a basic AVL system as a source of vehicle location information. In addition, the AVL system may include the intelligence necessary on-board the vehicle to convert coordinates into a location on a route ("map matching"). Alternatively, this may be done by the dispatch system at the control center. AVL systems are usually specified to a particular level of accuracy, measured in feet or meters.

On-board processor

The on board processor is an integral part of an AVL/SD system, and is thus a requirement for TCP. It consists of a central processor for performing various on-board tasks, driving displays and annunciators, and managing communications. The processor also houses the AVL system components.

Control head/driver interface

The on-board processor must also drive a control/head driver interface consisting of a display and keypad or keyboard, and possibly other components. This is critical to TCP as a means for conveying operating instructions, as well as submitting and receiving responses to customer requests for connection.

Vehicle area network

A vehicle area network is basically a local area network for on-board components. It is not a requirement for support of TCP. However, an open systems, non-proprietary solution virtually requires the use of a standards-compliant vehicle area network. Thus, it is a desirable approach for on-board systems.

Schedule adherence monitoring

AVL/SD systems are required to have a basic schedule adherence monitoring capability for determining the status of a vehicle relative to its schedule. This capability is required for TCP. This capability may reside on board the vehicle or at the control center in the computer aided dispatch system. Deviations from schedule serve as the basic trigger for determining that a connection may be endangered.

Headway adherence monitoring

Carriers with short headway operations (under 3-5 minutes) may desire the capability for monitoring the spacing between vehicles on a short headway route as an alternative to schedule adherence monitoring. This is not a required element for support of TCP unless it is desired for carriers to hold vehicles on a short headway route in order to avoid “near misses”.

On-board passenger information

It is desirable that carriers include with their AVL/SD systems an on-board infrastructure for visual and audio announcements. The common elements of this infrastructure include one or more of the following: PA system for driver announcements; visual alphanumeric displays; audio annunciators. This capability could be a future requirement if support for customer requested connections is implemented.

En-route passenger information

En-route passenger information at stops, stations or terminals is not a strict requirement for support of TCP. However, it is an essential component of any strategy for improving connection service to customers. It typically consists of visual displays and accompanying ADA-compliant audio annunciators displaying the status and ETA for next vehicles by route. This technology is being pursued in parallel by the RTA in its Active Transit Station Signs project.

Computer-aided dispatch (CAD)

Computer-aided dispatch (CAD) is the hardware and software system that leverages location and schedule adherence information to allow dispatchers to better manage service. It typically includes a central data store holding the current status of all vehicles. It supports dispatcher tasks with such tools as displays of buses on a route, queuing emergencies, exception situations and other tasks or messages for the dispatcher’s attention. It also allows a dispatcher to easily communicate a data message or operating instructions to a vehicle operator.

The dispatch system relies on mobile data communications that connect the control center with vehicles and supervisors. A critical determinant of the accuracy of data at the control center is the scheme for communicating with those vehicles. A *synchronous polling* scheme means that communications with a vehicle takes place at a regular time interval regardless of conditions. The more frequent the polling, the greater radio capacity is needed to support this approach. An *exception reporting* scheme, on the other hand, means that under normal circumstances, communication with vehicle on-board processors is infrequent and brief, serving only to confirm that the vehicle’s radio and processor are operating and in range for radio communications. When an exception condition occurs, such as a vehicle falling behind schedule, a report is made to the control center with the amount of deviation. Such reports continue, sometimes at greater frequency, until the vehicle is on time again or finishes its run. More frequent reporting may also be instituted under other circumstances, such as when a vehicle is approaching an intersection with signal priority available, or a protected connection point.

A CAD system, either totally centralized or with a central hub, is a prerequisite for participation in the TCP system.

Mobile data communications

A requirement for any AVL/SD system, and thus for participation in TCP, is mobile data communications to support the transport of messages between the control center and vehicles. This may be provided via a variety of means, including a private radio network, fee based use of a public network such as cellular, or dedicated short range communications (DSRC) with transceivers connected via land lines to the control center. Whatever approach is chosen, adequate capacity is required for communications with vehicles so that current and accurate location information can be made available to the control center.

Scheduling system

An essential component of any AVL/SD system is an integrated scheduling system. For fixed route operations, the scheduling system is used by operations planners and managers to generate timetables and work assignments needed to support the operating plan. An electronic link is required to the AVL/SD system so that when changes are made to routes, runs or timetables, these are communicated to the AVL/SD system so that schedule adherence can be properly tracked.

For paratransit carriers, a scheduling system takes approved trip reservations and recommends vehicle itineraries that will efficiently accomplish those trips. Paratransit scheduling is also often done manually.

An integrated scheduling system is a prerequisite for fixed-route carrier participation in the TCP system. Paratransit carriers are not required to have such a system.

Service restoration capabilities

Service restoration capabilities are an add-on to CAD systems, providing potential solutions to service problems for the dispatcher via artificial intelligence. They may be configured simply to suggest options to a dispatcher, or to implement them without dispatcher intervention.

Connection protection (see below) can be viewed as a specific case of the application of schedule adherence monitoring combined with service restoration capabilities. In this case, both the schedule of the "from" and "to" vehicles are monitored; if a connection is found to be endangered, then the service restoration action of holding the "to" vehicle may be suggested or instituted by the CAD system.

Comprehensive service restoration capabilities are not required for participation in TCP. However, limited service restoration capabilities will have to be developed in order to process endangered connection alerts form the TCP system and forward "hold at connection point" data messages to vehicles.

Traffic signal priority request

Traffic signal priority request is a capability for a transit bus or light rail vehicle to receive priority treatment at a signalized intersection in order to stay on schedule or make up time against schedule. It may be accomplished by the vehicle on-board processor communicating with wayside signal equipment, or by the control center communicating with either wayside equipment or with a central traffic control computer.

Traffic signal priority request is not required for support of TCP, but can help reduce endangered connections by keeping vehicles on schedule.

Passenger counting/load estimation

Transit operators need information on passenger boardings and alightings for a number of reasons. For real time use, current passenger counts or percentage load estimates are useful in identifying potential delays, and making service decisions concerning the loading or transfer of passengers. For historical purposes, ridership information, especially with boarding and alighting counts by stop, is critical to the operations analysis and service planning functions.

With respect to TCP, real time passenger counting information is not a requirement, but can enhance decisionmaking. For example, one may not want to hold a crush loaded vehicle for connecting passengers, nor need one protect a connection when the "from" vehicle is empty.

There are a number of technologies used to detect passenger boardings and alightings and to derive current passenger counts. These include infrared sensor beams in doorways and pressure ("treadle") mats on vehicle steps or in doorways. An alternative method that estimates bus loading on a percentage basis (not boardings or alightings) is instrumentation that measures vehicle axle loadings and infers a load level from those readings.

Intra-Agency Connection protection

Connection protection functionality, as discussed in previous task reports, includes some or all of the following:

- the ability to sense that a connection is endangered
- notification of involved vehicles
- evaluation, based on predefined criteria, of whether the "to" vehicle should be held or other action taken
- the ability to make recommendations for action
- the ability to implement the decision, including transmitting operating instructions if necessary

The ability to protect intra-agency connections is not required for a carrier to participate in TCP. However, it is unlikely that a carrier would want to build the software and communications capabilities necessary for interfacing with TCP without leveraging them also to improve its own service.

Here are additional specific CAD system requirements for support of the TCP system:

- Current, accurate status information on all vehicles must be available at the central site/hub for provision to the TCP hub. A high degree of location accuracy at the central site/hub is required for the TCP system to accurately sense endangered inter-carrier connections. While there is no specific accuracy value required, it can be said that as accuracy decreases, the effectiveness of the TCP system will decrease as fewer of the endangered connections can be identified.

- The system must be able to generate current time and location messages to the TCP system based on the data and on predefined criteria concerning which routes/runs/trips must be reported. Assuming that status on all vehicles must be forwarded to support other functions, this is a significant processing and communications load that must be provided for in the design of carrier AVL/SD systems.

- The system must be able to receive and process notifications of endangered connections and possibly operating instructions from the TCP hub.

Compliance with national/regional standards

Section 5 of the Task 3 report reviewed the relevant regional and national architecture and standards relevant to the TCP project. Here is a brief capsule of those findings:

- One of the main focuses of the Gary-Chicago-Milwaukee (GCM) Priority Corridor Project is the development of the Multi-Modal Traveler Information System (MMTIS). The GCM Gateway is its central element. The Gateway collects data from transportation management hubs throughout the corridor area, processes it, then distributed it through a variety of means to operators, government agencies, media, and the public. The TCP system hub is expected to connect with the Gateway.

  The GCM Gateway is being designed and built in full compliance with the National ITS Architecture, the NTCIP standards, and TCIP profiles (see below). Since it must connect with a number of unlike devices and assure communications with and between them, the Gateway utilizes Common Object Request Broker Architecture (CORBA) as its primary center-to-center communication protocol.

- The National Transportation Communications for ITS Protocol (NTCIP) is the primary communications and data standard concerning the integration of ITS applications. The GCM MMTIS and Gateway system designs will follow the NTCIP Class E profiles for center to center communications. These are still under definition and development.

- The Transit Communications Interface Profiles (TCIP) is an ambitious effort to define the physical, data link and message set requirements for communications between transit vehicles, control centers, other transit facilities, and regional ITS centers such as Traffic Management Centers. TCIP explicitly includes connection protection as a covered functionality. While all known data elements have been defined in detail, there have been no transaction sets developed to support connection protection. That work will be included in Phase 2 of the TCIP project, beginning in year 2000.

Since the GCM MMTIS/Gateway designs are or will be compliant with national ITS standards, the focus of the TCP system design effort will be on satisfying all GCM MMTIS/Gateway design standards. In addition, it is expected that the design team may play a role in the development of national TCIP profiles for transfer connection protection functionality.

Since most standards other than the GCM MMTIS/Gateway design are still in earlier stages of definition and development, there is little in the way of concrete standards requirements for RTA service boards to follow in design and deployment of their ITS AVL/SD and other related systems. However, there are several relevant guidelines for the service boards:

? All designs, specifications and procured or developed systems should follow open systems principles, using non-proprietary industry standards for communications and data definition.

? Specifications and design should follow the relevant object/data element definitions found in NTCIP and TCIP. Systems not developed using these definitions should have data definitions that are able to be one-to-one mapped directly to the relevant NTCIP or TCIP definitions.

? The hardware and software platforms upon which service board AVL/SD systems are developed and implemented must be capable of supporting an installation of CORBA facilities to facilitate communications with the TCP hub or the GCM Gateway. In addition, they should be capable of communications using the Transmission Control Protocol/Internet Protocol (TCP/IP).

? Further design and development of GCM Gateway and MMTIS facilities or components should be monitored closely by RTA and the service boards to assure that those requirements are taken into account as much as possible in ongoing service board design and development of AVL/SD systems.

Paratransit system issues

A detailed review of paratransit AVL/SD systems was not undertaken as part of this study. However, it can be said that such systems must follow the same design principles and guidelines outlined above. In addition, there are several specialized requirements involved in integrating TCP with paratransit AVL/SD systems:

? For transfers *from* paratransit *to* another service, the connection protection problem is one of monitoring whether the requested dropoff time will be met or not, then looking at whether this endangers the connection with the other service. For transfers *to* paratransit *from* another service, the problem is a specialized version of the no-show problem, since a late connecting service may cause the driver to arrive at the pick-up point before the passenger has arrived.

? A separate “request for connection” function is not needed for trips originating on paratransit. The information can be (and often is today) easily recorded when the passenger calls to make a reservation and gives a origin or destination of a Metra stop, transit hub or designated transfer point. Enhancements would be needed allowing the reservations operator to confirm that the passenger intends to transfer and record the connecting service desired. Access to fixed route schedule files might also be desirable.

? In order to protect connections from paratransit to another carrier, regularly updated ETAs from the paratransit vehicle are required. These can typically not be generated automatically because there is no schedule to compare actual locations and times to. One way to get ETAs is to have the driver report them based on his or her judgement, then use them to determine if a connection is endangered. The others, significantly more complicated, would be to develop historical link travel times for repetitive trips, then use them to predict ETA's; or, to integrate a software package for trip routing into the AVL/SD system, then use the generated route along with actual or historical link travel times. However it is done, it will be a complicated matter to resolve in the TCP design if paratransit is to be included.

? For connections from another carrier to paratransit, connection protection is usually thought of as providing the driver with updated ETA information after he or she has arrived at a pick-up point and the connecting service has yet to arrive. This is because there are no electronic links currently available. However, the preferable approach will be to notify TCP well before the scheduled pick-up time, then update the reservation with actual expected arrival times so that a vehicle can be dispatched at the proper time in order to minimize waiting time. Ad hoc communications can still take place if there is a last minute change in status.

? In the design and development of paratransit AVL/SD systems, service boards and their contract operators should take into account the potential requirements for the ability to 1) update pick-up times at transfer points based on actual status of the connecting service; and 2) report actual ETA's on trips where the passenger(s) wish to connect with another service.

REVIEW OF SERVICE BOARD AVL/SD SYSTEMS

In this section, the AVL/SD system plans, designs and development for each of the RTA service boards are reviewed. First, a table detailing functional capabilities, development status and standards compliance of four service board AVL/SD systems is provided. These systems are: the CTA Bus Emergency Communications System (BECS)/Bus Service Management System (BSMS); CTA's Rail Service Management System (RSMS); Metra's Train Information Management System (TIMS); and Pace's Intelligent Bus System (IBS). Second, a summary narrative about each carrier's systems is provided.

Table of carrier system functionality

Table 1 details the system functionality of four carrier AVL/SD systems that would potentially be required to interface with the TCP system. It follows the structure used in the previous section to review AVL/SD system functionality. Also, as noted earlier, all are not requirements for interface with an inter-carrier transfer connection protection system.

Chicago Transit Authority (CTA)

The CTA has separate AVL/SD systems for its bus and rail operations. The Bus Emergency Communications System (BECS)/Bus Service Management System (BSMS) will be used to manage mainline bus operations and service. Rail service is currently managed using the Rail Service Management System (RSMS).

BECS/BSMS

BECS and BSMS taken together represent a comprehensive system designed to better manage all aspects of bus service delivery. BECS comprises basic AVL, an on-board processor, vehicle area network, and data communications capabilities. BSMS is to add computer-aided dispatch (CAD), a driver interface, schedule and headway adherence monitoring, en-route passenger information, signal priority request, service restoration capabilities, intra-carrier connection protection, and an interface for inter-carrier connection protection.

CTA uses the current release of HASTUS for bus service scheduling and development of bus work assignments. An electronic interface with BSMS is to be included in the delivered BSMS.

The design of BECS/BSMS calls for adherence to open systems principles and standards. It should be capable of handling any requirements for linking with the TCP hub or GCM Gateway under current or future communications protocols or standards.

SYSTEM COMPONENTS	CTA BECS/BSMS	CTA RSMS	METRA TIMS	PACE IBS
Stage of Development	Orbital Sciences Corp. under contract to provide BECS and BSMS demo. Some equipment on buses already. BSMS installation is expected during 2000.	Fully implemented and operational.	Invitation for Bid (IFB) No. 65380 was issued in early 1999. The bid opening date was April 29, 1999. Contract award for the pilot was recently made to GeoFocus, Inc. The pilot covers five railcars on two Metra routes.	Pace RFP 84000, for consulting services to develop IBS specifications, was issued in early 1999. The contract was awarded in May 1999 to Macro Corporation. Specifications development has a scheduled duration of 5 months. It is hoped that initial implementation will begin in 2000.
Automatic Vehicle Location (AVL)	BECS specifies differential GPS (DGPS) for support of emergency response. BSMS specifies an enhanced location subsystem using odometer and route-matching technology. Both include specific accuracy requirements.	Relies on train sensors located along tracks. These are monitored by the dispatch computer via existing wireline connections. Accuracy is dictated by the frequency of detectors. Sometimes more than one train can be in a segment between detectors.	GPS transceivers specified as part of MIT. Must provide train location, velocity and acceleration outputs. No accuracy requirements stated.	AVL system is specified, including route map matching and schedule adherence as well as possible additional items. Required accuracy not yet determined.
On-Board Processor	BSMS specifies an on-board processor supporting J1587 and J1708 standards and networked via standard J1708 connections.	There is no on-board processor for support of this application.	Mobile Information Terminal (MIT) installed on an accessible railcar in each trainset. It controls on-board devices and includes all components necessary to the functioning of TIMS.	IBS concept includes an on-board processor.
Control Head/Driver Interface	BECS specifies a driver interface terminal also used by BSMS.	The driver receives commands via voice or via cab or wayside indicators. There is no display and keypad supporting this application.	Keyboard with LCD display included in the MIT.	IBS concept includes a driver interface.
Vehicle Area Network	BECS/BSMS specify a standard J1708/J1587 vehicle area network allowing communications between all attached devices. Standard J1708 connections and industry standard cabling are specified.	Not applicable	All devices are connected to the MIT. No network protocol specified.	Not explicitly addressed in the high level functional requirements.
Schedule Adherence Monitoring	On-Board capability. Displayable at control center	Schedule adherence is determined at the control center by RSMS.	Incorporated in system to support display of ETAs and paging of operating personnel in the case of exception situations.	Specifically identified as an on-board capability.
Headway Adherence Monitoring	Project goal. Means unclear at this time.	Minimum headways are enforced by the signal system. The system monitors schedule adherence and dwell times to identify problems. Dispatchers can use system commands to enforce spacing in case of a service interruption.	Commuter rail operations are entirely schedule driven. Minimum spacing is automatically enforced by signal systems.	Not explicitly identified at this time. Would apply to few, if any, Pace routes.

Table 1: Service Board AVL/SD System Functionality

SYSTEM COMPONENTS	CTA BECS/BSMS	CTA RSMS	METRA TIMS	PACE IBS
On-Board Passenger Information Infrastructure	PA system available. On-board signs/annunciator not being procured with BSMS, but are to be supported as J1708-attached devices using standard J1587 message ID's (MIDs).	None at present other than PA system. Future plans include equipping rapid transit cars with audio and visual displays.	Option 1 of IFB includes separately priced provision of on-board visual and audio displays	IBS concept includes en-route transit information, including on-board, pre-trip and stop based.
En-Route Passenger Information Infrastructure	Active bus stop signs displaying ETA to next vehicle by route are included in BSMS demo.	Lights at selected stations warn of an approaching train. Future plans include station displays.	Existing infrastructure of display monitors in downtown terminals and LED displays at outlying stations will be used.	See above.
Computer-Aided Dispatch (CAD)/Reporting Scheme	BECS provides basic dispatcher control center infrastructure. BSMS expands with second monitor for route level displays. System uses 70 second polling, moving to 15 seconds on an exception basis when a bus is early/late or when otherwise required (e.g. for signal priority request). 70-second poll includes basic location update available to applications but not to dispatch displays.	Train sensors generate a signal when trains pass them. Signals are sent to wayside indicators to effect service adjustments. There is no polling and no wireless communications involved.	TIMS is not a CAD system and is not electronically linked with the existing dispatch systems controlling Metra train movements. TIMS will include a schedule database, and will provide screens for tracking train status, controlling passenger displays at stations, controlling on-board passenger information equipment, and reports.	Pace has division-based dispatchers. IBS concept includes a CAD system which would have a central computer supporting client workstations at the different divisions where dispatching is currently done. Ideally the system would support a seamless migration to centralized dispatch in the future if desired. IBS concept calls for a high degree of on-board system intelligence, and envisions an exception reporting architecture.
Mobile Communications Subsystem	CTA purchasing an upgraded private radio data network to support BECS/BSMS. A total of 8 25 kHz channels available.	In addition to the wireline capabilities of RSMS, hand-held radios operating in the 470-474 MHz range are used for two-way communications between dispatchers and operators.	For pilot, vendor will provide an ATCS standard packet switched radio network for use for TIMS mobile communications. For full implementation, Metra prefers a private ATCS radio system.	Pace will utilize channels from its existing trunked radio system, now used exclusively for voice communications. A total of five channels are currently in use in the 858-860 MHz band.
Scheduling System (fixed route)	CTA recently moved to current version of HASTUS. Means of supplying HASTUS data to BECS/BSMS not finalized; most likely through "data preparation workstation".	Schedules are developed by Service Planning using G/Sched. They are then transferred in the form of a WordPerfect tile to RSMS where they can be processed.	See above.	Pace currently uses HASTUS and has recently upgraded to a new version. IBS concept includes a link (ideally electronic) between HASTUS and the IBS central processor.
Service Restoration Capabilities	Support for identification of service impacting events (SIEs) and system suggestion of service restoration actions is called for at stage where BSMS is extended to entire fleet.	System provides commands for a wide variety of service restoration actions, available to the dispatcher for use as appropriate. These commands automatically reschedule one or more runs as appropriate.	Not in TIMS scope.	Not specifically identified.

Table 1: Service Board AVL/SD System Functionality

SYSTEM COMPONENTS	CTA BECS/BSMS	CTA RSMS	METRA TIMS	PACE IBS
Traffic Signal Priority Request	Included in BSMS demonstration. Expected to use radio short-range radio communications with wayside equipment. Current IDOT standard is based on embedded inductive loops.	Not applicable – no operation on highway network; trains have right-of-way at grade crossings.	Not applicable; commuter trains already have the right-of-way.	Specifically included as an IBS priority capability. Will follow IDOT standards.
Passenger Counting/Load Estimation	Approximately 40% of vehicles currently covered. Link to BECS/BSMS not specified at this time.	There is no automated counting on-board vehicles. There are plans to utilize information from the AFC (fare collection) system to estimate loadings.	Manual passenger counts on-board trains for ridership tracking purposes. No link to TIMS or dispatching.	Incorporated in IBS concept, with real time integration of this data with other on-board data.
Intra-Carrier Connection Protection	Included in BSMS demonstration. Means still under development. Initially will support at least one of two approaches (pre-defined or on request). Protection of CTA rail connections will come later.	Supervisors perform limited connection protection between trains according to policies and procedures. Future plans after BSMS is implemented are to interface the two systems to provide protection.	Not in TIMS scope.	Included in IBS concept.
Inter-Carrier Connection Protection	Unspecified hooks to be in place for this in BSMS.	Special sensors trip lights at certain stations to inform buses and passengers that a train is approaching.	Not in TIMS scope.	Included in IBS concept.
Architecture/Standards Compliance	BSMS design based on open systems approach. Will support TCP/IP as required. Other standard communications protocols yet to be decided on, but no indication they could not be supported.	Control center installation conforms to open systems principals. Not known how forthcoming TCIP profiles will match up with RSMS functionality.	The TIMS Master Base Station computer is attached to a Metra Ethernet LAN providing access to Metra's WAN using TCP/IP. Connection should be possible. Expect all standard communications profiles could be supported. Unclear if TCIP profiles could be supported from the TIMS application.	Development guidelines for IBS explicitly call for the design to be consistent with Federal, State and Regional ITS architectures.

Table 1: Service Board AVL/SD System Functionality

Orbital Sciences Corporation is under contract to CTA to deliver BECS and BSMS. The new BECS data communications system has been installed, along with on-board BECS equipment. As of this writing, activation of BECS by garage is underway. Installation of the BSMS demonstration system (a portion of one garage) is slated to begin later in 1999 and be completed in the second half of 2000.

RSMS

The RSMS is an AVL/SD system covering CTA's rail operations. It provides AVL capabilities through track sensors, linked with the control center and CAD system via wireline connections. In addition to CAD and AVL, RSMS includes schedule and headway adherence monitoring, limited en-route passenger information using train arrival lights at selected stations, and extensive service restoration capabilities. Future plans include on-board and en-route passenger information displays and announcements, and integration with BECS/BSMS to provide connection protection between CTA bus and rail.

The CTA uses G/Sched to develop schedules for rail operations. It is interfaced to RSMS via a WordPerfect file from which RSMS extracts the schedule information it requires.

The RSMS installation conforms to open systems principles. It is not known how RSMS will match up with the forthcoming TCIP profiles.

RSMS is fully installed and operational.

Metra

Metra's TIMS is designed to collect location information from operating trains for passenger information and dispatcher use. TIMS will include a schedule database, and will provide screens for tracking train status, controlling passenger displays at stations, controlling on-board passenger information equipment, and reports.

The TIMS pilot system is to include five cars on two Metra routes – SouthWest Service and the Milwaukee District North Line. It is to be deployed at the Metra Consolidated Control Facility, where Metra-operated lines are dispatched. Dispatchers can use the information as an alert to service problems and to better manage operations. Passenger information displays can be driven by it in order to provide riders with better information about their journeys. TIMS will provide information on train status relative to schedule, and ETA's.

The TIMS system includes GPS-based AVL capabilities, an on-board processor with operator interface, packet switched radio data communications following the Advanced Train Control Systems (ATCS) standard, schedule adherence monitoring, an option for on-board audio and visual displays, and use of existing station-based displays to provide en route information. While dispatchers can view and update TIMS information via a dedicated workstation, there is no direct electronic link between TIMS and Metra or contract carrier dispatch systems.

The TIMS system specification complies with open system principles. It is not known how TIMS will match up with the forthcoming TCIP profiles.

Metra issued an RFP for development of TIMS early in 1999. With the job recently awarded to GeoFocus, Inc., Metra hopes to have their pilot up and running by early 2000. Full Metra system implementation would follow a successful pilot. It is not clear if, or how, contract operator dispatchers might be given access to the system.

Pace

The Pace IBS system is planned to be a comprehensive system for bus service management. It is well defined at a high level, based on past design work and the detailed efforts of the Pace IBS

Table 1: Service Board AVL/SD System Functionality

committee. The current design includes AVL, an on-board processor, driver interface, CAD system, mobile communications using frequencies form the existing private trunked radio system, schedule adherence monitoring, on-board and en-route passenger information infrastructure, traffic signal priority request, integrated passenger counting, and provisions for both intra-carrier and inter-carrier connection protection.

Pace currently uses HASTUS and is upgrading to the current release. The high-level IBS design calls for a link between HASTUS and the IBS central system.

IBS is intended to adhere to open system principles so as to promote competitive procurement of future components. In addition, Pace has indicated that they intend for IBS to be compatible with Federal, State and Regional standard architectures.

Pace has retained Macro Corporation as consultants to perform IBS specification development. This work began in June 1999. Implementation of the initial pilot system is hoped to begin in 2000.

Table 1: Service Board AVL/SD System Functionality

TCP AND STANDARDS COMPLIANCE ISSUES

The project team reviewed each service board's AVL/SD systems with respect to 1) the functional requirements for support of TCP, and 2) compliance with GCM and national architecture and standards. For each service board, this section identifies areas where there may be compliance issues, along with the actions that may be required to address them.

CTA

BECS/BSMS

? The approach to intra-carrier connection protection has not been finalized. Therefore, there is still time to provide guidance to CTA and Orbital Sciences Corporation. In addition, it is not known whether BECS/BSMS will support passenger requests for connection, predefined connections, or both.

? There may be an issue with the level of location accuracy available at the BSMS central system. Since CTA's system architecture is based on exception reporting; under normal operations, there will be a location update available every 70 seconds at the central site. Under exception conditions or potentially during periods of light operations, a location update will be available every 15 seconds. The result of this is that at peak periods, a bus could be up to 70 seconds earlier or later than the system currently shows. Higher accuracy would require additional radio frequencies to be made available – an unlikely prospect. It is not yet known whether this level of accuracy will be adequate to support the TCP system.

? In the future, if customer requested connections are implemented, on-board passenger information displays may need to be added to display responses, in case long response times make it infeasible to give passengers an immediate response.

RSMS

? The RSMS design does not currently include any provision for connection protection with CTA bus or other carriers, either predefined or passenger-requested. It is planned to develop this capability after BECS/BSMS is substantially implemented.

? Since the system currently has extensive service restoration capabilities built in, and the ability to hold trains at station platforms, it should not be unusually difficult to extend these capabilities to be used for connection protection.

? In the future, if customer requested connections are implemented, an on board processor with data communications and a operator (driver) interface may be needed for input of requests and receipt of responses, unless it is feasible to do this via voice with rail controllers. In addition, on-board passenger information displays may need to be available to display responses, in case long response times make it infeasible to give passengers an immediate response.

Metra

? Metra's TIMS system is not electronically linked with Metra or contract carrier dispatch systems. Further, integrating the systems in this way could be prohibitively expensive and might be technically impossible. As a result, there will be some limitations to Metra's participation in TCP, as outlined in the bullets below:

Table 1: Service Board AVL/SD System Functionality

- Metra can be a fully participating partner in the TCP base system. This means that TIMS enhancements should be possible to 1) electronically transmit train status to the TCP system; and 2) receive notices of endangered connections from TCP and forward them to a dispatcher terminal as an alert. However, Metra's ability to respond to endangered connection alerts will be inherently limited by the need for dispatchers to consult the separate TIMS display in order to receive the information.

- It would probably be infeasible for Metra to fully participate in any future TCP customer request option. It is true that TIMS could be modified to accept customer connection requests on board its trains and forward them to the TCP system. However, Metra could not respond without human intervention to customer requests forwarded from other carriers. This would result in an unacceptable response time to customer requests, negatively impacting public acceptance of the program.

Pace

- Since the current IBS design is high-level only, the approach to intra-agency connection protection is not finalized. This means that there is still time to provide guidance to Pace and Macro Corporation for specific requirements related to the TCP system.

- As with the CTA's BECS/BSMS, Pace expects that IBS will utilize an exception reporting architecture, which can limit accuracy at the central system. The normal "health" polling rate has not yet been determined. Also like the CTA, Pace must make do with a limited number of radio frequencies, with little prospect of obtaining additional ones. Thus, at this point it is unknown whether Pace will be able to provide sufficient location accuracy at the IBS central system to support the TCP system.

- Pace has made a commitment to an open systems architecture and to compliance with all applicable GCM, TCIP and NTCIP standards and profiles.

Table 1: Service Board AVL/SD System Functionality

SUMMARY OF FINDINGS AND REQUIRED ACTIONS

A general summary observation from the consulting team's review is that all three service boards are to varying degrees still open to design input if it addresses requirements to support TCP. For the same reason, it is impossible to assess compliance at a detailed level. Further, the relevant national standards and to a lesser extent the GCM design are still being developed and refined.

With all this uncertainty, it is perhaps most important that there be ongoing communications about developments in each relevant area (GCM, NTCIP, TCIP, BSMS, RSMS, TIMS, IBS, Active Transit Station Signs and Parking Management Systems projects, RTA Itinerary Planning System (IPS)) so that the service boards can synchronize and adjust their efforts as necessary. All three service boards have acknowledged a willingness to work toward the objectives of the TCP systems. We also expect that in later tasks of this project, we can provide more specific TCP functional design guidelines to assist the service boards in their efforts. Especially important among these will be requirements for location accuracy at the control center.

The remainder of this section summarizes the findings and required actions we can identify at this time:

- The service boards need to continue to assure that their AVL/SD system designs, specifications and procured or developed systems follow open systems principles, using non-proprietary industry standards for communications and data definition. It is particularly important that they be capable of supporting an installation of CORBA facilities to facilitate communications with the TCP hub, GCM Gateway, RTA, other service boards, and additional future hubs. In addition, they should be capable of communications using TCP/IP.

- The service boards should endeavor to assure that their AVL/SD specifications and designs incorporate the relevant object/data element definitions found in NTCIP and TCIP. Systems not developed using these definitions should develop and test data definitions that are one-to-one mappable directly to the relevant NTCIP or TCIP definitions.

- Service boards should be aware in their systems planning that TCP may impose significant system modifications and additional processing requirements on their AVL/SD systems. The required functions and workloads will include generation of service status reports to TCP, and processing endangered connection notifications from TCP. These applications may generate enough additional message traffic to warrant a capacity review of service board wide area data communications facilities.

- In their ongoing AVL/SD system design and development efforts, the service boards need to take into account the need for a relatively high degree of vehicle location accuracy at their central site/hub. The more accurate the information available at the carrier hub, the more effective the TCP system will be in sensing endangered inter-carrier connections. Accurate data at the carrier hub is also a likely requirement of the Active Transit Station Signs and Parking Management Systems projects being progressed by the RTA and service boards in parallel with this project.

- In their ongoing design and enhancement of paratransit AVL/SD systems, service boards and their contract operators should take into account the potential requirements for enhancements to paratransit reservations systems to facilitate the gathering of more specific information about desired connections. In addition, consideration will need to be given to providing the ability to 1) update pick-up times at transfer points based on actual status of the connecting service; and 2) report actual ETA's on trips where the passenger(s) wish to connect with another service.

Table 1: Service Board AVL/SD System Functionality

REGIONAL TRANSPORTATION AUTHORITY
TRANSFER CONNECTION PROJECT (TCP)

TASK 7 FINAL REPORT:
REVISING CONNECTION POLICIES

Prepared by:
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February 22, 2000

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Table 1: Service Board AVL/SD System Functionality

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EXECUTIVE SUMMARY

This report provides a template for the analysis of existing policies, procedures and responsibilities around serving inter-agency connections. It is the fifth in a series of reports from the Regional Transportation Authority (RTA) Transfer Connection Protection (TCP) Project.

In Section 2, the document recaps the "inter-agency connection problem" faced by RTA service boards, where day-to-day coordination of inter-agency connections is hampered by lack of information and facilities for direct communications. It also summarizes the TCP system and its stages of implementation, as follows:

- Stage 1: TCP base system for automatic connection of pre-defined inter-agency connections
- Stage 2: Paratransit TCP, extending the base system to cover connections to and from paratransit trips

Section 2 also provides a discussion of how the TCP system, as a part of the Gary-Chicago-Milwaukee (GCM) Corridor Intelligent Transportation Systems (ITS) Architecture, may help address the inter-agency connection problem.

Section 3 begins with definitions of terms, then lays out a template for service board policies on inter-agency connections. This template can assist agency personnel in planning and performing a review of inter-agency connections from a variety of perspectives. It identifies a series of questions that can be asked to spur thinking and point to further analysis needs. Finally, it provides a framework for identifying recommended changes and advancing them for senior management approval.

INTRODUCTION

The Inter-Agency Connection Problem

Many public transit users use inter-agency connections as part of their daily trips – beginning them on the services of one service board, and completing them on another. In some cases, especially feeder routes, agencies recognize this by coordinating their scheduling at connection points. In others, there is no explicit coordination of schedules. In these instances, agency staff on the scene may still attempt to coordinate through visual or other means.

Even with coordinated scheduling, problems with inter-carrier connections can develop easily with even modest service problems such as a late vehicle. If one vehicle approaching a possible connection is late, then there is the possibility that passengers on the late vehicle will miss this connection if the other vehicle is running closer to schedule. This will result in a longer-than-anticipated passenger wait time. If service is frequent on the route, then the wait may be minimal. However, in other situations, such as longer headway routes or night/weekend/owl service, the wait may be substantial. Unfortunately, today there is no straightforward way for agencies to collect and share this information with each other on a current basis so that adjustments can be made.

Longer wait times due to missed connections often lead to a number of negative impacts on passengers: late arrival or a missed appointment, aggravation, exposure to inclement weather, and in some cases real or perceived security threats to the waiting passenger. If the problem is more widespread, it can lead to ridership and revenue losses. Employees are affected as well, having to deal with irate passengers. There is also the chance of negative publicity being generated about the problem.

The RTA Transfer Connection Protection (TCP) Project

The new AVL and dispatch systems being installed by all three RTA service boards create an opportunity to address the inter-agency connection problem. The RTA Transfer Connection Protection (TCP) project takes advantage of that opportunity, by creating an infrastructure for pooling of schedule and schedule adherence data, continually examining it for potential inter-agency connection problems, then notifying the agencies when one is found. The TCP system will operate as part of the larger Gary-Chicago-Milwaukee (GCM) Corridor Architecture for Intelligent Transportation Systems (ITS).

The TCP system as envisioned at this point falls into two stages. Stage 1, the base TCP system, automatically detects predefined connections in danger of being missed, and informs service boards electronically, with subsequent updates. Stage 2, Paratransit TCP, enhances the base system by including the contract paratransit operations of the Chicago Transit Authority (CTA) and Pace. Desired connections are identified at reservation time and later provided to the TCP system. It then protects these connections just as the Stage 1 system does.

The TCP system will operate around the clock, seven days a week. It will focus on protecting connections to longer headway routes, limited service period routes, evening/weekend/owl service, and last trips of the day. Most "near misses" can also be prevented by the system if there is enough radio capacity to support frequent vehicle to dispatch computer messages with updated schedule adherence.

The TCP system and its motivation have been described in greater detail in several previous project reports. These are described below:

? The Task 1 report, *Needs Analysis,* identifies needs, priorities, and the relationship between service management and TCP.

- The Task 2 report, *Synopsis of Existing Carrier Connection Policies,* details the existing connection-related policies of each service board, then summarizes common threads and key findings.
- The Task 4 and 5 report, *Inventory Existing Scheduling/Dispatching System/Integrate With AVL and Scheduling/Dispatching System,* reviews the features of transit AVL/dispatch systems and their relevance to the TCP system. It then discusses the AVL/Dispatch systems plans of each of the service boards, and identifies TCP and standards compliance issues to be addressed by each.
- The Task 6 report which presents functional requirements for the TCP system.

Purpose of This Report

This report is designed to complement the systems design efforts undertaken under the TCP project. In order for the system to be effective, the agencies participating need to have appropriate policies in place concerning the priority to be given to inter-carrier connections, as well as procedures for implementing the priorities. This report provides the RTA and its service boards with a checklist or "template" for reviewing and revising connection policies along these lines.

In conjunction with this report, it may be helpful to review the TCP Task 2 report, *Synopsis of Existing Carrier Connection Policies,* mentioned above.

POLICY FRAMEWORK FOR INTER-AGENCY CONNECTIONS

Purpose of this section

This section provides a policy template for use by the service boards, with RTA support, in setting and refining specific policies and procedures concerning inter-agency connections. It identifies a series of questions that can be asked to spur thinking and point to further analysis needs. It then provides a framework for identifying recommended changes and advancing them for senior management approval.

The policy template does not tell the service boards what their policies should be. Instead, it identifies questions worth asking and issues that need to be addressed. Potential uses include a stand-alone study by a single service board, a collaborative study among two or three service boards, or an RTA-sponsored review.

Definitions of terms

There are a number terms used in the following material that have similar meanings. This section defines the terms as they are meant to be interpreted, and provides hypothetical examples relevant to the TCP project:

Mission (or Mission Statement)

A summary statement indicating why the organization exists and what it hopes to provide its customers with. *Example:* "The mission of <agency> is to provide superior quality service to all its customers, supporting seamless connections with other agencies in the region."

Goal

A high-level agency target consistent with its mission or other imperatives, often the result of a planning effort. *Example:* "<agency operating unit> will improve its performance on inbound connections without significant increases in overtime costs."

Objective

A specific measurable target in support of a goal. *Example:* "<agency operating unit> will improve performance on off-peak inter-agency connections at <specific connection points> by 10% while holding overtime costs steady with a maximum increase of 1.5%."

Policy

A high-level or detailed statement indicating the organization's position or intent on a particular issue. *Example:* "It is <agency's> policy when making service decisions to fully consider the needs of passengers connecting to and from other agencies' services."

Rule

A formal requirement stipulated in an agency's rule book or other repository of instructions that field service personnel are required to follow. Rule infractions are subject to discipline; compliance with rules is a condition of employment and is often covered in collective bargaining agreements. *Example:* "(Rail) operators shall hold for connecting passengers when a connecting train is on an adjacent track in the station."

Procedure — Similar to a rule. They may have the force of rules or may simply be guidelines. *Example:* "When at a connection point, drivers should visually check for connecting vehicles in sight before departing."

Practice — An informal, undocumented procedure that has evolved in an agency over time.

Policy Template for Inter-Agency Connections

The following policy template is designed to guide agencies in reviewing all aspects of inter-agency connection policies, procedures and performance, with the goal of identifying changes leading to improvement. The template is in four Steps:

? Step 1, Organize, covers the tasks necessary to define, staff, plan and control the effort.

? Step 2, Inventory, lists a number of things that should be inventoried at the outset of the project, including relevant goals and objectives, policies, and existing inter-agency connection points.

? Step 3, Analyze, suggests a series of questions to stimulate further discussion and lead to internal or external analyses, all toward the end of identifying problem and opportunity areas with respect to inter-agency connections.

? Finally, Step 4, Recommend Changes, provides a template for doing just that. Recommended changes to mission, goals, objectives, policies, etc. can be identified, to then be summarized and presented for senior management review, approval, and ultimate dissemination and implementation.

REGIONAL TRANSPORTATION AUTHORITY
TRANSFER CONNECTION PROTECTION (TCP) PROJECT
POLICY TEMPLATE WORKSHEET

STEP 1: ORGANIZE

Identify stakeholders – those who have a vested interest in the revised policies, objectives, etc. that may result from this effort.

Identify project leader – an individual with the skills, experience and agency understanding to lead the effort.

Set up project team – a set of individuals with the support of their respective managers, who can contribute as team members to the success of the effort. Operating positions that should be represented include operators/trainmen, field supervisors, and dispatchers.

Set up senior management review team – top managers who will review the team's work in a timely fashion and provide the necessary feedback, support and approvals.

Lay out a plan of action – Clearly state the project objective(s). Identify the tasks needed and their relationships to one another (i.e. precedences). Identify milestones representing key points in the project.

Assign area and task responsibilities – appropriate to each individual's skills and regular job responsibilities.

Set up a project timetable – based on the availability of team members and the relationships between tasks. The timetable for reaching milestones becomes a high-level project schedule.

Get Senior Management Review Team OK – for all the above deliverables.

REGIONAL TRANSPORTATION AUTHORITY
TRANSFER CONNECTION PROTECTION (TCP) PROJECT
POLICY TEMPLATE WORKSHEET

STEP 2: INVENTORY

Mission – identify the entire agency mission or selected components relevant to intermodality or inter-agency connections.

Goals – identify any existing agency goals relevant to intermodality or inter-agency connections.

Objectives – identify any existing agency, departmental or local goals relevant to intermodality or inter-agency connections.

Policies – identify any existing agency, department, or local-level policies relevant to intermodality or inter-agency connections.

Rules, procedures and practices – identify any current rules, procedures or practices governing inbound or outbound inter-agency connections. This includes the current responsibilities, information flow and decisionmaking around inter-agency connection protection.

External requirements or constraints – identify any regulatory, legal, political or interest group issues that may affect the analysis or influence decisionmaking.

Characteristics of existing inter-agency connections – identify existing connection points: connecting carrier, location, your route(s) and runs/trains involved, connecting carrier routes and runs/trains involved, and one-way or two-way connection. Further analysis of specific trip-to-trip connections is also desirable, and will require sharing of schedule files between agencies. Estimated numbers of daily users of the connection are also very helpful. Finally, known problem areas based on driver feedback, patterns of passenger complaints, or other sources can be focal points for early improvement efforts.

Constraints to protecting connections – identify general or specific constraints that affect the ability to protect 1) inbound inter-agency connections; 2) outbound inter-agency connections. These may be internal (e.g. budget, equipment, facilities capacity, downstream impacts, lack of information) or external (e.g. holds at stops delay traffic; connecting carrier procedures, lack of information, local prohibitions on idling buses)

REGIONAL TRANSPORTATION AUTHORITY
TRANSFER CONNECTION PROTECTION (TCP) PROJECT
POLICY TEMPLATE WORKSHEET

STEP 2: INVENTORY (Continued)

Market research or surveys – identify any internal or available external research or survey results pertaining to customer satisfaction with connection performance (ideally inter-agency connections); perceptions about service over connections; identification of specific problem areas or problem connections. One possible source could be ongoing survey/measurement programs for customer service, such as the Pace Customer Service Index (CSI) program. RTA also has a User Survey with similar results.

Plans for future inter-agency connections – identify any such plans, due to service expansion, new stops/stations or transfer facilities, or new cooperation around existing connections.

REGIONAL TRANSPORTATION AUTHORITY
TRANSFER CONNECTION PROTECTION (TCP) PROJECT
POLICY TEMPLATE WORKSHEET

STEP 3: ANALYZE

After collecting and reviewing the material in Section 2, the project team must proceed to identify any changes they will recommend in mission, objectives, policy, etc. One way to proceed with this is to ask a series of questions and brainstorm about the responses. Once these and/or other questions identified by the team have been posed and discussed, and supporting analyses completed, the findings can be organized into recommended changes using the template in Section 4.

When considering these questions and the formulation of changes in Section 4, it may be useful to consider in what time frame each of the identified changes might be first relevant and effective:

? Immediate or short-term changes
? Changes with/after agency AVL/dispatch implementation
? Changes with/after Stage 1 TCP
? Changes with/after Stage 2 TCP

<u>Suggested Questions/Issues/Topics</u>

1) Do we know where inter-agency connections are actually taking place? If not, how can we find out? [There are often data sources that could provide this information, such as fare collection system data or patterns in ticket purchases. Current service monitoring and route analysis may also yield useful information. A market research study is recommended if there is not already one addressing this point.]

2) What are the priority connection points or specific connections where improvements will have the greatest impact? Identify not only location but time of day, one-way or two-way, etc. For example, there could be a regular crunch at a specific connection point after school lets out, or after a factory shift change.

3) How do we address the problem of responsibility to the customer for their trip when there is more than one agency involved? Should there be an agreement with connecting carriers on assigning responsibility for monitoring and follow up on recurring problems? (Examples could include either the first or second carrier always having primary responsibility, or having the farecard owning system be responsible. The airline "code sharing" example may also be relevant.) Should there also be ongoing reviews between agencies to prioritize connections and review possible schedule adjustments or other improvement measures?

STEP 3: ANALYZE (Continued)

4) If we wish to improve performance across certain inter-agency connections, what decision criteria should our dispatchers, field supervisors and or computer-aided dispatch (CAD) systems take into account? (Examples could include downstream impacts on: 1) a held vehicle and its current passengers; 2) passengers waiting to board this vehicle; 3) later trips to be made by this vehicle/crew; 4) crew availability (hours of service restrictions); 5) crew overtime; 6) safety considerations.

5) How much is our agency willing to accept deterioration in on-time performance in order to advance the goal of better intermodality and inter-agency connections?

6) How might the roles of agency staff, especially field operations staff, change in line with increased focus on inter-agency connections? How might the autonomy of those people be increased or decreased? [For example, a field supervisor equipped with a mobile data terminal and access to TCP information might now be able to make on-the-spot decisions about holding for inter-carrier connections. Also, dispatcher priorities could come to include a broader perspective of multi-modal service.]

7) Are the current policies or guidelines on authorized hold times without dispatcher approval still adequate? How about guidelines for dispatchers themselves, if any?

8) How are our fixed-route and/or paratransit contractors affected by the contemplated changes? Do current or future contracts need to be modified to reflect specific service expectations with respect to inter-agency connections?

9) With our agency's participation in the TCP base system (Stage 1), are we willing to hold a vehicle for another carrier's inbound connecting vehicle? What will be our agency's criteria in making the determination about whether to do so? How might this change with Stage 2?

10) What does it mean to "guarantee" a connection? Should this be considered at some point in the future? For example: FedEx essentially guarantees overnight delivery by mid-morning in its largest markets. Yet 1% of shipments fail to meet the service "guarantee". They are willing to make recompense to shippers. Might something similar to this, such as a free or reduced-cost ride voucher system, work in public transportation in the future, say for selected connections or some class of connections? Or could a regional program for guaranteed ride home or guaranteed trip completion be an effective alternative?

Agency project teams are encouraged to develop additional questions that will stimulate thinking and identification of improvement opportunities for inter-agency connection performance.

REGIONAL TRANSPORTATION AUTHORITY
TRANSFER CONNECTION PROTECTION (TCP) PROJECT
POLICY TEMPLATE WORKSHEET

STEP 4: RECOMMEND CHANGES

For all items, indicate timeframe: now, after AVL/dispatch implementation, with/after TCP Stage 1, with/after TCP stage 2

Modify Mission -- explicitly incorporate inter-agency connections and intermodality if not already there.

Add appropriate goals and objectives – can begin before TCP system through selected low tech or direct agency to agency information sharing.

Establish new policies or modify existing ones – to address (for example) agency priorities for inter-agency connections, or expectations of all employees with respect to inter-agency connections and the passengers who use them.

Identify needed changes to rules and procedures – these can then be progressed at appropriate times.

Identify needed changes with service contractors (fixed route or paratransit) – so that they can be included when contract renewals or new procurements occur.

Identify specific cooperative actions desired with connecting service boards – so that discussions can be scheduled to come to agreement and progress them.

Develop a draft implementation plan – encompassing actions to be taken, priorities, roles and responsibilities, schedules, milestones, costs and measures of effectiveness.

Assemble and present final recommendations – for senior management review team consideration and approval.

Modify implementation plan, then seek final approval – based on comments received.

Disseminate and implement approved changes – at an appropriate time after significant changes have been implemented with AVL/Dispatch or TCP system technologies.

REGIONAL TRANSPORTATION AUTHORITY
TRANSFER CONNECTION PROTECTION PROJECT (TCP)

TASK 8 FINAL REPORT:
FUNCTIONAL REQUIREMENTS

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February 22, 2000

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INTRODUCTION

Project Overview

The Gary-Chicago-Milwaukee (GCM) priority corridor program has produced a regional architecture which all projects using intelligent transportation systems (ITS) must follow. The program anticipates and includes plans for a regional Transfer Connection Protection (TCP) system. However, a design is not specifically defined. As a result, the RTA in conjunction with the Service Boards is undertaking the design for a TCP system that will be incorporated in future GCM program plans and complement intra-agency TCP systems being planned and/or under development by the Service Boards.

The RTA's TCP system will help improve service for passengers connecting between the services of two different Service Boards. This will be done by alerting service board dispatch systems to inter-agency connections that are in danger of being missed. Corrective action can then be considered. For passengers, this will mean reduced waiting time, improved security, and less uncertainty. With the TCP system, Service Boards should see gradual increases in ridership and revenue, as well as improvements in operating efficiency and customer satisfaction.

Project Goals and Objectives

RTA has identified the following goals for the TCP system:

? Enhancing the quality of en-route service to customers
? Improving system productivity and customer satisfaction
? Enhancing the contribution of public transportation systems to overall community goals (e.g. safety)
? Expanding the knowledge base of professionals concerned with Advanced Public Transportation Systems (APTS) innovations.

Specific objectives have also been adopted in support of reaching these goals:

? Minimizing travel times for transit riders making connections
? Reducing the number of "missed" connections
? Increasing transit ridership
? Minimizing cost
? Improving accessibility to areas and activities attracting connecting passengers
? Improving operating efficiency through coordination
? Allowing for simplification of route structures and/or schedules

Purpose and Organization of this Document

The purpose of this document is to present high-level functional requirements for the TCP System. It has a particular emphasis on 1) guiding planners and decision-makers as ITS evolves in the GCM region, and 2) giving service board and GCM system designers as much guidance as possible on features they should consider as they progress their own efforts. Since most of the systems with which the TCP system will interact are still in the design or implementation phase, this document must be understood as preliminary and illustrative. If and when detailed design of the TCP system is pursued, then current designs and technology capabilities (such as increased wireless communications capacity and throughput) may suggest modifications to the approach outlined here.

The document begins with this Introduction. It continues in Section 2 with a brief summary of the TCP system concept, an evolution from preliminary concepts presented in previous project task reports. Next, Section 3 reviews compliance with national ITS architecture and CGM corridor architecture requirements, and sets out specific functional requirements relating to these architectures. Sections 4-5 present specific functional requirements for the base TCP system and for its Stage 2 enhancements (Paratransit TCP). Sections 6 and 7 conclude the document with high-level software and hardware requirements.

Glossary of Terms

ADA:	Americans with Disabilities Act
APTS:	Advanced Public Transportation Systems. This term is used to refer to the suite of ITS applications relating to public transportation.
ATSS:	Active Transit Station Signs
AVL:	Automatic Vehicle Location
BECS:	Bus Emergency Communications System. This is the first part of the CTA's comprehensive bus ITS system, focusing on AVL and emergency communications.
BSMS:	Bus Service Management System. This is the second part of CTA's comprehensive bus ITS system, focusing on service management.
Control point:	Any point where actual location and schedule adherence are recorded at the carrier's central dispatch or AVL system. This may include commuter rail stations, bus transit time points, or rail signal system control points.
CORBA:	Common Object Request Broker Architecture
Endangered connection:	A connection determined by the TCP system to be in danger of being missed.
ETA:	Estimated Time of Arrival
ETD:	Estimated Time of Departure
Exception reporting:	A scheme for reporting schedule adherence information between a mobile vehicle and a control center. In order to conserve radio system space, the vehicle only reports schedule adherence when it is early or late by more than predetermined threshold values. Pure exception reporting means that there is no provision for periodic reporting of schedule adherence to the control center irregardless of the value.

FHWA:	Federal Highway Administration
"From" vehicle or carrier:	In a one-way connection, the vehicle that is bringing passengers to the connection point. In two-way connections, both vehicles are "from" vehicles.
Gateway TIS:	Gateway Traveler Information System. This is the primary system within the GCM corridor architecture. It collects status, incident and other information from various agency servers and field devices.
GCM:	Gary-Chicago-Milwaukee
IBS:	Intelligent Bus System. This is Pace's comprehensive bus ITS implementation.
ITS:	Intelligent Transportation Systems
Illinois Transit Hub:	A planned component of the GCM architecture. When implemented, the Illinois Transit Hub will be the focal point for all data communications to, from and between public transportation agencies in the RTA service area.
Inter-agency connection:	A connection between the services of one carrier (e.g. Pace) and another (e.g. Metra).
ISP:	Information Service Provider. This is defined in the National ITS Architecture as an entity collecting, processing and providing ITS data to one or more users. The TCP system is an ISP operating within the Transit Management subsystem of the architecture.
J2374:	Society of Automotive Engineers (SAE) standard J2374 – Surface Vehicle Information Report. This is the new name of the LMRS – Location Referencing Message Specification, to be used as a common location identifier by all ITS systems.
LRMS:	Location Referencing Message Specification. See J2374 above.
Market Packages:	Components of the National ITS Architecture (NITSA) that identify the pieces of the Physical Architecture that are required to implement a particular transportation service.
NITSA:	National ITS Architecture
NTCIP:	National Transportation Communication for ITS Protocol
Physical Architecture:	This fundamental component of the National ITS Architecture (NITSA) provides agencies with a physical representation (though not a detailed design) of the important ITS interfaces and major system components.
Schedule adherence:	A measure that describes how far off schedule a vehicle is.
TCIP:	Transit Communications Interface Profiles
TCP:	Transfer Connection Protection

TIMS:	Train Information Management System. This is Metra's ITS system, currently under pilot development, for tracking the location and schedule adherence of its trains using Automatic Vehicle Location.
TIP:	Trip Itinerary Planning
"To" vehicle or carrier:	In a one-way connection, the vehicle that takes passengers away from the connection point. In two-way connections, both vehicles are "to" vehicles.
USDOT:	United States Department of Transportation
User Service Requirements:	In the National ITS Architecture, these are specific functional statements of what must be done to support the ITS User Services (see User Services below). The approximately 1,000 User Service Requirements were developed specifically to serve as a requirements baseline to guide Architecture development.
User Services:	These high level functional statements document what ITS should do from the user's perspective. There are currently 31 User Services recognized as part of the National ITS Architecture.
WAN:	Wide Area Network

Related Reports

There are five reports that the reader may find useful in understanding the motivation of and work to date on this project. The Task 1 report, *Needs Analysis,* identifies project stakeholders, service board needs and priorities, and the relationship between service management and TCP. The Task 2 report, *Synopsis of Existing Carrier Connection Policies,* details the existing connection-related policies of each service board, then summarizes common threads and key findings. The Task 3 report*, Review Industry Practices And Experience,* looks at related technologies in use at transit agencies in North America and Europe, as well as at U.S. passenger airlines and freight railroads. It also overviews national and regional ITS architectures and standards, and their applicability to the TCP design. The Task 4 and 5 report, *Inventory Existing Scheduling/Dispatching System/Integrate With AVL and Scheduling/Dispatching System,* reviews the features of transit AVL/dispatch systems and their relevance to the TCP system. It then discusses the AVL/Dispatch systems plans of each of the Service Boards, and identifies TCP and standards compliance issues to be addressed by each. Finally, the *TCP Executive Summary* provides a high-level overview of the project and its rationale designed for senior managers.

TCP SYSTEM CONCEPT

Overview

The RTA's Transfer Connection Protection (TCP) program is a two-stage program of computer systems and policies to address missed inter-agency connections. It is believed to be the first effort of its kind in the world. TCP's main goal is to reduce passenger wait times at inter-agency transfer points, by minimizing the number of missed connections.

The RTA's base TCP system will continuously monitor the on-time status of regional transit operations, focusing strictly on pre-defined inter-agency connections. It will try to identify any such connections that are *endangered*, or with a significant probability of being missed. It will then alert service board dispatch systems to these endangered connections, so that they can consider corrective action. The results of this for passengers will be reduced waiting time, improved security, and less uncertainty. Service boards should see gradual increases in ridership and revenue, as well as improvements in operating efficiency.

The TCP system will operate around the clock, seven days a week. It will focus on protecting connections to longer headway routes (over 10 minutes). Specifically, the TCP will target:

? Daytime connections to routes with long headways or limited service periods, as well as certain rush hour feeder services.
? Evening, weekend and especially owl service, where most headways are longer, and missed connections mean very long wait times.
? The last trip of the day (or service period), where passengers may be stranded by a missed connection.

One of the most annoying situations for passengers is a "near miss", where upon arrival at the connection point they can see the connecting vehicle having just departed. The TCP system will also help carriers address this issue. However, radio capacity constraints such as those experienced today by CTA and Pace will impact the system's effectiveness, meaning that many endangered connections, including many near-misses will be missed.

TCP will be developed and implemented in two stages, with additional long-range enhancements. The subsequent sections describe these stages.

Stage 1: TCP Base System

This system will automatically detect endangered inter-agency connections. It will include the hardware, software and networking needed for communications between the Service Boards' AVL and dispatch systems and a central TCP computer server. This server will continuously review the status of current operations and identify any pre-defined inter-agency connections that are in danger of being missed. When an endangered connection is identified, the involved Service Boards will be notified electronically, so that they can consider corrective action.

Stage 2: Paratransit TCP

In this stage, the TCP base system will be enhanced to include the contract paratransit operations of CTA and Pace. Passengers will request their desired connection when they reserve their trip. Before the trip or at the time of pickup, the desired connection will be forwarded to the

TCP system for protection. TCP will then notify the paratransit dispatch system if the connection is endangered.

This capability leverages the paratransit AVL and dispatch systems now being progressed for cost reduction and service improvement. It will require modification to these systems, current or planned, as well as full networking with their respective Service Boards' systems.

Additional Future Enhancements

There are at least four further customer service extensions to the TCP system that could in the future add value for passengers. The first is protection of customer requested connections, which would be forwarded to connecting carriers for acceptance or declination. The second is a customer notification option that would allow customers to define their regular trips to the system, then be automatically notified when a connection is endangered. Third is a customer trip completion alternatives option that would enable passengers to request alternative itineraries via transit or other modes (e.g. taxi) for completing their trip if a requested connection is declined. The fourth is the consideration of real-time passenger loading or count information to help improve the effectiveness of the TCP system and reduce unnecessary hold time.

NATIONAL & REGIONAL ITS ARCHITECTURE COMPLIANCE

The TCP system will function in the context of a well-developed regional ITS architecture – the GCM Corridor Architecture. This architecture, in turn, is compliant with the National ITS Architecture (NITSA). Compliance with NITSA or a regional architecture (such as GCM) is required for all projects receiving funds from the federal Highway Trust Fund, including the Transit Account.

This section defines the TCP system in terms of the NITSA and GCM architectures. It then goes on to look in more detail at the relationship between TCP and individual elements of the GCM architecture.

National ITS Architecture Compliance

The National ITS Architecture (NITSA) is a common framework for use by ITS system planners and designers. It provides both logical and physical views of the full range of ITS functions, physical entities and information flows. This architecture is now widely used in new ITS projects. One of the things it particularly aids in accomplishing is the incorporation of *all* relevant functions for a particular application.

This section defines the TCP system in terms of several principal elements of NITSA. First, **User Services** and **User Service Requirements** were the original user requirements to which the architecture was designed. They describe units of system functionality. Second, in the high level **Physical Architecture,** the subsystems and communications links relevant to a project such as TCP are identified. Finally, **Market Packages** are logical groups of functionality and equipment that might typically be considered for implementation by system planners and designers.

This review is based on NITSA Version 2.0, as is required for demonstrating architecture compliance under the USDOT Interim Guidance. Where the current Version 2.3 differs significantly, this is noted in the discussion.

User Services/User Service Requirements included in TCP

User Services were identified early in the process of developing NITSA. They represent the capabilities ITS is expected to provide to its users, including service providers and travelers. There are currently 31 defined User Services, grouped into seven Bundles. Within each User Service are a series of User Service Requirements – "shall" statements that describe specific capabilities.

The user service relevant to the TCP project is Public Transportation Management. It falls under the Public Transportation Management User Service Bundle. Within this user service, there are 18 relevant User Service Requirements. Table 3-1 lists User Services and User Service Requirements found to be relevant to the TCP project.

Table 3-1 : NITSA User Services and User Service Requirements Relevant to the TCP System

REQUIREMENT NUMBER	USER SERVICES/ USER SERVICE REQUIREMENTS
2.1	**Public Transportation Management User Service**
2.1.0	ITS shall include a Public Transportation Management (PTM) function.
2.1.1	PTM shall include an Operation of Vehicles and Facilities (OVF) function that provides computer assisted control of the operation of vehicles and their associated facilities.
2.1.1.1	To enable the automation of the vehicle and facilities operations OVF shall provide the capability to gather the needed data to include, but not be limited to, the following:
2.1.1.1(a)	Vehicle passenger loading by bus stop and trip segment.
2.1.1.1(b)	Bus running times between time points.
2.1.1.1(f)	Real-time vehicle location reports.
2.1.1.2	OVF shall include a Command and Control (CC) capability.
2.1.1.2.1	CC shall provide the capability for real-time Vehicle Command and Control (VCC).
2.1.1.2.1.1	VCC shall provide the capability to compare received information with predetermined operating condition specifications and note any deviations.
2.1.1.2.1.2	VCC shall provide the capability to transmit noted deviations to central control.
2.1.1.2.1.3	VCC shall provide the capability to display any noted deviations.
2.1.1.2.1.4	VCC shall provide the capability to automatically issue corrective Instructions to the driver including, but not limited to, the following
2.1.1.2.2	When CC detects a vehicle(s) has deviated from schedule it shall provide the capability to automatically determine the optimum scenario for returning the vehicle or fleet to schedule.
2.1.2	PTM shall include a Planning and Scheduling Services (PSS) function to automate the planning and scheduling of public transit operations.
2.1.2.2	The PSS shall include a Schedule Generation capability.
2.1.2.2.4	The PSS Schedule Generation function shall provide the capability to disseminate schedules to, but not be limited to, the following:
2.1.2.2.4(b)	Transportation Management Centers.

Physical Architecture

At its highest level, the NITSA Physical Architecture view is comprised of Subsystems, Communications Links and Terminators. (Terminators are people, devices, organizations or other entities that interact directly with ITS but are not part of the architecture itself. Examples include travelers, kiosks, and metropolitan planning organizations.) A view of the high level Physical Architecture without terminators is shown in Figure 3-1. For the two stages of the TCP system, there are four Subsystems involved: Transit Management, Transit Vehicle, Information Service Provider (ISP) and Planning. (In Version 2.3, Planning is replaced by “Archived Data Management”.) These Subsystems are linked by Wireline and Wide Area Wireless Communications. The Terminators involved include Transit Drivers and Transit System Operators.

The TCP system itself is viewed as an Information Service Provider embedded in the Transit Management subsystem.

Market Packages

Market Packages are subsets of the NITSA Physical Architecture that address specific functions or services, such as Transit Vehicle Tracking. A market package collects together several different subsystems, equipment packages, terminators, and architecture flows that provide the desired service. Market Packages can be used by ITS planners and designers to quickly access the components of NITSA that are relevant to the particular requirement being addressed.

There are six Market Packages representing functionality required for the TCP system. These Market Packages are briefly described in the following subsections along with their applicability to TCP.

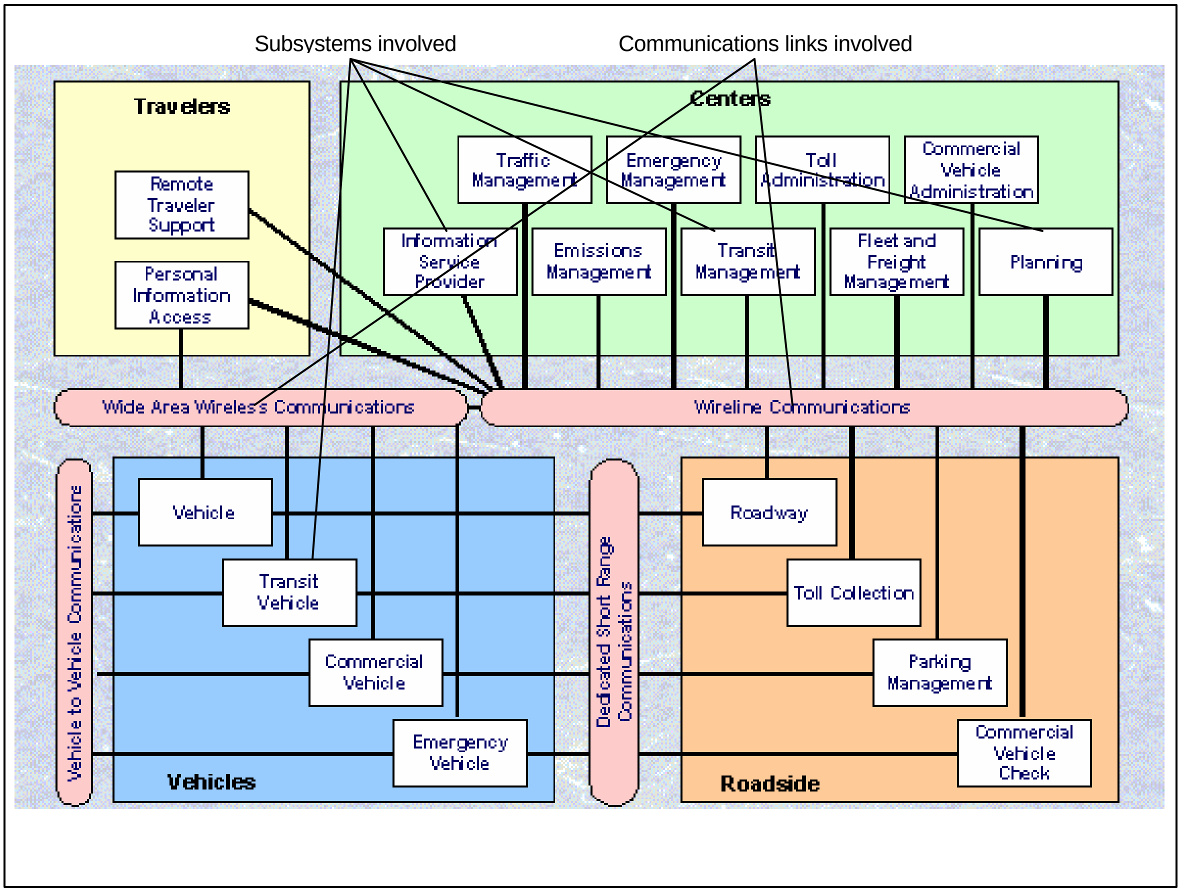

Figure 3-1: National ITS Architecture (Version 2.0)

Transit Vehicle Tracking

The market package provides for tracking of transit vehicles via an Automated Vehicle Location (AVL) system, as well as real-time schedule updates. Relevant information about location and schedule adherence is passed from the Transit Vehicle Subsystem to the Transit Management Subsystem. This subsystem processes the information and makes it available to the Information Service Provider Subsystem via wireline communications.

The TCP system will make use of information obtained through this Market Package in order to sense endangered connections.

Transit Fixed-Route Operations

This market package handles routing and scheduling for fixed route vehicles, along with driver assignment and monitoring. It is essentially what the dispatcher sees at a dispatch system console. This market package exchanges information via wireline with the Information Service Provider Subsystem.

The TCP system will make use of information obtained through this market package in order to sense endangered connections. Messages from TCP of endangered connections may also be provided to dispatchers through this subsystem.

Demand Response Transit Operations

This market package provides demand responsive transit managers with information analogous to that of the Transit Fixed-Route Operations. In this Market Package, the prospective traveler works with the Information Service Provider Subsystem to request service and receive a reservation.

In Stage 2 of deployment, the TCP system is envisioned as interacting with paratransit contract operator dispatch systems and vehicles to provide estimated time of arrival (ETA) information for services connecting to a paratransit trip, and to receive ETA's from a paratransit trip connecting with a scheduled fixed-route service.

Transit Passenger and Fare Management

This market package involves the collection, storage and dissemination of information on fare paid and passenger loadings. Vehicle mounted devices or sensors collect the information. It is communicated as needed to the Transit Management Subsystem using wireless links.

If real time passenger loading information is available, future enhancements to the TCP system will examine it, in order to avoid issuing an alert when the "from" vehicle in a connection is empty. Eventually, TCP could further exploit this information to attempt to optimize which connection alerts to issue on a regional basis.

Multi-modal Coordination

This market package involves communications between transit and traffic agencies for improved service coordination. This increases traveler convenience at connection points, and also improves operating efficiency. It also involves coordination with traffic management to the extent that transit performance can be improved without degrading traffic network performance. Signal priority capabilities are also included in this market package.

This market package directly incorporates the capabilities of the TCP system. However, NITSA envisions bilateral coordination between transit agencies, rather than a central Information Service Provider (ISP) such as TCP that evaluates integrated data from the agencies, then alerts them to potential missed connections. The best description of TCP and where it fits into NITSA is that TCP is an ISP embedded in the Transit Management Subsystem. This is similar to the way NITSA describes a reservations system.

ITS Planning

This market package supports data collection and archiving for ITS planning purposes.

The base TCP system will provide data to the archive in the form of endangered connection alerts sent to RTA Service Boards. It may also be able to audit whether vehicles accomplished connections, although it cannot verify whether or not any individual traveler made that connection.

Note: ITS Architecture Version 2.3 eliminates this Market Package, replacing it with three separate ones: ITS Data Mart (single agency), ITS Data Warehouse (multiple agencies, modes, jurisdictions), and the ITS Virtual Data Warehouse (physically distributed components). The TCP system would draw on the capabilities of the ITS Data Mart and ITS Data Warehouse market packages.

GCM Corridor Architecture Overview

The GCM Corridor

The transportation corridor linking Gary and Milwaukee through Chicago is known as the Gary-Chicago-Milwaukee (GCM) corridor. This corridor was selected by the U.S. Department of Transportation (USDOT) as one of four priority corridors in which regional integration of various ITS systems would be explored and tested. The program under which this is being done is the GCM ITS Priority Corridor Program; it began in 1993. The Federal Highway Administration (FHWA), state, county and local DOTs, regional transportation agencies such as RTA and transit operators are among those included in the program. The stated objective of this program is to improve the efficiency and effectiveness of the Corridor's transportation infrastructure through the planning, design, deployment, and evaluation of leading edge ITS applications.

Planned GCM Corridor Architecture

The GCM Corridor Architecture, being developed under the GCM ITS Priority Corridor Program, is to serve as the official ITS regional architecture for the corridor region. This is significant in particular because ITS architecture compliance under the USDOT Interim Guidance on Architecture Conformity is gauged primarily in terms of the regional ITS architecture. Therefore, projects such as the RTA's TCP project must be defined in the context of the corridor architecture.

The GCM Corridor Architecture Functional Requirements dated November 17, 1997 identify both an initial and "ultimate" corridor architecture. In the initial architecture, an ITS hub is identified for each of the three states in the corridor. All other ITS-related systems connect to their respective state hub. These three hubs, in turn, are connected to the GCM Corridor Gateway Traveler Information System (TIS) (see section 3.2.4 below). They forward to the Gateway all data necessary to support regional ITS systems, such as regional multimodal traveler information systems.

The "ultimate" corridor architecture, pictured in Figure 3-2, differs primarily in how data networking is handled. One significant addition, however, is the Illinois Transit Hub – a separate hub for the RTA Service Boards and other agencies operating in the RTA region of Illinois such as Amtrak. The Illinois Transit Hub is discussed further in Section 3.2.5.

National Transportation Communication for ITS Protocol (NTCIP) and Transit Communications Interface Profiles (TCIP)

In addition to the architecture guidance provided by NITSA, the TCP system design will rely on evolving standards from two national standards projects. These are the National Transportation Communications for ITS Protocol (NTCIP), and the Transit Communications Interface Profiles (TCIP). Both specifically focus on communications and message sets to be used in ITS designs.

The NTCIP's primary purpose is to provide a communications standard that enables full interoperability and interchangeability between Intelligent Transportation System (ITS) devices and traffic control devices. Toward this end, the NTCIP provides a communications interface that links disparate hardware and software products. This provides flexibility for future expansion without tying agencies to specific hardware or software vendors.

NTCIP is the primary communications and data standard concerning the integration of ITS applications. GCM projects are monitoring the development of the NTCIP Class E profiles for center to center communications, and incorporating them as they are approved.

The TCIP program is developing the transit component of NTCIP. TCIP is sponsored by the Institute of Transportation Engineers and funded by the US Department of Transportation's Joint Program Office for ITS. It is an ambitious effort to define the physical, data link and message set requirements for communications between transit vehicles, control centers, other transit facilities, and regional ITS centers such as Traffic Management Centers. TCIP explicitly includes connection protection as a covered functionality.

Phase 1 of TCIP, completed during 1999, established a transit ITS data interface "Framework" and eight "Business Area Object Standards." In Phase 2, the TCIP Project Team will develop the transaction sets, application profiles and guidebooks required to test and implement TCIP.

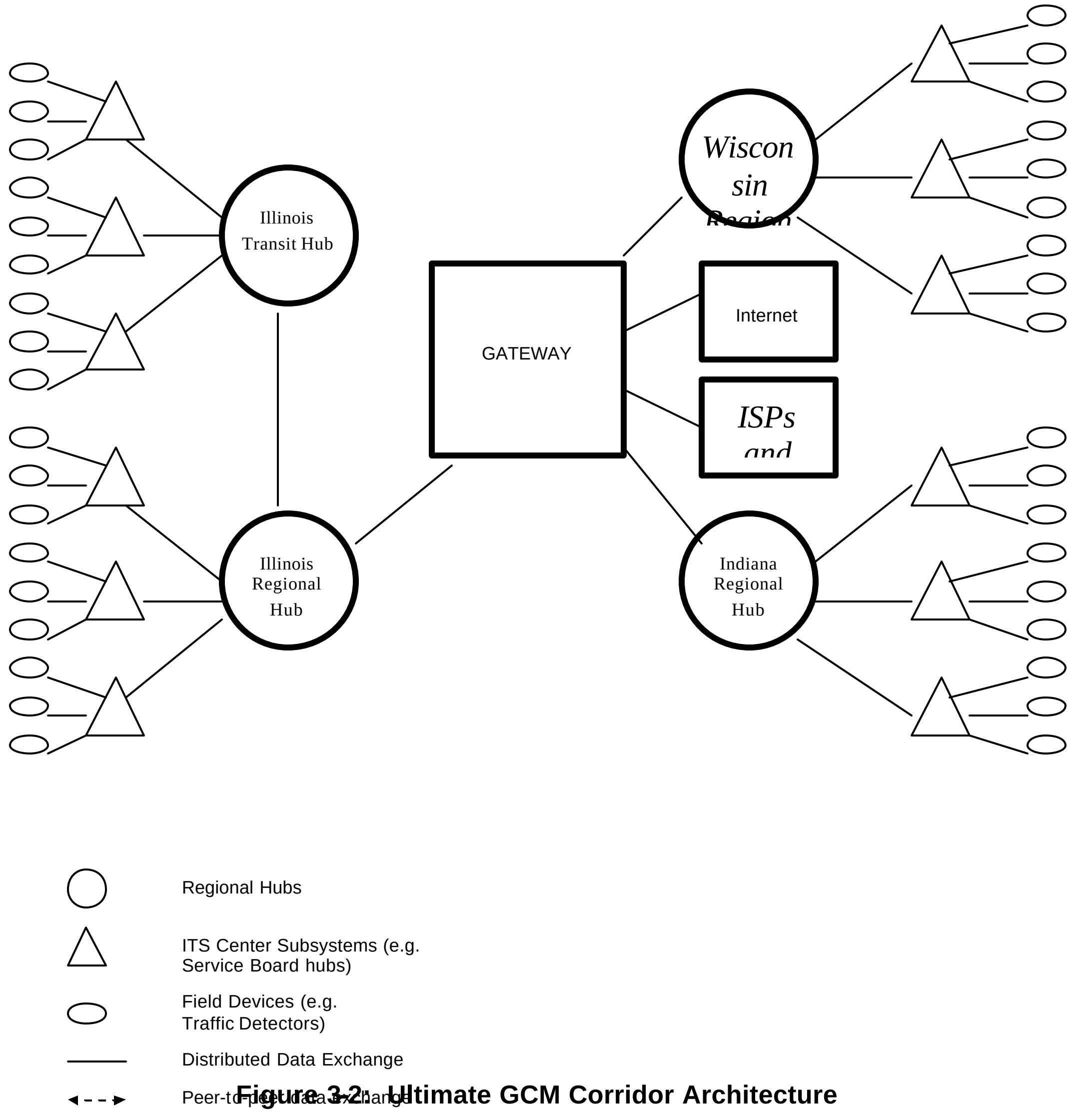

Figure 3-2: Ultimate GCM Corridor Architecture

The GCM Gateway system is being designed and built in full compliance with the National ITS Architecture, the NTCIP standards, and TCIP profiles. Since it must connect with a number of unlike devices and assure communications with and between them, the Gateway design calls for conformance to standards and protocols for Center to Center Communications developed under NTCIP.

The future detailed design will incorporate compliance with relevant NTCIP and other communications standards adopted by GCM. In addition, it will conform to the transaction sets developed during the Phase 2 TCIP effort. These requirements are explicitly incorporated in Section 3.3 below.

GCM Gateway Traveler Information System

The Gateway Traveler Information System (TIS) is the central element of the larger GCM effort entitled "Multi-Modal Traveler Information System" (MMTIS). The Gateway TIS is designed to integrate information from multiple sources in order to serve the needs of travelers and operating agencies alike. In order to do this, it collects and processes dynamic and static transportation data from operating agencies in the GCM area so as to provide a single, corridor-wide source of transportation information. The Gateway provides data to both operating agencies and travelers. Also, as was noted above, the Gateway design follows and will continue to follow NITSA, NTCIP and TCIP as they develop.

The major processes listed as part of the Gateway design include:

- ? Communications Interface (or System Data Acquisition and Data Dissemination)
- ? Data Processing (translation of data to Gateway standard format, fusion and/or aggregation)
- ? Data Management
- ? Operator / Console Interface
- ? Data Services (Archiving, Backup)
- ? GIS Database Interface
- ? Internet Server

One long-term goal of the Gateway TIS development effort is the testing and implementation of a standard method of referencing locations. The Gateway System Definition has adopted the Location Referencing Message Specification (LRMS) as its standard for coding location of vehicles or other entities. The LRMS is now known as Society of Automotive Engineers (SAE) standard J2374 – Surface Vehicle Information Report. It was developed by Oak Ridge National Laboratories, under contract to FHWA. It includes multiple interface protocols such as a geographic coordinate profile and a cross-streets profile. NITSA version 2.3 references the J2374 standard, noting that its interface profiles are in varying states of development, and are expected to continue evolving as ITS testing and implementation progresses.

Several stated goals and objectives of the Gateway system are particularly relevant to the TCP system:

- ? To facilitate the sharing of information between both private firms and public agencies involved in the transportation of goods, materials and people in the GCM Corridor.
- ? To work towards implementation and conformity of a single location referencing system within the Corridor for distributing traveler information.
- ? To assist in the improvement of transportation flows in the GCM Corridor.
- ? To assist in the expansion of multimodal transportation flows.
- ? To improve the level of cooperation between transportation agencies within the Corridor.

Illinois Transit Hub

The Illinois Transit Hub was mentioned above as part of the "ultimate" Gateway design. The purpose of this hub will be to collect, coordinate, present and distribute information from Illinois transit agencies in the RTA service area. These agencies would thus communicate through the hub (or a Wide Area Network (WAN) including the hub). Data from transit agencies will provide information for itinerary planning, including static schedules, real time status information, and possibly incidents. Data flows from the transit hub to the Gateway (through the Illinois Regional Hub) include dynamic and static schedules, incidents, and road conditions. There are no data flows currently planned from the Gateway to the transit hub; however, if the need should arise, data could be provided via the connection to the Corridor WAN. The Illinois Transit Hub is the logical place for the TCP system to reside and to obtain necessary data on transit operations status.

It should be noted that design efforts for the Illinois Transit Hub have not yet begun. As a result, if TCP is ready for deployment before the Illinois Transit Hub, it (and the service board dispatch systems) would communicate directly with the Gateway to provide and receive information.

TCP Functional Requirements Derived from NITSA and GCM

TCP Functional Requirements Derived from NITSA and GCM

This section pulls together TCP functional requirements derived from the GCM architecture and NITSA.

TCP shall adhere to the current release at detailed design time of the location referencing standards embodied by SAE Standard J2374, Surface Vehicle Information Report.

The TCP system shall be configured under the direction of RTA or GCM standards and practices.

The TCP system shall conform with the relevant communications profiles of the NTCIP release current at detailed design time.

The TCP system shall conform to TCIP Business Area Object Definitions, as well as specific transaction sets and other relevant requirements, according to the current release at detailed design time.

The TCP system shall conform to the current version of the GCM Corridor Architecture at detailed design time.

TCP BASE SYSTEM REQUIREMENTS

Overview

The TCP base (Stage 1) system is designed to be an aid to the RTA Service Boards in coordinating their connecting services with one another. It works by using service board schedules and real time status information available from the Illinois Transit Hub (or Gateway TIS) to identify inter-carrier connections that may be in danger of being missed. It then informs the carriers involved so that they can consider corrective action, and continues to update status until the connection point is reached.

The high level architecture of the base TCP system is shown in Figure 4-1.

The TCP base system has no traveler information component or public visibility. It works "behind the scenes" to aid service improvement. It requires only minimal functionality changes to carrier AVL/dispatch system designs. It also leaves full control of operations and operating decisions with the individual Service Boards. It does, however, begin to lay the groundwork for mutual accountability among the Service Boards for inter-carrier service quality.

The effectiveness of the TCP system relies primarily on two things:

? How carriers use the alerts it provides

? The quality and accuracy of real-time schedule adherence reports from the Service Boards. Vehicle to carrier exception reporting of schedule adherence deviations directly affects base TCP system effectiveness, depending on the exception reporting threshold used.

Relationship of TCP with the Illinois Transit Hub

Since the Illinois Transit Hub is still in the pre-design stage as of this writing, it is not clear what the specific functionality of the Hub will be, nor the rules and means for accessing data received from carriers. Here are the TCP system's requirements from the Transit Hub, or Gateway TIS if the Transit Hub is not yet implemented:

Access to Information

The Illinois Transit Hub shall make current transit schedules and real time schedule adherence reports available to the TCP system via an automatic, electronic and seamless process.

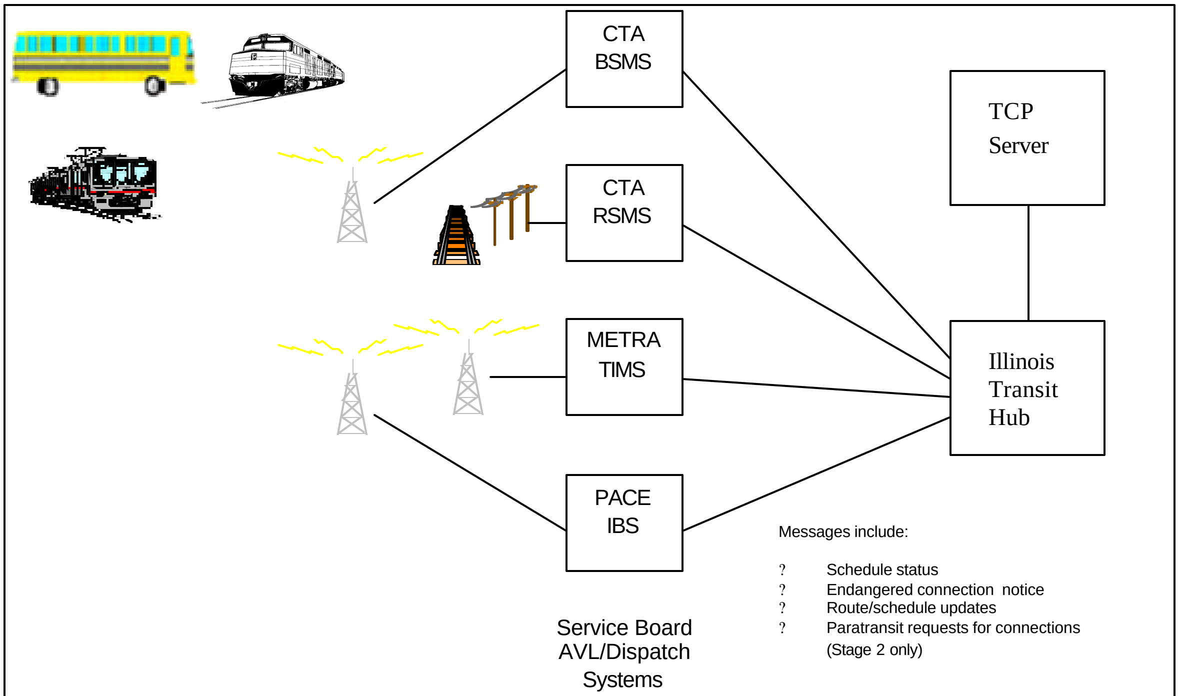

Figure 4-1: High-level TCP Base System Architecture

Distribution of Functionality

Subject to the discretion of Illinois Transit Hub designers/operators in cooperation with TCP system designers, any or all of the TCP functions shall reside on a dedicated TCP server as part of the Illinois Transit Hub local area network.

Base System Data Collection Requirements

Overview

The data requirements of the TCP system are similar to those of transit traveler information applications such as the RTA Active Transit Station Signs (ATSS) project. Both systems need real-time information about transit operations. The TCP system uses this information to determine whether any pre-defined inter-carrier connections are endangered. Both systems are also sensitive to whether or not exception reporting is used and the impact on the accuracy of information. The base TCP system's effectiveness is further reduced when pure exception reporting is utilized by a carrier's AVL/dispatch system – meaning that there are no schedule adherence reports at all unless the vehicle is earlier or later by more than a user-settable parameter known as a threshold.

The systems that will provide data and receive alerts from the TCP system include:

? Chicago Transit Authority's Bus Emergency Communications System/Bus Service Management System (BECS/BSMS) – currently in advanced design and implementation
? Chicago Transit Authority's Rail Service Management System (RSMS) – currently in full operation
? Metra's Train Information Management System (TIMS) – contract awarded
? Pace's Intelligent Bus System (IBS) – specifications near completion

All messages to and from TCP shall be NTCIP and TCIP compliant and also follow any relevant GCM architecture guidelines.

Base System Static Data Requirements

The TCP system shall require route definitions from each carrier, with inter-carrier connection points explicitly identified. These shall always be the most recent, currently applicable versions. Temporary detours or reroutes shall also be included. The definitions shall be maintained in a system database, with conflicts resolved by the TCP system operator (see section 4.7.1.4).

To be protected by the TCP system, an inter-carrier connection point must be defined as a control point by both participating carriers.

The TCP system shall require run/train and schedule definitions from each carrier. Inter-carrier connections shall be unambiguously identified in these run/train/schedule definitions, including connection point, connecting carrier, route and directionality of the connection:

? One way to the connecting carrier only
? One way from the connecting carrier only
? Two-way connection – meaning that the two vehicles must co-dwell at the connection point long enough for passengers to make the transfer in each direction

The TCP system shall require processing of the run/train/schedule files of all participating carriers to produce a view of protected inter-carrier connections containing at

minimum connection point, first carrier, first carrier route, first carrier run/train, first carrier scheduled arrival time, second carrier, second carrier route, second carrier run/train, second carrier scheduled arrival time, and directionality (first carrier to second carrier only; second carrier to first carrier only; two-way). This process shall also produce a report of conflicts between schedule files to be handled for resolution by the TCP system operator (see Section 4.7.1.4).

The TCP system shall require entry of carrier preference on receipt of endangered connection alerts – see Section 4.5.2.2 below. Specifically, the carrier shall be able to specify whether it wishes to receive Endangered Connection Alerts and Alert Update Reports when it is the "from" carrier.

Base System Dynamic Data Requirements

Dynamic data requirements include all real time data reports from carriers relevant to the TCP system's mission of identifying endangered inter-carrier connections. They also include stipulations about accuracy. There are several considerations that affect data accuracy, and thus TCP system effectiveness. They are:

- The density (spacing) of control points. (Control points are points at which carriers measure schedule adherence.) The further away from the connection point the previous control point is, the more room there is for delays to occur and endangered connections to be undetected.
- The use of pure exception reporting, where no report is made from the vehicle to the control center unless the report is late by more than a user-selectable threshold. (Exception reporting is used to compensate for limitations in available bandwidth, to reduce central system processing requirements, and to reduce the volume of events to be processed by the dispatcher.)
  - If pure exception reporting is not used, then schedule adherence is usually reported at a predefined interval. The freshness of the schedule adherence data reported to the TCP system, and thus the system's effectiveness, would thus be a function of that interval.
  - If pure exception reporting is used, then the TCP system's effectiveness would be directly related to the threshold value currently in use. For example, if a "from" vehicle is 7 minutes late, but the exception reporting threshold is 10 minutes, then the TCP system will never know the vehicle is late, and will fail to detect an endangered connection.

The TCP system shall require all schedule adherence reports for runs/trains involved in inter-carrier connections. These reports shall include at minimum, carrier, route, run/train, schedule adherence (±MMSS), control point location, and date/time the calculation was made. A carrier-defined and supplied report ID can also be accepted for future analysis and retrieval if desired.

Control points of observation in schedule adherence reports are assumed by the TCP system to be 100% accurate – i.e., if two control points are physically near each other, the carrier's system has matched to the proper location.

It is strongly desired that the TCP system receive *actual* rather than estimated schedule adherence reports for each control point for all runs/trains. However, estimated values are acceptable if they are "smart" estimates, using real-time actual measurements such as distance traveled since the last actual location reading. Estimates based strictly on extrapolation using scheduled or historical running times are not acceptable.

If actual schedule adherence reports are not available for all runs/trains due to exception reporting, then:

An exception reporting threshold of 0 for early vehicles is required.

An exception reporting threshold of 5 minutes or less for late vehicles is required.

Actual schedule adherence reports used by the TCP system shall be accurate to within +/- 30 seconds at the control point and time of observation. (This number corresponds to the specified accuracies of Service Board AVL/Dispatch systems).

As an alternative to the use of schedule adherence reports, the TCP system may use ETA or estimated time of departure (ETD) reports from one or more carriers. In this case, the TCP system would assume that the reports are accurate, and act on that basis. In addition, use of ETA's/ETD's is contingent on two conditions:

a) That the ETA's/ETD's refer to arrival at the inter-carrier connection point
b) That all other accuracy and exception reporting threshold requirements are still met.

Location Referencing

All data and reports including location information shall provide locations according to the GCM Gateway system location referencing requirements at detailed design time. It is anticipated that these will involve one or more profiles of the SAE J2374 Standard, Surface Vehicle Information Report.

Base System Data Processing Requirements

Overview

The TCP system screens schedule adherence reports as they become available. When a report is found to indicate an endangered connection, then an alert message is prepared for the carrier needing to take action (or optionally to both). These reports are provided to the information distribution function; they are also archived for post-analysis.

Specific Requirements

These requirements assume that schedule adherence reports and not ETA's/ETD's are being furnished by carriers. If ETA's at the connection point are supplied by a carrier, then they can be used directly without any additional manipulation.

The TCP system shall check each schedule adherence report to see if it is of interest for analysis. Reports shall be of interest if they:

a) Pertain to a monitored connection for which no alert has yet been issued, and are within a user-settable distance of the connection point; or
b) Pertain to a monitored connection for which an alert has already been issued, and the vehicles are short of or at the connection point.

For reports of interest under condition a), the TCP system shall determine whether the connection is endangered by the following method:

a) Calculate an ETA at the connection point for the vehicle being reported on.
b) Calculate an ETA at the connection point for the other vehicle in the connection.
c) Compare the two ETA's to determine if the connection is endangered. If it is a one-way connection, the connection is endangered if the receiving or "to" vehicle is projected to leave the connection point before the arriving or "from" vehicle can arrive, and the transfer of passengers be completed. If it is a two-way connection, then the connection is endangered if it appears that the vehicles will

not co-dwell at the connection point long enough to allow the transfer to be completed.

If there is determined to be an endangered inter-carrier connection based on a report of interest under Section 4.4.2.1 condition a), an "Endangered Connection Alert" report would be prepared for distribution to one or both of the carriers. These reports are described in Section 4.5.2.1.

For reports of interest under Section 4.4.2.1 condition b), the TCP system prepares an "Alert Update Report". These reports are described in Section 4.5.2.1.

The TCP system will continue to process schedule adherence reports pertaining to a protected connection until it processes a schedule adherence report for both runs/trains at the connection control point. At this point it will create a record with this information for the TCP archive. The TCP system shall also have the ability to assure that reporting does not continue indefinitely if one or both control point reportings are never received.

The TCP system shall be able to distinguish between distinct connections involving the same run/train/vehicle at the same or different control points, and to track and take action on each separately.

Base System Information Distribution Requirements

Overview

The TCP system forwards Endangered Connection Alerts and Alert Update Reports to the carrier in the position to take action to protect an endangered connection, and optionally to the other involved carrier. It also forwards on a scheduled basis predefined historical reports concerning connection alerts issued and metrics of connection success.

Specific Requirements

The TCP system shall promptly assemble and forward Endangered Connection Alerts and Alert Update Reports to the "to" carrier in the connection as discussed in Sections 4.4.2.3 and 4.4.2.4. These reports shall include at minimum, report type identifier, from carrier, from route from run/train, predefined connection point, schedule adherence(±MMSS), control point of observation, and date/time of observation. If, alternatively, ETA's at the predefined connection point are being used, then ETA would replace the schedule adherence element.

The TCP system shall forward Endangered Connection Alerts and Alert Update Reports to "from carriers" according to their preferences (see Section 4.3.2.5).

The TCP system shall forward on a scheduled basis historical reports concerning endangered connection alerts issued, as well as metrics of estimated connection success.

Base System Archiving and Management Reporting Requirements

Overview

The TCP system will create an archive of all Endangered Connection Alerts and Alert Update Reports. This archive will be used for post audits of system effectiveness. It will also support management reports on TCP system activity

Data Archiving Requirements

The TCP system shall maintain an archive of all Endangered Connection Alerts and Alert Update Reports. Each record will include both the specific content of the report, and the status data on both vehicles used to make the determination. The records shall be available on line for a user-settable number of days (no less than 90), then afterwards through loadable storage media.

The TCP system shall maintain an archive of actual schedule adherence at protected connection points, with full information from both relevant schedule adherence reports.

If an Illinois Transit Hub or Gateway TIS archive is available with retention parameters comparable to those of the TCP system archive, the TCP system archive may store a record locator or reference number to information stored in that archive, rather than duplicating it in the TCP archive.

The TCP system archive shall conform to all relevant guidelines for such archives in the GCM specifications applicable at detailed design time.

Management Reporting Requirements

The TCP system shall support regularly scheduled management reports summarizing system activity in terms of Endangered Connection Alerts issued and Alert Update Reports issued. These shall be appropriately broken out or subtotaled with respect to relevant parameters such as connection involved, or carrier/route/run involved.

The TCP system shall support regularly scheduled management reports summarizing metrics of estimated connection performance. These shall be based on the archive records showing schedule adherence for both carriers at connection points.

Base System Operator Requirements

Base System Operator Requirements

The TCP system shall require the ability to support a system operator, either locally or at a remote location. This person would be responsible for a variety of system administration tasks. In addition, the person would be able to monitor TCP system activity and make adjustments to system parameters as conditions require.

The TCP system shall support archive management through the system operator interface.

The TCP system shall provide capabilities for the system operator to review statistics on current system activity, including at a minimum, reports received and alerts/updates issued by time period, as compared to measures of typical volume.

The TCP system shall provide the ability for the system operator to dynamically adjust parameters governing the TCP system functionality and performance, including but not limited to the ability to disable alerts or updates systemwide, by carrier or by subclassifications within carrier.

The TCP system shall provide the system operator with an interface to review conflicts between carrier schedule files with respect to inter-carrier connections, and rectify them. The interface shall be user-friendly, with minimal keystrokes required to accomplish basic tasks. A graphical user interface (GUI) is required.

Base System Performance Requirements

Base System Performance Requirements

The TCP system must complete its review of a received schedule adherence report affecting a covered connection, and transmit any required alert messages, within no more than one minute of its receipt at the Illinois Transit Hub (or Gateway TIS if the Transit Hub is not implemented at the time of TCP implementation). A faster turnaround time, if possible, is desired.

Base System Carrier Requirements for Participation in TCP

Base System Carrier Requirements for Participation in TCP

Following are the minimum requirements for carrier participation in Base System (Stage 1) TCP:

Carriers shall have AVL, dispatch and scheduling systems that are installed, operating and stable, and that cover all or most of their territory. These systems shall identify vehicle location and schedule adherence, then make it available to dispatchers for service management purposes.

Carrier systems shall be able to regularly compile for transmission to the TCP system current route, run and schedule information as outlined elsewhere in this document. Carrier systems must assure that the current version of this information is transmitted to the TCP system in time for use when it becomes valid.

Carrier AVL/dispatch systems shall be able to promptly create messages with schedule adherence information for transmission to the TCP system whenever a new update is received. Alternatively, these systems may provide ETA messages to the TCP system as defined elsewhere in this document.

Carrier schedule adherence messages to the TCP system shall meet all accuracy, freshness and other requirements enumerated elsewhere in this document.

Carrier dispatch systems shall be able to receive and process Endangered Connection Alerts and Alert Update Reports from the TCP system, as defined elsewhere in this document.

Carriers must establish and maintain a communications interface between their systems and networks and the Illinois Transit Hub, according to GCM specifications current at detailed design time.

STAGE 2 REQUIREMENTS: PARATRANSIT TCP

Introduction

The Stage 2 capabilities of the TCP system are designed to bring the benefits of inter-agency information sharing to the paratransit operations of the Service Boards. In this stage, the TCP system will protect paratransit trips with inter-agency transfers from/to fixed-route services. It was assumed for this study that paratransit to paratransit connections (e.g. CTA paratransit carrier to Pace paratransit carrier) would be handled outside the TCP system, since there is no scheduled service involved and since the frequency of these trips should permit manual handling between dispatchers. However, the TCP system could in theory be extended to handle this situation as well.

The first step in paratransit TCP is the enhancement of paratransit reservations systems in order to collect full information about desired transfers at the beginning or end of the paratransit trip. Since reservations are most often taken a day before the trip actually occurs, they are not immediately transmitted to the TCP system. Later, at an appropriate time determined by the carrier, the desired transfer information is forwarded to the TCP system and dynamically added to the list of protected connections.

At this point, the handing depends on whether the desired transfer is at the beginning or end (or both) of the paratransit trip. If the paratransit trip ends with a transfer to another carrier, then the paratransit system must provide an updated drop-off time (ETA) to the TCP system if there is a significant change from the value in the reservation. (ETA's are used because there is no schedule for paratransit trips). This will allow the TCP system to send an Endangered Connection Alert to the other carrier if necessary.

For trips beginning with a transfer from another carrier (and with no transfer at the end of the trip), the paratransit system does not have to provide additional information to the TCP system after the transfer information has been sent. Instead, in case of a connecting service problem, the TCP system will provide the equivalent of an Endangered Connection Alert to the paratransit dispatch system. If received early enough, this may allow the dispatcher to adjust dispatch of the trip to more closely conform to the expected arrival of the connecting service. This will result in improved paratransit driver and vehicle productivity.

These two components of Stage 2 TCP do not have to be installed together. For example, if carriers and their paratransit contractors determine that they do not wish to require drivers or dispatchers to estimate ETA's and enter them for reporting to TCP, then the capability could be implemented for protecting only connections at the beginning of paratransit trips.

Participation of a fixed route carrier's paratransit contractors in Stage 2 TCP requires that they have installed and operationally proven AVL and dispatch systems covering all or most of their operation. It does not necessarily require any involvement of the sponsoring carrier's fixed route dispatch systems. All that is required is that the paratransit dispatch systems be networked to the fixed route carrier so that messages can be forwarded to the TCP system through the carrier's connection.

Additional Data Collection Requirements

Overview

Stage 2 TCP requires adding the ability to receive paratransit connection requests in real time and dynamically add them to the list of connections being monitored. It also requires the ability to receive connection point ETA updates from paratransit carriers, actual pick-up or drop-off times at the connection points, cancellations after information has been submitted to TCP, and updated paratransit carrier preferences.

Additional Static Data Collection Requirements

Each paratransit contractor shall receive a unique identifier in the system rather than using the sponsoring carrier's identifier. These shall be linkable via a table to the sponsoring carrier's identification. Paratransit contractors providing services for more than one service board shall have a separate unique identifier corresponding to each service board and to be used exclusively on trips being provided under contract to that service board.

Because paratransit carriers do not follow fixed routes or schedules, the TCP system has no other static data collection requirements for paratransit except for the preferences noted in Section 4.3.2.5 above.

Additional Dynamic Data Collection Requirements

The TCP system requires data on a requested connection with paratransit in order to initiate protection and alerts. It requires updates on trip status, including cancellations, in some cases. It also requires timely reporting of the actual pick-up or drop-off time at the connection point for purposes of management reporting. In addition, because paratransit operations may connect with any fixed-route operation, the TCP system will now require *all* schedule adherence reports from the service boards, not just those for runs/trains involved in inter-carrier connections. Also, since paratransit customer reservations are often specifically linked to a specific run/train of a fixed-route service, it will require fixed-route carriers to report annulments, cancellations, reroutes, or any event causing the run/train not to operate over all or part of its route.

The TCP system shall require access to schedule adherence reports for all runs/trains operated by service boards, not just those involved in pre-defined inter-carrier connections.

The TCP system shall require a message requesting protection for a paratransit trip connecting with a fixed-route service. This message will originate with the dispatch system of the paratransit operator. The exception is that if protection is desired to begin before the reservation is forwarded to the dispatch system, then it could originate from the reservation system at the contractor or sponsoring carrier.

The message requesting protection shall include, at minimum, the carrier, a unique trip number, connection point, event (pick-up or drop-off), planned date/time for the event, connecting carrier, connecting route, and (optional to the paratransit carrier) ID of connecting Metra service (by train ID or departure time and direction).

For paratransit trips *dropping off* passengers for inter-carrier connections, the TCP system shall receive accurate updates to ETA's whenever available. Updates are required if the trip will arrive at the connection point late by more than an agreed-upon number of minutes (suggest an initial value of 5).

The TCP system shall receive an actual pick-up or drop-off report from the paratransit system including carrier, unique trip number, connection point, pick-up/drop-off identifier), date/time, connecting carrier.

The TCP system shall receive reports of trips cancelled after being reported to TCP for protection.

All reports received from paratransit carriers by the TCP system that include a location shall have the location coded according to the requirements identified in Section 4.3.4.1 above.

Starting with Stage 2, the TCP system shall require fixed route-carriers to report annulments, cancellations or other service disruptions that would cause the run/train not to operate over its entire route. This report would include the carrier, route, run/train, and an indicator of cancellation/annulment or other service disruption. In this stage, the report is not intended for detailed processing to determine precise locations affected. It is instead intended to support a notification to connecting paratransit carriers in the case when a connection request has been made involving the affected run/train. The paratransit dispatcher can then follow up by voice communications with the fixed-route carrier to determine the precise nature of the difficulty.

Additional Data Processing Requirements

Additional Data Processing Requirements

The TCP system shall process requested paratransit connections and dynamically add an entry to its table of protected connections.

The TCP system shall process ETA updates received from paratransit carriers for trips with drop-offs at connection points, in the same way as schedule adherence reports or ETA's received from fixed-route carriers.

The TCP system shall create Endangered Connection Alerts and Alert Update Reports for paratransit connections just as for fixed-route to fixed-route connections. Such reports to paratransit carriers shall be forwarded in the format of an updated ETA at the connection point. Endangered Connection Alerts shall also be used to notify paratransit carriers of run/train cancellations, annulments or service disruptions affecting any requested connection, either at a pick-up or drop-off point.

Additional Information Distribution Requirements

Additional Information Distribution Requirements

The TCP system shall forward Endangered Connection Alerts and Alert Update reports to involved paratransit carriers. Otherwise, no additional requirements.

Paratransit carriers will receive the same or analogous management reports as fixed-route carriers, relating specifically to connections they are involved in.

Additional Information Archiving and Management Reporting Requirements

Additional Information Archiving Requirements

The TCP system shall archive data on paratransit connections in the same fashion as it does for fixed-route to fixed-route. Otherwise, no additional requirements.

Additional Management Reporting Requirements

The TCP system shall account for paratransit carriers and paratransit connections as separate selectors or categories in management reports. Otherwise, no additional requirements.

Additional System Operator Requirements

None.

Additional System Performance Requirements

None.

Additional Carrier Requirements

Paratransit Carrier Requirements

Paratransit carrier requirements for Stage 2 are analogous to those of fixed-route carriers for Stage 1.

In order to be approved for participation, paratransit carriers must have the approval of their sponsoring carrier, and must have dispatch and AVL systems installed and operationally proven on all or most of their system.

Paratransit carrier AVL and dispatch systems shall be able to compose and forward to the TCP system a connection request structured from reservations data. Carriers can determine the timing of this message based on their operating practices.

Paratransit carrier AVL and dispatch systems shall be able to forward ETA updates, actual pick-up or drop-off at connections points, and cancellations occurring after TCP has been notified.

Paratransit carrier AVL and dispatch systems shall be able to receive and process Endangered Connection Alerts and Alert Update Reports.

Paratransit carriers must have a communications interface with their sponsoring carrier allowing messages to/from their systems to be handled through the Illinois Transit Hub, in conformance with NTCIP and TCIP standards and profiles, and GCM guidelines current at detailed design time.

Fixed-route Carrier Requirements

Participating fixed-route carriers shall report run/train cancellations, annulments or other service disruptions that would cause the run/train not to operate over its entire route. Refer to Section 5.2.3.7 above.

SOFTWARE REQUIREMENTS

Introduction

To ensure interoperability and ease of data sharing among agencies, the GCM Gateway system design follows a set of software development rules established in 1997. Since the TCP server will draw its data from the Illinois Transit Hub and/or the Gateway TIS, and may eventually provide data to these systems, it is important that the TCP server design follow the same system design protocol. Some specific software requirements relevant to the TCP server design are detailed in the remainder of this section.

Specific Requirements

Object-Oriented Design

To reduce system maintenance cost and to facilitate system expansion in the future, the modular design or object-oriented design concept shall be implemented in the early stage of TCP system detailed design. This is especially important given that three Service Boards, and in the future the RTA and other carriers will all share use of the system.

Data Communication Automation

The base TCP system relies on each service board to provide AVL and dispatch information to the central TCP server so that endangered connections can be detected. To reduce human error, automatic data communication between the TCP server and the Service Board dispatch systems shall be used. Location and schedule adherence information from each service board must be received automatically by the TCP server without human intervention. This can be accomplished by appropriate hardware and software design.

Message Set Definition

According to the functional requirements of the base TCP system, one or both involved carriers will be notified if an endangered connection is identified. This notification will be sent to the dispatch system of the involved service board by the TCP server such that the delay impact can be minimized. Due to the limitation of communication bandwidth and space in the display device, a concise message set shall be pre-defined to cover all possible situations. The selection of this message set shall consider the hardware and software used by each service board. If appropriate approved TCIP message sets exist at detailed design time, they shall be used.

Database Concurrency

The fleet schedule provided by each service board, along with actual reports of schedule adherence, are used by the TCP server to determine when connecting vehicles will arrive at the connection point. Since the fleet schedule and AVL/dispatch information in the TCP server are provided by each service board, it is critical that there shall be concurrency control among the database management systems in the TCP server and at the three Service Boards so that updates to service board databases can be simultaneously posted to the TCP server database.

Common Object Request Broker Architecture (CORBA)

Considering the potential reality of unlike systems using different programming languages at different Service Boards or even within Service Boards, the CORBA component shall be required to provide a common interface to ensure the interoperability and data interchangeability between components and between Service Boards. The CORBA provides a uniform interface for sending and receiving messages among different components in different system. A simple example of CORBA can be a Java program in a system to invoke a call to a function in a C/C++ program in another system to perform necessary operations.

Security

Real time operating data provided by Service Boards is sensitive information that must be protected from unauthorized access during transmission or during storage and use at the TCP server. At the same time, the TCP System must have access to this information in order to function. Therefore, the design of the TCP server software shall provide for full data security and protection from unauthorized access to data, as well as the introduction of unauthorized data.

Performance

Though there will be a growing customer information role for service board scheduling and dispatch systems, their primary mission remains the support of service board revenue service. The TCP system has the potential to add a significant processing load to service board systems, especially in later phases. Thus, the TCP system shall be designed such that its performance standards keep the TCP server from in any way becoming a bottleneck for service board operations.

HARDWARE REQUIREMENTS

Introduction

The hardware guidelines provided in GCM Functional Requirements documents are quite applicable to TCP system design as well. The following requirements shall be applicable for TCP system design unless they are superseded by additional or more detailed guidelines before detailed design time.

Specific Requirements

Hardware Independence

The TCP system design shall not be restricted on the basis of existing hardware in each service board or of the hardware selected for the TCP system itself. When new functionality is added requiring new hardware, operation of the TCP system shall not be impacted by installation of the new hardware.

Communication Equipment

Depending on the data volume and transmission method between service board systems, the Illinois Transit Hub and the TCP server, a range of communications media may be used (e.g. T1, DSL or fiber optic cable). Other hardware such as bridges, routers, repeaters, gateway, etc. are required for communications within a service board as well as between the service board, Illinois Transit Hub, and the TCP server. The detailed system design will determine which logical network topology shall be used for the TCP application.

Portability

The TCP system shall be capable of being ported to other similar hardware platforms and scaleable in terms of the number of I/O connections, processes, user interface features, etc., that are supported.

Scalability

The TCP system shall be highly expansible when it comes time to add new function to it or to integrate it with other systems to provide additional services.

Performance

The schedule adherence information received by the TCP server will result in frequent database updates. Depending on the database schema design, this process may result in rapidly progressing hard disk fragmentation that eventually reduces system performance. It is important that the TCP system hardware have adequate memory resources and system utilities to address this problem.

Hardware/Software Survey and Inventory

A hardware/software survey and inventory of existing and planned service board projects related to TCP shall be required as part of detailed design. Such a survey and inventory provides critical information for the detailed design effort. A preliminary estimation of data volume and data type transmitted along the communication line is also essential to the selection of physical and logical network communication hardware/software components.

REGIONAL TRANSPORTATION AUTHORITY
TRANSFER CONNECTION PROTECTION (TCP) PROJECT

TASKS 9-10 FINAL REPORT:
FINAL SPECIFICATION
HIGH-LEVEL COST ESTIMATES

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TranSmart Technologies, Inc.
May 23, 2000

TABLE OF CONTENTS

INTRODUCTION

This document is the latest in a series of reports produced as part of the Northeastern Illinois Regional Transportation Authority (RTA) Transfer Connection Protection (TCP) project. The purpose of the TCP project is to perform a feasibility study and perform preliminary design for a system to facilitate improved inter-agency connections between the three Service Boards of the RTA: the Chicago Transit Authority (CTA), Metra, and Pace. Improved connections will result in faster passenger transfers at connection points.

This report presents high level specifications for the TCP system, along with gross estimates of potential system costs. When this document is taken together with the Task 8 Final Report: Functional Requirements, the result is a comprehensive high-level specification for the TCP system.

The remainder of this introduction goes on to recap the functionality of the TCP system, review alternative approaches to building a TCP system, present the selected architecture, and suggest a possible deployment strategy. Section 2 provides high level specifications for the TCP Base System; Section 3 covers the extension of the system to cover service board paratransit services. Sections 4 and 5 provide software and hardware guidelines, respectively. Section 6 presents the costing methodology and gross estimates of potential costs for the TCP system.

System Functional Overview

The Base TCP system is designed to facilitate improved inter-agency connection performance, as measured by the sum of the passenger waiting time at the connection point. It does so by facilitating the sharing between connecting carriers of real-time service status information derived from computer-aided dispatch and automatic vehicle location (CAD/AVL) systems. The TCP system is a "business-to-business" application. It does not directly provide customer information, nor does it provide any customer interface. It is strictly a tool for the service boards to manage inter-carrier connections better.

It should be noted that *intra*-carrier connections – between the vehicles of a single service board – are being handled by the service boards themselves in the design of their CAD/AVL systems.

The Paratransit TCP system is an extension of the base system concept to cover the paratransit services offered by the service boards. The same concept applies: sharing of information between mainline service operations and paratransit service operations can lead to improved inter-carrier connections. In addition, since demand for paratransit service exceeds supply, the system can also lead to improved paratransit vehicle and driver productivity.

Alternative approaches to TCP

In looking at how to realize the TCP concept, the first decision that had to be made was this: Will the system protect carrier pre-defined connections, customer-requested connections, or both? Table 1-1 below illustrates the pros and cons of the two approaches. To summarize, the use of pre-defined connections allows precise selection of connections for maximum impact. However, it can also result in vehicles being held even if no one wants to make the connection that day, since there is no provision for customer input.

The use of customer-requested connections, on the other hand, focuses attention on connections of immediate interest to actual customers. However, when used for inter-carrier connections, this approach is unlikely to succeed due to 1) customers asking too late for the carriers to respond, and 2) the complex and time-consuming process necessary to get a connecting carrier to agree and respond back to the requesting vehicle.

	Pros	**Cons**
Pre-defined connections	1. Carriers can select connections for greatest impact. 2. Approach is transparent to customers.	1. May hold vehicles when no one wants to connect. 2. Requires active inter-carrier management of connection definitions. 3. Improved service only available to customers if they are using a pre-defined connection.
Customer-requested connections	1. Vehicles are held only when an actual customer has requested the connection. 2. A significant step toward personalized service.	1. Unwieldy approval process. 2. Passengers may not ask or may ask too late for adjustments to be made. 3. Could delay boardings on higher-volume routes. 4. Irate customers if promised connection is not delivered.

Table 1-1: Pros and Cons of Alternative TCP Approaches

For the TCP project, it was originally planned to pursue both pre-defined and customer-requested connections. However, after RTA review of the draft functional requirements for customer-requested connections, RTA decided to drop this approach from the proposed architecture. The primary reason is a concern that the connecting carrier approval may not be consistently available in a timely fashion. This approach, however, is still identified as a possible future enhancement.

With the decision to focus on pre-defined connections, a second fundamental decision presented itself. How centralized or distributed should TCP functionality be? Should the onus for inquiry processing and endangered connection identification fall on the TCP central system, or should it be distributed to the various service boards' systems? This decision has implications for system cost and effectiveness. Should the TCP system simply forward service status inquiries and responses from one carrier to another? Or, should it provide a higher degree of intelligence and control so that carriers only receive messages when there is a an "endangered connection"? Or, should its function fall somewhere between these two extremes?

This question was originally framed in the Task 1 Report. There, five degrees of centralization were identified. These are summarized in Table 1-2. They range from a bilateral messaging concept, where the TCP system is little more than a smart message switch, all the way to a proactive optimizing concept, where the TCP system not only identifies endangered connections, but selectively notifies carriers of them after identifying a regional optimal solution for which connections to protect.

The approach ultimately chosen for the TCP system was number 4, Proactive, Exception-based TCP. In this option, the TCP system identifies endangered connections and notifies the carriers that are involved, providing current status information. This approach minimizes carrier processing requirements, allows carriers to collaboratively select connections to be protected, and proactively notifies them of endangered connections. Each carrier also retains the authority to decide whether or not to hold its vehicles to make a particular connection.

System Architecture

Figure 1.1 provides a high level architecture diagram of the TCP Base System, showing the interrelationship of the basic system components. Current carrier plans provide for vehicles and carrier CAD/AVL systems to exchange location, schedule adherence data and operating instructions. The TCP system calls for carrier systems to promptly share current location and schedule adherence data with the Illinois Transit Hub, as well as route and run reference files when updated. The Hub makes this data available to the TCP system. The TCP system returns endangered connection alerts and updates to the carrier CAD/AVL systems. Carriers determine if vehicles are to be notified and instructed to hold.

System approach	Description	Comments
1. Bilateral message-based TCP	Each carrier system supports a set of standard inquiries. Carriers electronically process and reply to each other's service status inquiries, using the information to manage connections and monitor performance. The central TCP system simply switches the messages, with limited edits.	? No central data store. ? Carrier systems process inquiries and responses. ? Carrier CAD/AVL systems must detect endangered connections. ? Connection problems identified only if an inquiry is made. ? Greatest communications requirements of all approaches. ? Most decentralized approach.
2. Inquiry-based TCP	Carrier systems constantly update a central database of operational status information at the Illinois Transit Hub. Individual carriers inquire against it to get the current status of other carriers' connecting services. TCP processes and responds to the inquiries. Carriers retain all responsibility for identifying and requesting needed information.	? Central data store. ? Carrier systems process only inquiry responses. ? Carrier CAD/AVL systems must detect endangered connections. ? Connection problems identified only if an inquiry is made.
3. Repetitive notification TCP	This approach is similar to inquiry-based TCP, except that most inquiries are stored once in a "carrier profile", then executed automatically as directed.	? Central data store. ? Minimal inquiries required. ? Carrier CAD/AVL systems must detect endangered connections. ? Connection problems identified only if an inquiry is made.
4. Proactive, exception-based TCP	Carriers forward real-time status information to the transit hub. The TCP system continuously matches this information to schedules for pre-defined connections, and attempts to identify endangered connections. Upon doing so, the system notifies the carriers involved, including the latest status on the involved vehicles. This continues until the connection is made or missed. Performance monitoring is also supported on this system.	? Central data store ? No inquiries required. ? Intensive processing at central site. ? Carriers don't have to detect endangered connections. ? Carriers automatically notified of endangered connections. ? Connections not pre-defined are not protected. ? Less processing required at carriers. ? Lower communications requirements.
5. Proactive, optimizing TCP	Same as approach 4 above. In addition, the system employs an algorithm to examine groups of potential connections at a sub-regional level and select a set of protection actions which minimizes the sum of overall transfer times, preferably weighted by the number of passengers involved. Exception reports are then sent only for connections that are part of the optimal solution.	? No inquiries required. ? Most intensive and complex processing at central site, plus data store. ? Optimization problem must be solved and implemented. ? Carriers don't have to detect endangered connections. ? Carriers automatically notified of endangered connections. ? Connections not pre-defined are not protected. ? Least processing required at carriers. ? Lowest communications requirements.

Table 1-2: Possible Degrees of TCP System Centralization

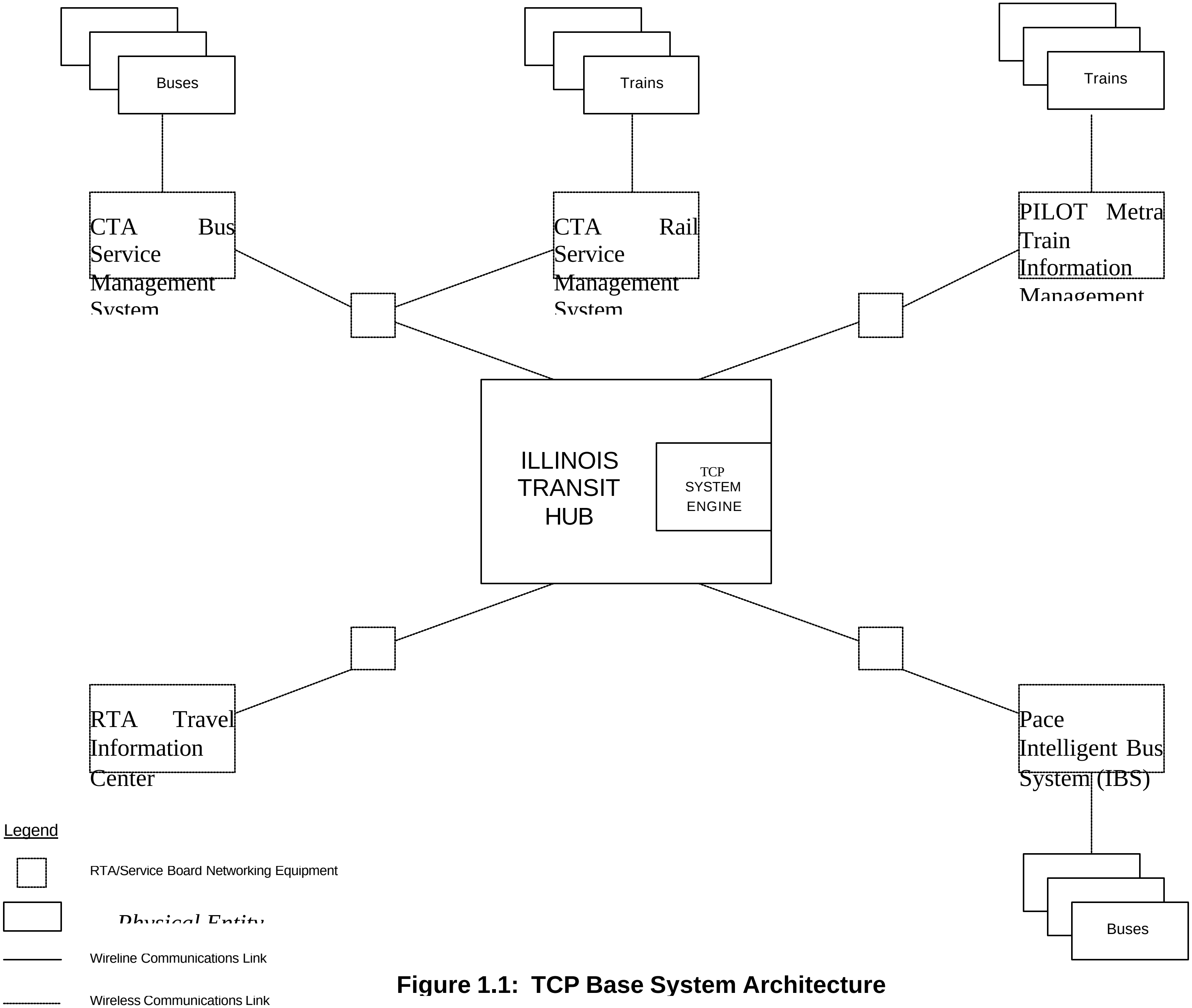

Figure 1.1: TCP Base System Architecture

Figure 1.2 shows the architecture of the TCP system when the Stage 2 Paratransit TCP capabilities are added. It is the same as that of the TCP Base System, but with the addition of paratransit carriers and vehicles networked with their respective sponsoring carriers. Paratransit carriers forward connection requests prior to trip dispatch, as well as estimated time of arrival (ETA) at connection points when relevant. They then receive alerts and updates just like fixed route carriers.

Information Requirements

For convenience, this section provides a summary of the information requirements of the TCP system. Definitive information collection, processing and distribution functional requirements can be found in the Task 8 Final Report: Functional Requirements.

The information requirements of the TCP system are similar to those of transit traveler information applications such as the RTA Active Transit Station Signs (ATSS) project. The TCP system requires both static information such as route definitions, run/train schedules, and connection definitions, and dynamic, real-time information on the location and schedule adherence status of in-service vehicles or trains. These are provided by four current, planned or experimental service board CAD/AVL systems:

- CTA's Bus Emergency Communications System/Bus Service Management System (BECS/BSMS)
- CTA's Rail Service Management System (RSMS)
- Metra's experimental Train Information Management System (TIMS), if fully implemented at some point in the future
- Pace's Intelligent Bus System (IBS)

Dynamic information will also include paratransit connection requests based on trip reservations.

Review of Functional Requirements

TCP system functional requirements are definitively described in the Task 8 Final Report: Functional Requirements. Brief summaries are provided here for the TCP Base System and Paratransit TCP System.

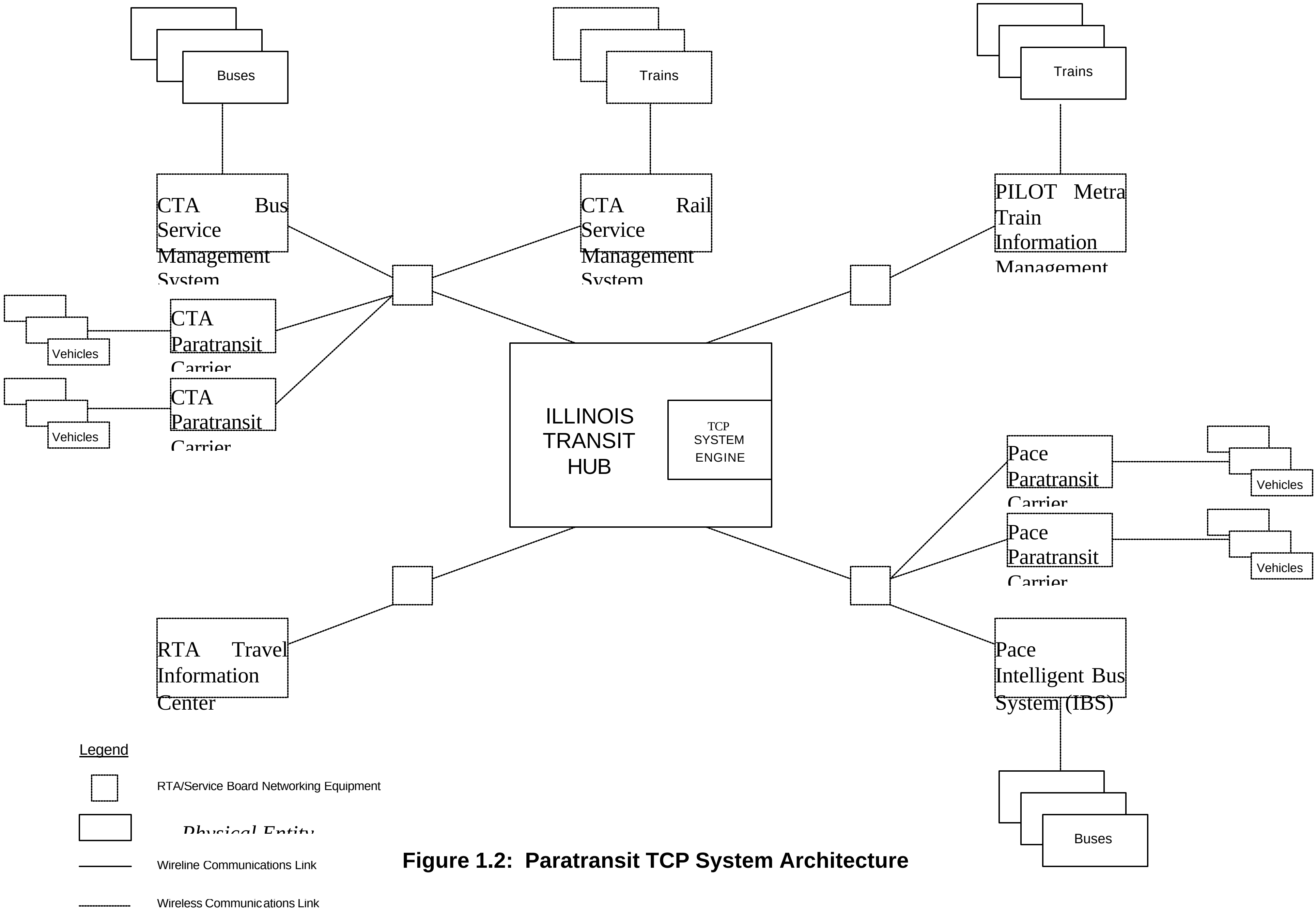

Figure 1.2: Paratransit TCP System Architecture

TCP Base System Requirements

Via the Illinois Transit Hub, the TCP System receives route definitions, run/train schedules, and connection definitions from the carrier in advance of their effective date and time. Also via the Illinois Transit Hub, it receives location and status information from carrier CAD/AVL systems as it is received from vehicles. The TCP system continuously monitors this information against schedules and connection definitions in order to identify endangered connections. A connection is endangered if the “from” vehicle is behind schedule to the extent that the “to” vehicle will have departed from the connection point before the “from” vehicle arrives. When such a situation is detected, the TCP system notifies the connecting carrier (or optionally both carriers), and provides ETA at the connection point for the “from” vehicle. The carriers (or their CAD/AVL systems) determine whether or not to take action to protect the connection, based on the status of the affected route and regional conditions. The TCP system continues forwarding updates to the carrier(s) until both vehicles have departed the connection point.

Paratransit TCP Requirements

Paratransit operations are handled somewhat differently, as they are not schedule-based but demand-responsive in nature. When a reservation is taken for a trip involving an inter-carrier connection, additional information is collected, such as route and destination or run/train number. Then, the paratransit carrier submits the connection request to the system at some point prior to dispatching the trip. It is forwarded to the TCP system via the sponsoring service board. At the TCP system, it is entered as a one-time connection to be monitored, then protected if necessary just as any other pre-defined connection would be. Additionally, for trips terminating at a connection point, the paratransit driver, dispatcher or CAD/AVL system must notify the TCP system when ETA at the connection point changes in order for the connection to be protected.

Deployment Strategy

There are several prerequisites for deploying the TCP system as specified in this project:

- There must be two carriers with implemented and functioning CAD/AVL systems covering all or a substantial portion of their operations.
- There should be at a very minimum 6-12 months experience with these systems after acceptance of the system and completion of implementation.
- There must be mutual agreement on the parameters for a demonstration and for further implementation.

It is expected that deployment would take place in the following sequence:

1) Demonstration project with two carriers at a handful of selected sites (see Section 1.3.3 below).
2) Based on results, deployment of additional connections between the two demonstration carriers, focusing on the types where the greatest benefit was observed.
3) Addition of the third carrier – first one partnership, then the other.
4) Continued addition of connections by the carrier pairs until an ideal tradeoff between benefit and complexity is reached.

Connection Point Identification

Identification of connection points is being handled under a separate project: *Regional Transit Coordination Plan: Location Study*. RFP 11340 was recently issued by RTA for this project. It indicates that "[t]he study will identify all existing and proposed interagency transfer locations, classify them by the transit modes available, quantify the magnitude of transfer activity at existing locations, and estimate the ultimate potential for transfer activity at both existing and potential locations."

The RFP identifies 7 tasks associated with the project:

1) Identify "Universe" of Existing Transfer Locations
2) Identify "Universe" of Potential Transfer Locations
3) Classify Transfer Locations by Service Available and Other Important Characteristics
4) Quantify Existing Interagency Transfer Activity
5) Estimate the Relative Demand for Interagency Transfer Activity at Existing and Potential Locations.
6) Prioritize Transfer Locations by Category for Further Study
7) Prepare Final Report

In addition to the work identified in this RFP, two additional attributes need to be identified for connection points to be covered by the TCP system. These are:

1. Transfer times for each possible connection – this is required to support the TCP system's determination of whether a connection is endangered. For example, this would encompass all possible combinations of four bus stops at a major intersection, or from loading bay to loading bay at a bus terminal, or from different commuter train platforms to one or two bus stops. Alternatively, transfer times could be calculated from physical attributes of the transfer paths, if available.
2. A surrogate for the security risk at the station during various service periods – this would be used in prioritizing connection points. For example, a measure could be used such as the ratio of reported incidents at a stop or on a route to passenger trips.

Connection Point Selection Criteria

It is suggested that the overall goal in selecting connection points is to maximize the benefit to customers. Accordingly, the following selection criteria for connection points are suggested:

- Passenger volume – this is the single most important criterion.
- Average wait time at the connection point – this may be impossible to measure, but surrogates or estimates from actual run/train operating data may be used. This can be used raw, or normalized by the “to” route headway – then the appropriate measure would be: (raw wait time/”to” route headway). A value closer to 1.0 suggests that many passengers are missing connections.
- Service board assessment – service board qualitative and quantitative input about problem connections from field personnel and supervisors, operations analysts, and customer service representatives (receivers of passenger complaints).
- Security risk at the connection point – see additional attribute #2 above.
- Public input – if involved constituencies express a particular concern about a particular connection point.
- Operational impact – if the service board(s) feel that there will be an operational benefit of activating connection protection for a particular point or points.
- Profitability or recovery ratio of involved routes – an item which may be considered in light of prevailing RTA and service board policies at the time of the analysis. Transfer connection protection could be viewed as a tool to build ridership on existing lower-return routes, or at the other extreme, as a “perk” appropriate to higher-return routes or even to premium services such as express routes where a higher fare is paid.

It should be noted that this same set of criteria may be applied to the selection of sites for study of schedule coordination or troubleshooting of existing service problems.

Demonstration Connection Points

Selection of connection points for the initial demonstration of TCP should actually employ the same criteria listed above. In addition, quality of existing performance measurements (both before and after) for evaluation purposes should be considered. The carriers involved should have a high degree of input into the selection of demonstration project points.

It is also suggested that as much as possible, the points selected represent a diversity of connection types, including for example: feeder route to trunk route; intersection of trunk routes; shared terminal facility or pulse point.

TCP BASE SYSTEM SPECIFICAT IONS

System Configuration

The TCP system architecture (refer to Figure 1.1) consists of several principal components. These are:

1. Carrier CAD/AVL systems
2. Wireline links between carrier CAD/AVL systems and the Illinois Transit Hub.
3. The Illinois Transit Hub
4. The TCP system engine
5. Wireless vehicle-carrier communications
6. Carrier transit vehicles

The last two of these relate to the communications between the carrier CAD/ AVL system and vehicles in the field. TCP is not expected to add additional functionality in these areas. Instead, carriers are expected to exploit this existing capability to deliver operating instructions to facilitate the protection of connections.

System Functions by Component

Carrier CAD/AVL systems

In addition to their existing or planned capabilities, these systems shall have the following capabilities for support of the TCP system:

> When a schedule adherence report is received from a vehicle involved in an inter-carrier connection, if a message is not already being sent to the Illinois Transit Hub on that vehicle, create a message in the same format. (Reference message requirements identified in the Task 8 Final Report: Functional Requirements, Section 4.3.3.1.)
>
> When an Endangered Connection Alert is received from the TCP System, process the message to determine if a hold action for one of the carrier's vehicles would be needed. If so, then it is the carrier CAD/AVL system responsibility to in some way determine whether action will be taken, and if so, what. This may be done automatically, or by presenting information to the dispatcher for decision-making. Existing carrier functionality can then be used to forward operating instructions to the driver.

Similarly, when an Alert Update Report is received from the TCP system, process the message to determine if a hold action for one of the carrier's vehicles was initiated or is now needed.

Wireline links between carrier CAD/AVL systems and the Illinois Transit Hub

Wireline links will be employed between the carrier CAD/AVL systems and the Illinois Transit Hub, of which the TCP System Engine will be a part. These links will be responsible for transport of data messages between these two system components.

The Illinois Transit Hub

The general purpose of the proposed Illinois Transit Hub is to provide the service boards with connectivity to the Gary-Chicago-Milwaukee (GCM) corridor Gateway system network. As now envisioned, the Hub will gather current service information on all transit operations, then make it available to the GCM Gateway system for use in regional traveler information services. It will also be the repository of static data on carrier routes, schedules, stop characteristics, and pre-defined connections.

In support of the TCP system, the Hub design shall provide prompt access to just-received carrier status data. It shall also provide ready access to current status on any vehicle reported to the Hub, and to static databases mentioned above.

The Hub design shall also provide for processing and forwarding of messages from the TCP system to the carriers' CAD/AVL systems.

The TCP system engine

The TCP system engine shall actively or passively access the latest status information from the Illinois Transit Hub. It shall work reports sequentially, checking each for potential endangered connections or for update information on previously identified endangered connections. It shall check first to see if the message represents an update to a previously identified endangered connection, following a sequence such as this:

- Check table of "active alerts" for applicability of this message
- Determine if this report corresponds to the connection point itself
- If it does, or if it is beyond the connection point, check to see if the connecting vehicle connection point report (or one beyond that point) has been received. If it has, then update the log of previously identified endangered connections to indicate that no further Alert Update Reports are needed after the current one

? Create an alert update report for the carriers involved in the active connections identified

Next, it shall check for additional connections which may be newly endangered by 1) determining if the vehicle is behind schedule (if the Hub data structure does not already provide this); 2) if so, accessing Hub data defining pre-defined connections to identify any in which the vehicle being examined is the “from” vehicle; 3) if there are any such connections, accessing the current status of the connecting vehicle and determining whether the connection is endangered; 4) if a connection is found to be endangered, using connection definition information retrieved earlier to identify involved carriers, create Endangered Connection Alert messages to those carriers; and 5) logging the endangered connection as an “active connection” for future reference.

Data Dictionary/Message Set Specifications

Data Dictionary/Message Set Specifications for the TCP system shall wherever possible conform to the relevant data object definitions in the Transit Communications Interface Profiles (TCIP) standards. Where these standards do not cover a specified piece of functionality (necessary data elements or messages not defined), then additional data elements and messages shall be defined as needed using the TCIP terminology, syntax and existing data element and message definitions.

Specific modifications expected to be required include but are not limited to the following:

The existing TCIP Control Center Object data element/message specifications shall be modified/adapted to provide for:

Data load to the Illinois Transit Hub from service board CAD/AVL system. This is similar to the CcDataLoadTemplate message from the TCIP Control Center (CC) Object.

Current service status information from service board CAD/AVL system to Illinois Transit Hub. This is similar to the data flow of schedule adherence from vehicles to the control center as described in the TCIP Control Center (CC) and On-Board (OB) Objects.

New data elements and messages covering these requirements shall be created:

a) Additional elements required by TCP system functionality, such as possibly a connection ID.
b) Endangered connection alerts from the TCP system to service board CAD/AVL systems.

c) Endangered connection updates, also from the TCP system to service board CAD/AVL systems.

Standards, Interface and Communications Requirements

General

a) Communications facilities are expected already to be in place to support transmissions between the RTA service boards and the Illinois Transit Hub. Therefore, these facilities are not specified here.

b) It shall be the responsibility of the originating system to format messages according to the agreed-upon standard message format. No message conversion shall be performed by the TCP system.

Relevant Standards

a) The TCP system hardware and software shall in all cases conform to the regional architecture as established by GCM Traveler Information System (TIS) guidelines current at the time of detailed design.

b) The TCP system software shall conform to the relevant TCIP data objects. Extensions shall be developed and identified as such where necessary due to functionality not envisioned in the TCIP model.

c) TCP system communications with service board CAD/AVL systems shall conform to any relevant National Transportation Communications Interface Protocols (NTCIP) standards. Relevant standards include, but are not limited to, the NTCIP Class B (Center-To-Center) standards.

Minimum Communications Requirements

a) Communications between the TCP system and service board CAD/AVL systems shall be accomplished using the TCP/IP protocol.
b) The Common Object Request Broker Architecture (CORBA) shall be installed at the Illinois Transit Hub and the three service boards to provide a common interface to ensure interoperability and data interchangeability.

PARATRANSIT TCP SYSTEM SPECIFICATIONS

System Configuration

The Paratransit TCP system architecture (refer to Figure 1.2 above) adds three more components to the TCP Base System Architecture:

1. Contract Paratransit Carrier CAD/AVL systems
2. Contract Paratransit Carrier vehicles
3. Wireline links between Contract Carrier CAD/AVL systems and service board network equipment for connectivity with the Illinois Transit Hub.

Unlike the TCP Base System case, Paratransit TCP may require the addition of functionality to the communications between (paratransit) dispatchers and vehicles. Such systems are normally capable of collecting time/location information and trip events, and of giving the driver pick-up time updates. However, they are usually not equipped to produce arrival ETA's either via polling the driver or via routing software with access to real time road travel times. One of these capabilities will be required. Also, as outlined in the Task 8 Functional Requirements, enhancements will be required to reservation systems, whether owned by the contract carriers or by the service board.

System Functions by Component

Contract Paratransit Carrier CAD/AVL systems

In addition to their existing or planned capabilities, these systems will have the following capabilities for support of the TCP system:

> The system shall have the ability to generate a message to the TCP system requesting protection for a connection with fixed-route service, and to forward the message to the TCP system at an appropriate interval prior to trip departure.
>
> When an Endangered Connection Alert is received from the TCP System, process the message to determine if the scheduled pick-up time for the affected trip should be changed. If so, then either take action, or notify the dispatcher so that he or she can do so. Existing functionality can then be used to forward operating instructions to the driver.
>
> Similarly, when an Alert Update Report is received from the TCP system, process the message to determine what if any action is now needed.

Contract Paratransit Carrier vehicles

If it is necessary for the driver to provide human estimates of revised ETAs, then the capability to do so via a pre-formatted data message shall be added to the on-board system.

For connections being made at the end of the paratransit trip, on board systems shall provide for entry or calculation of ETA updates in the case where the trip is falling behind its scheduled arrival time at the connection point.

Wireline links between Contract Carrier CAD/AVL systems and service board network equipment for connectivity with the Illinois Transit Hub

If this networking is not already in place, it shall be added so that paratransit carrier CAD/AVL systems can exchange messages with the TCP system via Illinois Transit Hub.

The Illinois Transit Hub

Assuming that the Hub is not already collecting any information from paratransit services, modifications shall be required so that paratransit connection requests and ETA update messages can be received, processed and stored for use by the TCP system.

The TCP system engine

The TCP system engine shall be capable of receiving/accessing, processing and responding to messages received from contract paratransit carriers via the Illinois Transit Hub. They shall be processed sequentially in a common queue with fixed route messages. Identification of endangered connections, etc, as described in the TCP Base system section, shall be performed in the same fashion for connections involved with paratransit.

Data Dictionary/Message Set Specifications

Data Dictionary/Message Set Specifications for the Paratransit TCP system shall wherever possible conform to the relevant data object definitions in the Transit Communications Interface Profiles (TCIP) standards. Where these standards do not cover a specified piece of functionality (necessary data elements or messages not defined), then additional data elements and messages shall be defined as needed using the TCIP terminology, syntax and existing data element and message definitions.

Specific modifications expected to be required include but are not limited to the following:

Existing TCIP Control Center Object data element/message specifications shall be modified/adapted to provide for:

a) Data load to the Illinois Transit Hub from paratransit carrier CAD/AVL system (via service board). This is similar to the CcDataLoadTemplate message from the TCIP Control Center (CC) Object.
b) Current service status information from paratransit carrier CAD/AVL system to Illinois Transit Hub (via service board). This is similar to the data flow of schedule adherence from vehicles to the control center as described in the TCIP Control Center (CC) and On-Board (OB) Objects.

New data elements and messages covering these requirements shall be created:

a) Additional elements required by TCP system functionality, such as possibly a connection ID.
b) Endangered connection alerts from the TCP system to paratransit carrier CAD/AVL systems (via service board).
c) Endangered connection updates, also from the TCP system to paratransit carrier CAD/AVL systems(via service board).

Standards, Interface and Communications Requirements

General

a) It shall be the responsibility of the originating system to format messages according to the agreed-upon standard message format. No message conversion shall be performed by the TCP system.

Relevant Standards

The TCP system hardware and software shall in all cases conform to the regional architecture as established by the GCM TIS guidelines current at the time of detailed design.

The TCP system software shall conform to the relevant TCIP data objects. Extensions shall be developed and identified as such where necessary due to functionality not currently realized in the TCIP model.

TCP system communications with service board CAD/AVL systems shall conform to any relevant National Transportation Communications Interface Protocols (NTCIP) standards. Relevant standards include, but are not limited to, the NTCIP Class B (Center-To-Center) standards.

Minimum Additional Communications Requirements

High-level preliminary estimates suggest that addition of the Paratransit TCP system functionality will result in an increase of about 10-20% communications traffic between the TCP system and the service boards. It is assumed here that this will not lead to additional investments in hardware or wireline communications capacity.

SYSTEM SOFTWARE GUIDELINES

Operating System

The TCP system shall operate on the same platform as the Illinois Transit Hub. At this point the platform could be Windows 2000, Unix or Linux (or superseding products). The final choice, to be made during technical design of the Hub, will be selected so as to best facilitate data sharing among the service boards, the TCP system, the Illinois Transit Hub and related systems, such as ATSS and the Parking Management System (PMS).

Database Management System

The TCP system shall be developed around a commercially available and widely-used relational database management system (RDBMS), which stores databases as a series of linked tables. The preferred platform currently is Oracle, for several reasons:

1. Backward compatibility with RDBMSs installed at the service boards
2. High performance in terms of the query response time
3. Support for several key interface and programming tools, such as Java and XML (Extensible Markup Language).

This recommendation is contingent on the selection of an RDBMS approach for the development of the Illinois Transit Hub, and other applications systems in that complex such as the Active Transit Station Signs (ATSS) System. If, however, the decision is made to design those systems using an object-oriented approach and object-oriented database management systems (OODBMS), this recommendation should be revisited. (OODBMSs are also known as object-oriented file systems. They are specifically designed to store complex data objects and associated links to other objects.) Under such circumstances, it might turn out that an object-oriented database management system was a better choice for the TCP system.

User Interface Design

The TCP system shall include a system operator interface employing two user displays (see Task 8 Final Report: Functional Specifications, Section 4.7). The system shall be Graphical User Interface (GUI)-based, with point-and-click access to required functions. It shall provide, at minimum, the following:

a) The ability to review and correct conflicts in static connection data in service board run/schedule files.

b) The ability to view aged connections not yet closed out, to terminate alert update reports, and to close out connections.

c) The ability to view and act on current endangered connections, including the ability to stop reporting or adjust the frequency of reporting.

d) The ability to perform administrative tasks such as management of archive data and system reference files, as well as to enable/disable TCP system features, carriers, some connections or all connections. Also, the ability to define and enforce levels of access (lock out) for all system users, limiting update access only to those requiring it. Password control must also be supported. (See Section 4.4.6 for further system security specifications).

e) The ability to send and receive email to/from service board dispatchers, Hub personnel, and others as necessary.

If Service Board route, schedule and run information integration is planned or in place at the Illinois Transit Hub in the context of a Geographic Information System (GIS), then the TCP system operator interface shall utilize that feature, allowing the operator to graphically view and select pre-defined connections.

TCP Software Design

Object-Oriented Design

To reduce system maintenance cost and to facilitate system expansion in the future, the modular design or object-oriented design concept shall be implemented in the early stage of TCP system detailed design. This is especially important given that the three service boards, and in the future RTA and other carriers will all share use of the system.

Data Communication Automation

The base TCP system relies on each service board to provide AVL and dispatch information to the central TCP server so that endangered connections can be detected. To reduce human error, automatic data communication between TCP server and AVL/Dispatch System in service boards shall be used. Location and schedule adherence information from each service board must be received automatically at the Illinois Transit Hub and made available to the TCP system without human intervention. Appropriate hardware and software design shall be applied toward this end.

Message Set Definition

The TCP system shall exclusively employ a concise, standard message set for communications with service board CAD/AVL systems. The selection of this message set shall consider the specific hardware and software in use at each service board.

Database Concurrency

Ideally, the Illinois Transit Hub would enforce full database concurrency between itself and the service board CAD/AVL and scheduling systems. However, there are several significant challenges associated with such an approach:

- Carrier systems will come from different vendors and have different architectures.
- The TCP Operator may have to make changes if different service boards' connection definitions conflict.
- Service boards may not send all real time schedule adherence reports to the Illinois Transit Hub/TCP system.

The choice of how to have the TCP system enforce database concurrence and data integrity depends on the design of the Illinois Transit Hub. In any event, the ability of the TCP system to sense endangered connections depends primarily on the accuracy not only of real time data, but of reference files (schedules, routes) as well.

The TCP system shall be designed to provide for the maximum possible database concurrence with the service board CAD/AVL and scheduling systems. The design of the Illinois Transit Hub with respect to service board database concurrency shall be fully taken into account in the TCP system design.

Common Object Request Broker Architecture (CORBA)

The TCP system deployment shall employ the CORBA component both at the Illinois Transit Hub and at the service board CAD/AVL systems. This is required in consideration of the reality and/or potential for unlike systems using different programming languages at different service boards or even within service boards. The CORBA component will provide a common interface to ensure the interoperability and data interchangeability between components and between service boards.

Security

Real time operating data provided by service boards is sensitive information that must be protected from unauthorized access during transmission or during storage and use at the TCP server. At the same time the TCP System must have access to this information in order to function. Therefore, the design of the TCP server software shall provide for full data security and protection from unauthorized access to data, as well as the introduction of unauthorized data.

Performance

Though there will be a growing customer information role for service board scheduling and dispatch systems, their primary mission remains the support of service board revenue service. The TCP system has the potential to add a significant processing load to service board systems, especially in later phases. Thus, the TCP system shall be designed such that its performance standards keep the TCP server and/or Illinois Transit Hub from in any way becoming a bottleneck for service board operations.

SYSTEM HARDWARE GUIDELINES

TCP Base System

This section covers communications equipment and computer hardware required for support of the TCP Base System.

Communication Devices

With respect to communications equipment, it is expected that the TCP system will utilize links between the service boards and the Illinois Transit Hub that are already operational. It is also expected that the TCP server and TCP operator's PC will be incorporated in an Illinois Transit Hub LAN. However, should this not be the case, there will be several requirements, as detailed below.

In support of communications with the TCP Base System, routers shall be installed at each service board, and at the TCP System installation.

For data transport between the service boards and the TCP system, three (3) T1 grade lines shall be provided – one for each service board.

In order to ensure interoperability between service board and TCP applications, CORBA shall be installed at each service board and at the TCP System Installation (requirement previously stated in Section 4.5.5).

The TCP server and TCP operator's PC, along with printers and any other peripherals, shall be connected by an appropriate local area network.

Computer Hardware

Because of the standardization of computer hardware, the hardware selection is the easiest part of system configuration. In general, the choice is closely linked with the selection of operating system. For example, Windows NT and Windows 2000 have a Hardware Compatible List (HCL) that specifies what hardware components can be used.

Following are the specific hardware requirements:

The TCP System Server shall be a dual processor PC, Pentium III Xeon or better, running the selected operating system. The system shall include on board or peripherally enough archive storage to hold five years' worth of Endangered Connection Alerts and Alert Update Reports (minimum 15 gigabytes). It shall include enough memory and fast access storage to support system requirements as specified in this report and in the companion volume of functional requirements. The system shall also include a high-resolution monitor, keyboard and pointer for system maintenance purposes.

A system operator workstation with PC, dual monitors and work area shall also be provided with the TCP Base System. This shall consist of at least one PC, Pentium III or higher, one 19" or larger high-resolution color monitor for display of current system statistics and details; one 17" or larger high-resolution color monitor for display of commands entered, command responses, and other information as required; and, one laser printer capable of printing at least 8 pages per minute (ppm).

Paratransit TCP System

The design of the Paratransit TCP system assumes that the communications path from the Illinois Transit Hub to the service board paratransit contract operators will be via the individual service boards' wide area networks (WANs). These connections are planned or under development anyway for other reasons. As a result, no additional communications devices or computer hardware requirements are expected.

ESTIMATED COSTS

TCP Base System

This section provides one-time and ongoing cost estimates for the TCP Base System and the Paratransit TCP system. It includes costs for hardware and software development, system testing, implementation, training and ongoing maintenance. Three cost figures for each component are offered: Low, High, and Best Estimate. Cost summaries are provided for the Base and Paratransit systems. Finally, all the information is summarized into a total project cost.

All costs are expressed in year 2000 U.S. dollars. A project life of 5 years is used for present value analysis purposes. Costs are based on retail prices of commercially available components, and cost estimates for tasks requiring professional services.

Software

TCP system software includes these distinct categories:

? Operating system
? Database management system
? TCP system
? Operator interface
? Other

Operating system and database management system software are commercially available from reputable vendors. On the other hand, the TCP system software and user interface will need to be developed from scratch using a set of software development tools such as Microsoft Visual C++, Visual Basic, or Sun Microsystems' Java Development Kits. The final selection will depend on what operating system is selected.

Operating System Cost

This analysis is based on the costs of Windows 2000. A finalized analysis will need to be based on the chosen platform for the Illinois Transit Hub, and thus for the TCP system (see Section 4.2).

Because the TCP system will be a new installation, full retail prices rather than upgrades apply. The low cost assumes a 5-user server; the high cost, a 10-user server.

The estimate in Table 6-1 assumes that separate software licenses will be needed for the TCP system and the Illinois Transit Hub. If this is not true, a lesser amount will be needed.

Table 6-1: Operating System Cost

Cost Component	OT/RE	Low Estimate	High Estimate	Best Estimate
Operating System	OT	$1,000	$1,200	$1,200

Cost of Database Management System

The database management system cost is based on the preferred choice of Oracle (see Section 4.3). The cost of an Oracle license ranges from $1,900 to $12,000 depending on numbers of users, number and speeds of CPUs, and web hosting capacity, if needed. High, low and best estimates are listed in Table 6-2, below.

Table 6-2: Database Management System Cost

Cost Component	OT/RE	Low Estimate	High Estimate	Best Estimate
RDBMS license	OT	$ 1,900	$ 12,000	$ 6,000

Cost of TCP Interface Design

It is assumed that the capability to make new as well as previous service board status reports available to the TCP system will be included in the Illinois Transit Hub design. It is also assumed that the ability for the Transit Hub to forward messages from the TCP System and other associated servers will be included.

As a result, no interface development costs are being included in this cost estimate.

If such costs were to be included, they would entail 5 days of the development team's time, or equivalent. They would also include CORBA services installed at the TCP System as well as each of the service boards, at a cost of $2,000 per site, or a total of $8,000.

Cost of TCP system application software

The main challenge in the detailed design and development of the TCP system will be in the fast, accurate identification of endangered connections. This will require close integration with the Illinois Transit Hub, as well as fast transaction processing. Also the provision of the operator interface will require either ground-up custom development, or possibly adaptation of a commercial, off-the-shelf (COTS) dispatch system.

For costing purposes, we assume a team of one system engineer and two software engineers at the following rates:

Table 6-3: TCP System Development Staff Rate Assumptions

Position	Direct Labor Rate	Payroll Associated Costs Multiplier	Fully loaded rate
System Engineer	$ 36.06/hr	1.5	$ 90.15/hr
Software Engineer	$ 24.04/hr	1.5	$ 60.10/hr

For staff days in design and development for the team, we estimate from 90 to 150 team days, with a best estimate of 120 team days. This estimate assumes that software testing is an integral part of the development process, so that unit and integrated testing with simulated inputs are included. Final or acceptance testing under production data loads is covered in section 6.1.3 below. This leads to development cost estimates as shown in Table 6-4:

Table 6-4: TCP System Development Cost

Cost Component	OT/RE	Low Estimate	High Estimate	Best Estimate
TCP System Development	OT	$151,000	$252,000	$202,000

Hardware

Communications Facilities

For the purposes of this analysis, we assume that the service boards have already achieved connectivity with the Illinois Transit Hub, so no additional expenditures are anticipated here. As information, however, if connections needed to be established, they would entail a setup fee of $1,000 per service board ($3,000), and monthly communications line lease of $2,000 per service board, or $6,000/month. In addition, a router would be needed at the TCP end as well as at each service board. These routers are expected to cost about $1,500 each or a total of $6,000.

These costs are not expected to be incurred, and so are not included in the cost summary shown in Table 6-11, Section 6.15 below.

Cost of Computer Hardware

Costs of the hardware requirements described in Section 5.1.2.1 above, are provided in Table 6-5 below:

Table 6-5: Computer Hardware Costs

Cost Component	OT/RE	Low Estimate	High Estimate	Best Estimate
TCP Server and Related Equipment	OT	$6,000	$10,000	$7,500
TCP Operator Interface PC	OT	$3,000	$5,000	$3,500
Operator Console and Associated Work on facility housing TCP/Transit Hub	OT	$20,000	$35,000	$25,000

Final Testing, Training And Implementation Costs

The cost of final testing, leading up to system acceptance, is estimated to be 15 staff days for each of the team members, or a total of approximately $25,000.

5 days of system training will be required for all staff who will be covering the TCP operator position. In addition a set of six one-half day orientations will be provided for service board dispatchers and MIS staff who can benefit from a knowledge of TCP system functions and benefits. Costs for development of operator training and system orientation courses are estimated at 2 days of system engineer and 15 days of software engineer time, or about $11,000. Training delivery and instructor preparation and follow-up, based on a single software engineer rate, is expected to total 20 days of instructor time, or about $10,000. Training materials and user manuals are expected to cost another $7,000.

It is assumed that ongoing training will be done by TCP system and Illinois Transit Hub staff.

System implementation is expected to require a full time commitment from the development team or equivalent staff for 20 days, or $34,000.

Costs in these three categories are summarized in Table 6-6 below.

Table 6-6: Testing, Training And Implementation Costs

Cost Component	OT/RE	Low Estimate	High Estimate	Best Estimate
TCP System Final Testing	OT	$17,000	$34,000	$25,000
TCP System Training	OT	$21,000	$33,000	$28,000
TCP System Implementation	OT	$25,000	$50,000	$34,000

System Operation and Maintenance Cost

TCP System Staffing Costs

We assume that the TCP System will require 24 hour/7 day operator coverage. Daytime staff will primarily deal with system integrity, reviewing and reconciling service board reference file updates, and with modifying system parameters in response to weather or special event emergencies where all vehicles are late. Evening, night and weekend staff will be monitoring the system during that priority period for protecting connections under long headway conditions.

We estimate that 1 System Administrator and 4 Full-Time Equivalent (FTE) Operators would be required to provide this coverage, if the TCP system were operated in a standalone fashion. However, we expect that these duties will be incorporated in the responsibilities of Illinois Transit Hub staff, and that TCP system duties would account for 10-35% of their time (best estimate 20%).

Table 6-7 gives salary assumptions for System Administrator and System operator positions. Table 6-8 gives the expected costs for these functions based on the above assumptions about percentage of time allocated to the TCP system.

Table 6-7: TCP System Operations Staff Salary Assumptions

Position	Annual Salary	Payroll Associated Costs Multiplier	Annual Cost	# Needed	Total Annual Cost
System Administrator	$ 65,000	1.6	$ 104,000	1	$ 104,000
System	$ 35,000	1.6	$ 56,000	4	$ 224,000

Operator					
TOTALS					$ 328,000

Table 6-8: TCP System Operations Cost

Cost Component	OT/RE	Low Estimate	High Estimate	Best Estimate
TCP System Operations	RE	$32,800	$114,800	$65,600

TCP System Maintenance Costs

For the purposes of this analysis, we assume that there will be ongoing maintenance requirements for both hardware and software. Estimates of these requirements are based on a percentage of the initial cost. For hardware and system software, this covers maintenance agreements or a portion of the cost of a staff person devoted to maintenance. Best estimate for this category is 15% of initial cost. For custom TCP system software, this represents expected requirements for system modifications. Best estimate for this category is 10% of initial cost.

Cost estimates are provided below in Table 6-9.

Table 6-9: TCP Base System Maintenance Cost

Cost Component	OT/RE	Low Estimate	High Estimate	Best Estimate
TCP Hardware/System Software Maintenance	RE	$ 1,350	$ 2,250	$ 1,650
TCP Custom Software Maintenance	RE	$15,100	$25,200	$20,200

Cost Summary

The total “best estimate” one-time cost for the TCP Base System is $329,200. The annual ongoing “best estimate” cost for the TCP Base System is $88,530. Using a discount rate of 8%, this yields a present value cost of $682,675.

The total estimated cost of the TCP Base system is shown in Table 6-10.

Table 6-10 TCP Base System Cost Summary

Cost Component	**OT/RE**	**Low Estimate**	**High Estimate**	**Best Estimate**

TCP Base System One Time Costs:				
Operating System	OT	$1,000	$1,200	$1,200
RDBMS license	OT	$1,900	$12,000	$6,000
TCP System Development	OT	$151,000	$252,000	$202,000
TCP Server and Related Equipment	OT	$6,000	$10,000	$7,500
TCP Operator Interface PC	OT	$3,000	$5,000	$3,500
Operator Console and Associated Work on facility housing TCP/Transit Hub	OT	$20,000	$35,000	$25,000
TCP System Final Testing	OT	$17,000	$34,000	$25,000
TCP System Training	OT	$21,000	$36,000	$25,000
TCP System Implementation	OT	$25,000	$50,000	$34,000
Total One Time Costs:		$245,900	$435,200	$329,200
TCP Base System Recurring Costs:				
TCP System Operations	RE	$32,800	$114,800	$65,600
TCP Hardware/System Software Maintenance	RE	$1,785	$4,230	$2,730
TCP Custom Software Maintenance	RE	$15,100	$25,200	$20,200
Total Recurring Costs:		$49,685	$144,230	$88,530
5-YEAR TCP BASE SYSTEM PV COST		$444,278	$1,011,069	$682,675

Paratransit TCP System

Software

Incremental cost of TCP system application software

No system software enhancements or additions are expected to be required for deployment of the Paratransit TCP system.

Moderate applications software enhancements will be required for support of Paratransit TCP system. They involve the following message and internal processing:

? Modifying the system engine to deal with single-point ETA's for paratransit trips rather than a multipoint schedule for runs/trains
? Processing connection request messages from paratransit carriers
? Processing ETA update messages from paratransit carriers
? Forwarding Endangered Connection Alerts and Alert Update Reports to paratransit carriers

This effort is estimated to take from 45 – 90 days (best estimate 60 days). Cost estimates for this work are shown in Table 6-11.

Modifications will also be required to contract carrier paratransit systems to:

1. Accept enhanced reservation data.
2. Create and forward connection request messages
3. Create and forward ETA updates when appropriate
4. Process Endangered Connection Alerts and Alert Update Reports, including where appropriate the update of trip pick-up times due to a late arriving connection

Work required to make these changes is not estimated in this report.

Table 6-11: Paratransit TCP System Development Cost

Cost Component	OT/RE	Low Estimate	High Estimate	Best Estimate
TCP System Modifications	OT	$43,000	$87,000	$58,000

Hardware

Communication Facilities

We estimate about a 20% increase in the message traffic for fully implemented Paratransit TCP over that of the TCP base system. This is due to the additional message traffic between the contract paratransit carriers and the Paratransit TCP system. This traffic will utilize the same communication line as does traffic between the TCP Base system and the service boards. Also, we assume that communications links are in place between the service boards and their contract paratransit carriers suitable for use in this deployment.

For purposes of this analysis, we assume that adequate additional capacity is available to accommodate this traffic on top of that from the installed TCP Base system. Therefore, no communications costs are included in the analysis.

Cost of Computer Hardware

The incremental computer capacity required to handle the additional processing is minimal. We assume that the TCP Base system installation is adequate to handle the additional load. Therefore, no additional hardware costs are included in the analysis.

Final Testing, Training And Implementation Costs

The cost of final testing, leading up to Paratransit TCP system acceptance, is estimated to be 10 staff days for each of the team members, or a total of approximately $17,000.

Training needs will be as follows: TCP operators will require a one day course on the new functions and messages associated with Paratransit TCP. In addition, a set of six one-half day orientations will be provided for service board paratransit staff and contract paratransit carrier dispatchers and MIS staff. Costs for development of operator training and orientation courses are estimated at 1 day of system engineer and 10 days of software engineer time, or about $5,500. Training delivery, based on a single software engineer rate, is expected to total 8 days of instructor time, or about $4,000. Training materials and user manuals are expected to cost another $10,000.

Once again, it is assumed that ongoing training will be done by TCP system and Illinois Transit Hub staff.

System implementation is expected to require a full time commitment from the development team or equivalent staff for 25 days, or $42,000. This number is higher than the base system number because there are many more sites to cover.

Costs in these three categories are summarized in Table 6-12 below.

Table 6-12: Testing, Training And Implementation Costs

Cost Component	OT/RE	Low Estimate	High Estimate	Best Estimate
TCP System Final Testing	OT	$13,000	$34,000	$17,000
TCP System Training	OT	$15,000	$23,000	$19,000
TCP System Implementation	OT	$30,000	$50,000	$42,000

System Operation and Maintenance Cost

TCP System Staffing Costs

While there will be increased data flowing to the TCP system with the implementation of the Paratransit TCP system, it is not expected that the operations and maintenance effort will change significantly. As a result, the low estimate is that there will be no increase in staffing costs in this category. Worst case is that there will be a 5% increase in Illinois Transit Hub staff expenses required with the addition of the Paratransit TCP system capabilities. The best estimate is a 2% increase in Illinois Transit Hub expenses, or $6,560.

Table 6-13: Paratransit TCP System Operations Cost

Cost Component	OT/RE	Low Estimate	High Estimate	Best Estimate
TCP System Operations	RE	$ 0	$16,400	$6,560

TCP System Maintenance Costs

It is expected that total custom software maintenance costs will increase commensurately with the cost of the Paratransit TCP System software enhancements. Expected costs are summarized in Table 6-14.

Hardware and system software maintenance costs are not expected to change with the addition of the Paratransit TCP system capabilities.

Table 6-14: Paratransit TCP System Maintenance Cost

Cost Component	OT/RE	Low Estimate	High Estimate	Best Estimate
TCP Custom Software Maintenance	RE	$4,300	$8,700	$5,800

Cost Summary

The total estimated incremental cost of Paratransit TCP system is shown in Table 6-15. In present value terms, the best estimate cost will be about $185,000.

Table 6-15 also summarizes TCP Base System costs and Paratransit TCP costs to arrive at a total present value cost for the entire system. Best estimate for this cost is $868,025. It should be noted that this total assumes that both projects will start concurrently – an unrealistic assumption. Therefore, this estimate should be used only to provide decision-makers with an idea of the magnitude of the entire project cost.

Table 6-15: Paratransit TCP System Cost and Total Combined System Cost

Cost Component	OT/RE	Low Estimate	High Estimate	Best Estimate
Incremental costs for Paratransit TCP System				
One Time Paratransit TCP Costs:				
TCP System Modifications	OT	$43,000	$87,000	$58,000
TCP System Final Testing	OT	$13,000	$34,000	$17,000
TCP System Training	OT	$15,000	$23,000	$19,000

TCP System Implementation	OT	$30,000	$50,000	$42,000
Total One Time Costs:		**$101,000**	**$194,000**	**$136,000**
Paratransit TCP System Recurring Costs:				
TCP System Operations	RE	$0	$16,400	$6,560
TCP Custom Software Maintenance	RE	$4,300	$8,700	$5,800
Total Recurring Costs:		**$4,300**	**$25,100**	**$12,360**
5-YEAR PARATRANSIT TCP PV COST		**$118,169**	**$294,217**	**$185,350**
5-YEAR TCP BASE SYSTEM PV COST		**$444,278**	**$1,011,069**	**$682,675**
TOTAL TCP PV COST		**$562,446**	**$1,305,286**	**$868,025**

REGIONAL TRANSPORTATION AUTHORITY
TRANSFER CONNECTION PROTECTION (TCP) PROJECT

TCP PROJECT FINAL REPORT
(TASK 11)

Prepared by:
Wilson Consulting
TranSmart Technologies, Inc.
October 13, 2000

WILSON
CONSULTING

TranSmart

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INTRODUCTION

This document is the last in a series of reports produced as part of the Illinois Regional Transportation Authority (RTA) Transfer Connection Protection (TCP) project. The purpose of the TCP project is to perform a feasibility study and perform preliminary design for a system to facilitate improved inter-agency connections between the three Service Boards of the RTA: the Chicago Transit Authority (CTA), Metra, and Pace. Improved connections will result in the reduction of traveler wait times and the number of missed connections.

This document summarizes work performed and key findings from all 10 completed project tasks. It then offers recommendations for future directions in the area of transfer connection protection. Previous Task Reports for the TCP project are as follows:

Task 1:	Needs Analysis (April 23, 1999)
Task 2:	Synopsis of Existing Carrier Connection Policies (May 25, 1999)
Task 3:	Review Industry Practices and Experiences (October 6, 1999)
Tasks 4-5:	Inventory Existing Scheduling/Dispatching System; Integrate With Automatic Vehicle Location (AVL) and Scheduling/Dispatch (SD) System (December 14, 1999)
Tasks 6-8:	Functional Requirements (February 22, 2000)
Task 7:	Revising Connection Policies (February 22, 2000)
Tasks 9-10:	Final Specification/High-Level Cost Estimate (May 22, 2000)
--	Executive Summary (October 25, 1999)

TASK SUMMARIES

Task 1: Needs Analysis

This first task in the TCP project was crucial in establishing a consensus about project goals, objectives and approach. A questionnaire was employed for initial determination of service board expectations, needs and concerns. Follow-up meetings or phone interviews were performed as necessary with project staff of each service board. Assumptions on connecting passenger needs and priorities were also developed, to be replaced in a future phase by the results of actual market research via surveys and/or focus groups.

Other project tasks included a review of TCP and how it conforms with the Gary-Chicago-Milwaukee (GCM) Priority Corridor regional ITS architecture guidelines; a review of transit service management and how TCP would contribute; identification and evaluation of several possible high-level approaches to the TCP system architecture; preliminary measures of effectiveness for the TCP system; and a set of preliminary conclusions.

Highlights of project findings are as follows:

- The principal goal of the TCP system is improved service to travelers through reduced waiting time and improved consistency of inter-carrier connections.
- CTA voices a strong interest in standardization and mutual agreement by the three service boards on common message sets and database formats.
- Metra sees potential new customers as key targets of this effort.
- Pace voices a strong concern for ease-of-use and desire for the availability of location-specific status information on specific services.
- Approaches for the TCP system range from implementing a relatively simple TCP server that would serve as a “smart switch” for bilateral connection protection messages between service boards, to a sophisticated engine identifying connections and optimally selecting a subset of them to protect based on the current state of the transit network in the region.
- A consensus developed among the stakeholders around a relatively sophisticated TCP server that would monitor both pre-defined and customer requested connections, and alert carriers when a covered connection was “endangered”.

Task 2: Synopsis of Existing Carrier Connection Policies

In this task, the Wilson Consulting team used Task 1 questionnaires, along with our knowledge of service board operations, to develop draft service board connection policy statements for each service board. We forwarded these to the carriers, received their comments verbally or in writing, and incorporated them into revised connection policy statements.

Here are the key findings from this task:

General Policies and Standard Practices

? Each of the service boards had one or more standard practices and/or rules concerning management of intra-carrier connections. However, there was only one formal mainline service policy identified: CTA policies and rules require mainline bus operators, as well as rail operators on adjacent tracks, to dwell at stops long enough to allow passengers to make connections.
? CTA and Pace contract paratransit operator practices provide that, when waiting for a connecting passenger, the contract operator's driver may wait several minutes for arrival of the connecting service (possibly longer with dispatcher approval).
? All service boards rely on visual coordination to protect mainline connections at selected points, either by direct visual identification, or (for CTA rail – bus connections) by use of a station "holding light" indicating a train is in or near a station.
? Pace uses operator-operator or operator-supervisor wide-area voice communications for routine (non-emergency) management of mainline intra-carrier connections (it has adequate voice radio capacity for this). CTA uses the station public address system at large terminals for connection management as well.
? Pace is the only carrier to explicitly involve the passenger in management of mainline connections. Passengers on Pace routes may request a connection with other Pace services from a Pace bus operator. The operator then uses voice radio to contact the other vehicle and in some cases the dispatcher to arrange the connection.

Intra-carrier connection policies and practices

? CTA policies and rules require mainline bus operators, as well as rail operators on adjacent tracks, to dwell at stops long enough to allow passengers to make connections.

? Pace mainline operators can extend their dwell times at connection points when visual contact is made with a connecting vehicle. They can also use voice radio to protect regular connections or passenger-requested connections. Also, at outlying Pace pulse points, operators routinely hold two minutes for late arriving buses, and may wait up to five minutes with supervisory approval.

? For Metra, at outlying points where connections are made between different lines, dwell times may be extended to protect connections if visual contact is made with a connecting train.

Inter-carrier connection policies and practices

? Metra-Pace, Metra-CTA and Pace-CTA mainline connections at selected points are protected based on visual contact between vehicles. In addition, Pace drivers may speak to local Metra station personnel or radio their dispatcher to request information if waiting for an expected Metra connection.

? Under current practices for CTA and Pace paratransit operations, customers desiring a connection must notify the carrier of the desired connecting service and transfer point. Also, when connecting between the paratransit services of CTA and Pace, the passenger must make a separate reservation with each paratransit carrier, coordinating drop-off and pick-up times.

? CTA and Pace operational practices with respect to inter-carrier paratransit connections are very similar. For pickups of connecting passengers, operators wait at a connection point for about five minutes after scheduled pickup time – the same as for any other passenger. Then, if the passenger has not appeared, operators contact their dispatcher, who may get additional information and extend the hold.

Task 3: Review Industry Practices and Experiences

This report reviewed experience with connection protection in the transit industry, as well as in two other transportation industries: freight railroads and passenger airlines. It also reviewed national and regional ITS standards pertaining to transit operations management. The goal of these reviews was to identify lessons learned that are applicable to the TCP project effort.

Other Industries' Experiences

The freight rail industry was found to have improved management of interline connections, through common business processes and bilateral data exchange messages that support those processes. The critical success factor for freight rail has actually been the ability of participating carriers to manage according to the new business processes on a consistent basis.

Passenger airlines at major hubs were found to face connection management issues similar to those of transit agencies – i.e., whether to hold outbound flights for delayed incoming passengers. One major U.S. airline was found to make these decisions for intra-carrier connections centrally, supported by massive detailed information and state of the art decision support tools. However, inter-carrier connection decisions were made locally, where personnel could best judge passenger transfer options and times on a dynamic basis.

U. S. Transit Experience

The team identified two U. S. bus transit operating agencies where intra-carrier connection protection is included in an installed AVL/SD system: Ann Arbor, MI and Fresno, CA. Both were found to use the same technology (now a Siemens system), which strictly supports passenger requests for connection, evaluating them for feasibility at the dispatch system and replying back to the driver.

Among systems not yet fully implemented, the Chicago Transit Authority Bus Service Management System (BSMS) design was found to call for support of both intra- and inter-carrier connection protection, but the specifics of how this will be done were not yet finalized.

No systems were identified where inter-agency transit TCP is currently being practiced with computer assistance.

International Transit Experience

There is more extensive experience internationally with connection protection and related technologies. Four examples of such systems were examined. Of these, two are full-blown transit AVL/SD systems installations, and two are specialized connection protection installations. Sites include London (Ontario) Transit, Üstra Hannover, Bologna, Italy, and an unnamed German site. None, however, directly address inter-carrier connection protection on a macro scale.

Standards Efforts and their Relevance to the TCP System

The team reviewed both the NTCIP (National Transportation Communications for ITS Protocol and TCIP (Transit Communications Interface Profiles) standards and guidelines. Both were found to dovetail with the requirements of the National ITS Architecture, and have elements specifically applicable to the TCP project. In particular, Transfer Connection Protection is specifically referenced in the draft TCIP Transit Control Center (CC) Business Areas Object, which provides data element definitions and message set definitions. However, it was found that implementing dialogues concerning support of intercarrier connection protection had not yet been developed.

Tasks 4-5: Inventory Existing Scheduling/Dispatching System; Integrate With AVL and SD System

For this task, the Wilson Consulting team documented the capabilities of service board CAD/AVL and scheduling systems, and identified what would be necessary for these systems to interface with the TCP system. These tasks were worked simultaneously.

The report first reviews the functional components of AVL/SD systems that potentially interface with or impact the TCP system. These components include:

? Automatic vehicle location (AVL) capabilities
? On-board processor
? Driver interface
? Mobile data communications
? Vehicle area network connecting all on-board devices
? Computer-aided dispatching (CAD)
? Schedule adherence monitoring
? On-board passenger information audio/video announcements
? Scheduling system electronically linked to the CAD system
? Passenger counting or load estimating
? Connection protection (intra-carrier)

The report next reviewed requirements for compliance with national and regional architectures and standards, including NTCIP, TCIP, and GCM Priority Corridor system architecture. In general, these standards and architectures were found to have anticipated functionality similar to TCP, but to have fallen short of full support. As a result, the efforts will have to be monitored for further advances.

The report then provided a detailed review of service board AVL/SD functionality. Four relevant systems were covered:

Car.	**System**	**Status (10/13/2000)**
CTA	Bus Emergency Communications System (BECS)/ Bus Service Management System (BSMS)	In implementation
CTA	Rail Service Management System (RSMS)	Fully implemented
Metra	Train Information Management System (TIMS)	Experimental pilot test completed
Pace	Intelligent Bus System (IBS)	RFP issued

Table 2-1: Status of Service Board Mainline CAD/AVL system efforts

Paratransit contract carrier CAD/AVL, reservations and scheduling systems were not reviewed in detail. However, several likely required enhancements for TCP were identified:

- Updated estimated time of arrival (ETA) information from TCP system Endangered Connection Alerts should be captured to update pick-up times when the trip is beginning at a connection point
- For drop-offs, the carrier should supply updated ETAs while en route to the transfer point.
- Paratransit reservations systems should be enhanced to capture more detailed information on desired connections.

The last two sections of the report reviewed each carrier's AVL/SD system in light of TCP functional requirements and national and regional ITS architecture and standards. The principal requirement is for ongoing tracking by RTA and the service boards of developments in GCM, NTCIP, and TCIP. Among other specific requirements:

- Service boards should continue to follow open systems principles in their design and procurement.
- System designs should incorporate relevant "object definitions", specifying data elements and message sets, from NTCIP and TCIP.
- Service board systems planning should anticipate the additional functionality, processing power, and center to center communications traffic that will be required for TCP and other regional applications.

- The TCP system will need to know of schedule deviations much smaller than dispatchers normally concern themselves with. As a result, service boards should work to minimize bandwidth requirements for their systems so that exception reporting thresholds can be set as low as possible.

Tasks 6-8: Functional Requirements

During this task, project goals and objectives were re-validated. National and regional ITS architecture compliance were documented. Functional requirements were then developed based on the consensus system approach from Task 1. However, before the requirements were finalized, customer-requested connection functionality was deleted from the design due to serious concerns about its feasibility for large-scale, multi-carrier environments.

With the implementation of the TCP system likely to be years off, the purpose of the functional requirements was envisioned as: 1) guiding planners and decision-makers as ITS evolves in the GCM region, and 2) giving service board and GCM system designers as much guidance as possible on features they should consider as they progress their own efforts.

TCP System Design -- General

The RTA's Transfer Connection Protection (TCP) program is a two-stage program of computer systems and policies to address missed inter-agency connections. It is believed to be the first effort of its kind in the world. TCP's main goal is to reduce passenger wait times at inter-agency transfer points, by minimizing the number of missed connections.

The RTA's base TCP system will continuously monitor the on-time status of regional transit operations, focusing strictly on pre-defined inter-agency connections. Based on data received form the service boards, it will identify any such connections that are endangered, or with a significant probability of being missed. It will then alert service board dispatch systems to these endangered connections, so that they can consider corrective action. The results of this for passengers will be reduced waiting time, improved security, and less uncertainty. Service boards should see gradual increases in ridership and revenue, as well as improvements in operating efficiency.

The TCP system will operate around the clock, seven days a week. It will focus on protecting connections to longer headway routes (over 10 minutes). Specifically, the TCP will target:

- Daytime connections to routes with long headways or limited service periods, as well as certain rush hour feeder services.

- Evening, weekend and especially owl service, where most headways are longer, and missed connections mean very long wait times.
- The last trip of the day (or service period), where passengers may be stranded by a missed connection.

One of the most annoying situations for passengers is a “near miss”, where upon arrival at the connection point they can see the connecting vehicle having just departed. The TCP system will also help carriers address this issue. However, limited radio data bandwidth and high exception reporting thresholds will seriously limit the number of near misses that are detected.

TCP will be developed and implemented in two stages, with additional long-range enhancements. The subsequent sections describe these stages.

Stage 1: TCP Base System

Via the Illinois Transit Hub (ITH), the TCP System receives route definitions, run/train schedules, and connection definitions from the carrier in advance of their effective date and time. Also via the ITH, it receives location and status information from carrier Computer Aided Dispatch (CAD)/AVL systems as it is received from vehicles. The TCP system continuously monitors this information against schedules and connection definitions in order to identify endangered connections. A connection is endangered if the “from” vehicle is behind schedule to the extent that the “to” vehicle will have departed from the connection point before the “from” vehicle arrives. When such a situation is detected, the TCP system notifies the connecting carrier (or optionally both carriers), and provides ETA at the connection point for the “from” vehicle. The carriers (or their CAD/AVL systems) determine whether or not to take action to protect the connection, based on the status of the affected route and regional conditions. The TCP system continues forwarding updates to the carrier(s) until both vehicles have departed the connection point.

Stage 2: Paratransit TCP

Paratransit operations are handled somewhat differently, as they are not schedule-based but demand-responsive in nature. When a reservation is taken for a trip involving an inter-carrier connection, additional information is collected, such as route and destination or run/train number. Then, the paratransit carrier submits the connection request to the system at some point prior to dispatching the trip. It is forwarded to the TCP system via the sponsoring service board. At the TCP system, it is entered as a one-time connection to be monitored, then protected if necessary just as any other pre-defined connection would be. Additionally, for trips terminating at a connection point, the paratransit driver, dispatcher or CAD/AVL system must notify the TCP system when ETA at the connection point changes in order for the connection to be protected.

Possible Future Enhancements

There are at least four further customer service extensions to the TCP system that could in the future add value for passengers. The first is protection of customer-requested connections, which would be forwarded to connecting carriers for acceptance or declination. The second is a customer notification option that would allow customers to define their regular trips to the system, then be automatically notified when a connection is endangered. Third is a customer trip completion alternatives option that would enable passengers to request alternative itineraries via transit or other modes (e.g. taxi) for completing their trip if a requested connection is declined. The fourth is the consideration of real-time passenger loading or count information to help improve the effectiveness of the TCP system and reduce unnecessary hold time.

Task 7: Revising Connection Policies

The purpose of this task was to develop a template for individual service boards to use in the analysis of existing policies, procedures and responsibilities concerning inter-agency connections.

The task report provided a recap of the "inter-agency connection problem" that is the motivation for the TCP system. The problem is this: day-to-day coordination of inter-agency connections is hampered by lack of information and facilities for direct data communications. The report also recapped how the TCP system will help address it.

The main body of the report presented a template for reviewing and revising service board policies on inter-agency connections. It was designed to assist service board personnel in planning and performing a review of inter-agency connections from a variety of perspectives. It identified a series of questions that can be asked to spur thinking and point to further analysis needs. Finally, it provided a framework for selecting recommended changes and advancing them for approval.

Tasks 9-10: Final Specification/High-Level Cost Estimate

In these tasks, a final specification and high level cost estimate for the TCP system were developed. The specifications went beyond the Task 8 functional requirements to provide more specifics on message and data requirements for the Illinois Transit Hub. Also included were software and hardware guidelines for the project, and a preliminary deployment strategy for the TCP system. More detail on several of these items is provided in the following subsections.

Software and Hardware Guidelines

The TCP specification also included software and hardware guidelines for the system. These are summarized below:

? An operating system should be chosen with consideration of choices already made by: 1) designers of the GCM architecture, and 2) the service boards.
? It is expected that a relational database management system (RDBMS) will be employed, unless object-oriented database management systems (OODBMS) have been widely used in companion projects such as the RTA's Active Transit Station Signs (ATSS) and Parking Management System (PMS) projects, or in the development of the ITH.
? The TCP system operator shall be provided with a dispatcher-like interface for the management of errors, anomalies, peak capacity problems, or regional weather emergencies such as snowstorms.
? Efforts must be made to assure that TCP route and schedule reference files are always synchronized with versions in the service boards' systems. Also, a data quality/integrity measurement and correction effort will be needed.
? Common Object Request Broker Architecture (COBRA) software components shall be installed at the TCP System/ITH, to facilitate connection on unlike systems across the regional communications network.
? The TCP System is expected to be collocated with the ITH. It is therefore assumed that other specifications concerning the regional communications network and the hardware/software needed to attach to it, will be covered in the ITH system design.

High-level Cost Estimates

Preliminary, high-level estimates of TCP system costs were also developed during this task. Both one-time and ongoing costs were developed. Costs were developed and presented with three estimates for each cost component: Low Estimate, High Estimate, and Best Estimate. Finally, total present value costs were calculated over a five-year horizon, using a discount rate of 8%.

Tables 2-2 and 2-3 show TCP Base System and incremental Paratransit TCP costs, respectively. All cost items considered are summarized in these tables.

Cost Component	OT/RE	Low Estimate	High Estimate	Best Estimate
TCP Base System One Time Costs:				
Operating System	OT	$1,000	$1,200	$1,200
RDBMS license	OT	$1,900	$12,000	$6,000

System Development	OT	$151,000	$252,000	$202,000
Server and Related Equipment	OT	$6,000	$10,000	$7,500
Operator Interface PC	OT	$3,000	$5,000	$3,500
Operator Console / Facility Work	OT	$20,000	$35,000	$25,000
System Final Testing	OT	$17,000	$34,000	$25,000
System Training	OT	$21,000	$36,000	$25,000
System Implementation	OT	$25,000	$50,000	$34,000
Total One Time Costs:		$245,900	$435,200	$329,200
TCP Base System Recurring Costs:				
System Operations	RE	$32,800	$114,800	$65,600
Hardware/System Software Maintenance	RE	$1,785	$4,230	$2,730
TCP Custom Software Maintenance	RE	$15,100	$25,200	$20,200
Total Recurring Costs:		$49,685	$144,230	$88,530
5-YEAR BASE SYSTEM PV COST		$444,278	$1,011,069	$682,675

Table 2-2: TCP Base System Cost Summary

Cost Component	OT/RE	Low Estimate	High Estimate	Best Estimate
Incremental costs for Paratransit TCP System				
One Time Paratransit TCP Costs:				
Paratransit TCP System Modifications	OT	$43,000	$87,000	$58,000
Paratransit TCP System Final Testing	OT	$13,000	$34,000	$17,000
Paratransit TCP System Training	OT	$15,000	$23,000	$19,000
Paratransit TCP System Implementation	OT	$30,000	$50,000	$42,000
Total One Time Costs:		**$101,000**	**$194,000**	**$136,000**
Paratransit TCP System Recurring Costs:				
Paratransit TCP System Operations	RE	$0	$16,400	$6,560
Paratransit TCP Custom Software Maintenance	RE	$4,300	$8,700	$5,800
Total Recurring Costs:		**$4,300**	**$25,100**	**$12,360**
5-YEAR PARATRANSIT TCP PV COST		**$118,169**	**$294,217**	**$185,350**
5-YEAR TCP BASE SYSTEM PV COST		**$444,278**	**$1,011,069**	**$682,675**
TOTAL TCP PV COST		**$562,446**	**$1,305,286**	**$868,025**

Table 2-3: Paratransit TCP System Cost and Total Combined System Cost

Deployment Strategy

There are several prerequisites for deploying the TCP system as specified in this project:

? There must be two carriers with implemented and functioning CAD/AVL systems covering all or a substantial portion of their operations.
? There should be at a very minimum 6-12 months experience with these systems after acceptance of the system and completion of implementation.
? There must be mutual agreement on the parameters for a demonstration and for further implementation.

It is expected that deployment would take place in the following sequence:

5) Roll out a demonstration project with two carriers at a handful of mutually-agreed-upon sites.
6) Evaluate results.
7) If findings are favorable, deploy additional connections between the two demonstration carriers, focusing on the types where the greatest benefit was observed.
8) Add the third carrier when properly equipped – first one partnership, then the other.
9) Continued addition of connections by the carrier pairs until an ideal tradeoff between benefit and complexity is reached.

It is also suggested that as much as possible, the points selected represent a diversity of connection types, including for example: feeder route to trunk route; intersection of trunk routes; shared terminal facility or pulse point.

POTENTIAL TCP ISSUES AND RISKS

There are a number of risks and issues associated with implementing a TCP system for Northeastern Illinois. These were summarized in the TCP Executive Summary, and are reproduced below.

Newness of the concept: TCP marks the first time that automated connection protection has been attempted involving multiple carriers and dispatch centers. Inevitably with a new concept, there will be more kinks to work out, and a higher risk of failure. This will have to be thoroughly addressed by RTA and the service boards through:

- Extensive system testing
- one or more pilot projects
- extensive involvement from technical experts, employee groups, customers and other stakeholders
- acceptance tests

Policies on holding for connections: The unprecedented availability of information with TCP will make connection policies an issue for each of the service boards. They will need to set decision criteria and operating policies governing when and how they will hold vehicles for inter-agency connections. Each of the situations discussed earlier will need to be examined: daylight service; evening/weekend/owl service; and near misses. Delays to other passengers will also have to be factored in. A start has been made with the documentation of existing service board connection policies as part of the TCP feasibility study. But much additional work will be needed.

Impact on on-time performance: Because holds for connections will increase with the implementation of TCP, service board on-time performance statistics may deteriorate slightly. However, overall service from the customer's viewpoint should improve. One useful approach to dealing with this issue will be the future development of systems that use TCP data to measure connection performance.

Outdated status information due to radio restrictions: This is a complex technical issue faced primarily by CTA and Pace. While AVL systems on vehicles are highly accurate and current, the frequency of transmissions between vehicles and dispatch computers is limited by radio capacity constraints. As a result, the accuracy and freshness of dispatch system information, while adequate for fixed-route dispatching, may not be good enough to support TCP. This is especially true when it comes to the elimination of "near misses", where a deviation of 60 seconds could cause TCP to fail to detect an endangered connection. The same concern may apply to other regional uses of status information from dispatch systems. More study by the RTA is needed, along with efforts by all concerned to maximize the accuracy and freshness of dispatch system information.

Public perception and acceptance: The base TCP system is really a tool to enhance management of inter-service board operations. If it is widely publicized as a way to improve customer service, missed connections could result in negative publicity for the system. To keep this from happening, careful attention must be given to how the system is publicized. In particular, care must be taken to clearly state what the system can and cannot do, emphasizing that there are practical limits on what can be done.

RECOMMENDATIONS FOR FUTURE DIRECTIONS

- ***RTA and the Service Boards should support and participate in regional efforts to integrate ITS technologies.*** This will promote implementation of a technically integrated and jurisdictionally coordinated transit system across the region. Standards should be followed that are in line with regional architecture for improved interoperability.

- ***Service Boards should continue or institute an agency-wide dialogue about ITS projects.*** The impacts should be discussed, as well as how best to integrate ITS into agency plans. Thorough and thoughtful reviews of regional integration project deliverables are also important.

- ***Service Boards should individually review current policies governing inter-agency connections.*** This is ideally done during the design process for ITS systems, but must be revisited closer to the implementation of those systems. Policy modifications to support improved connection performance under TCP should be developed, as well as any interim improvement measures that may be possible.

- ***Service Boards should assure that AVL and dispatch system design efforts incorporate the requirements of the TCP system*** as they are identified. These include:
    - Sending service status information to the TCP system.
    - Automatically processing messages from the TCP system, and implementing needed corrective action subject to dispatcher review.
    - Supporting GCM architecture requirements for communications between systems, which TCP will follow.
    - Following open systems principles in all design efforts.
    - At the appropriate points in the future, supporting the customer-requested TCP system and additional long range-enhancements.

- At the appropriate point in the future, CTA and Pace need to ***assure that paratransit AVL and dispatch systems are modified to allow participation in the Stage 2 capability for paratransit TCP.*** These are some of the changes that will be required:
    - Networking contract carrier AVL/dispatch systems to service boards. (Progress has already been made in this area.)
    - Collection of more detailed connection information at reservation time.
    - The ability to receive ETA changes for connecting services and to update reservations with this information where applicable.
    - The ability to calculate or accept from the driver updated ETA's at drop-off point.

? ***Further analysis of true customer needs and priorities for TCP is needed.*** The assumptions used in the feasibility study should be replaced by survey or focus group results in a future phase of the TCP project. If this were to result in a significantly different picture of customer needs and priorities, the primary impact would be not on the TCP system, but on the prioritization of regional ITS integration projects.

? ***The regional wireless bandwidth problem needs to be addressed. Customer information initiatives should be progressed with caution until this is done.*** As explained above, limited wireless bandwidth and high service board exception reporting thresholds can seriously impact the information available on a regional basis for customer information. This is because customer information applications currently require a higher degree of accuracy than dispatch systems. If, for example, service board vehicles are not reporting their lateness until they are 5 or more minutes late, then the TCP system will miss endangered connections with delays of less than 5 minutes. Also, active signs (and other applications) can be up to 5 minutes off with their displays or announcements.

? ***Progress to the next stage of TCP only when the timetable for completion of service board ITS implementation is known with a fairly high degree of confidence.*** Changes in the state-of-the-art in technology and ITS functionality can be best taken advantage of by timing the design of a new system so that it will be implemented relatively soon after the design is completed. Therefore, service board ITS efforts should be monitored in order to determine an appropriate time to proceed.