A Process for Improving Transit Service Connectivity

by

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Abstract

Serving every origin-destination pair with direct service would be unmanageable for a transit agency, so it relies on the willingness of passengers to transfer. However, a connection adds time, money, and discomfort to a trip, and many passengers are unwilling to make a transfer. This research develops a process for assessing the quality of transit service connectivity and comparing different improvement strategies. Previous research has explored passenger dissatisfaction with the transfer, also known as the interchange, and joint optimization of connecting routes.

Three types of elements affect every transfer. System elements include fare policy and pre-trip information. Facility elements include elements like weather protection and en-route information. Service elements include span of service and transfer waiting time. Services generally have the most opportunities for improvement, especially for agencies that schedule many trips but which have not built them around connections. There are generally many opportunities for facility improvements; while expensive, the benefits to transferring passengers will accumulate quickly at well-used transfer facilities. There are fewer opportunities for improving system elements, but they have the potential to improve transfers throughout the metropolitan region. This research explores guidelines and standards for these elements of connectivity and a way to monitor their change.

An application of the process to the Chicago Transit Authority (CTA) showed that the CTA could improve connectivity by lowering the price of the transfer; improving weather protection, en-route information, and concessions at the transfer facilities; and reducing transfer waiting time. The fare is likely to increase in the future, and this is an opportunity for eliminating the price of a transfer for many passengers without creating a drop in revenue. 47% of transferring passengers currently have no weather protection at their transfer facility. The majority of transferring passengers do not have access to waiting time information or shopping opportunities when they travel. Building shelters or covered walkways, posting more schedules, providing more up-to-date information, and leasing out more space to businesses would reduce these problems. The majority of transferring passengers make transfers that are neither coordinated nor to high frequency routes, and through modifications to schedules and service management, the transfer waiting time can be reduced for many passengers, especially those on low frequency routes.

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Chapter 1. Introduction

This thesis will present a process for assessing and improving transit service connectivity. Travel surveys have suggested that the requirement of a transfer, when passengers must make a connection from one service to the other, discourages many people from choosing transit. While transit agencies can and do aim to reduce the number of necessary transfers, there will always be trips that require a transfer. There is a wide range of improvements that can be made to the typical transfer experience, and these improvements can be categorized by how important they are to individual customers and what temporal and physical parts of the transit system they affect. The process assesses the current state of connectivity and provides guidelines for choosing cost-effective connectivity improvement strategies. Then it packages, evaluates, and prioritizes these improvements. This leads to the creation of a connectivity improvement plan.

In this thesis, the transit service connectivity improvement process is applied to the Chicago Transit Authority (CTA), with hopes of defining a strategy for increasing transit ridership and improving customer satisfaction in Chicago. The CTA operates seven rail lines and 139 bus routes in the city of Chicago. It is engaged in a capital improvement program, part of which is a research effort with MIT and the University of Illinois – Chicago for the purpose of examining ways in which Chicago transit can become more competitive in the 21st century.

1.1 Transit Service Connectivity

The ability to use multiple services for making a trip is what defines service connectivity. Automobiles, with the "universal access" they enjoy in most cities, do not face real connectivity problems; drivers can usually get from their origin to their destination without having to change vehicles en-route. However, direct service from every origin to every destination will never exist for transit, and many trips are not made by transit because the transfer is too inconvenient. Nevertheless, in most public transportation systems, 10% to 30% of riders make at least one transfer to reach their final destination

(APTA, 2000), and in some systems, this percentage may exceed 50%, as it does in Chicago.

Given that they are an inherent feature of many transit trips, a system suffers when facility and service design processes ignore transfers. In part because transit agencies have been neglecting service connectivity and the vast potential for its improvement, transit funding in the last decade has been focused on intermodalism, which shares many of the same challenges as service connectivity. Service connectivity refers to the connections between passenger transport services and includes intramodal as well as intermodal transfers. Intermodalism, on the other hand, considers freight transportation as well as passenger transportation, and it includes the integration of personal travel modes, such as automobile and bicycle, in multimodal networks. Despite the differences in scope, they both aim at improving the coordination between services so that systems operate more efficiently and more effectively.

To give just one example of the current wave of interest in this topic, the "Seamless Multimodal Mobility" research program at the Technical University of Delft in the Netherlands is motivated by the assumption that Europe will soon have an integrated transportation system that will allow passengers to use multiple service providers to access more destinations with shorter travel times and less psychological effort (TRAIL, 1999). The projects that are part of this program are divided among six clusters that deal with important aspects of multimodalism. The clusters are demand modeling, service network design, dependable scheduling, traveler guidance, synchronization of control of operations, and interorganizational coordination.

There are many different factors that affect the quality of the connections between services, and so if a transit agency wants to improve its service connectivity, it should consider the interdependencies and relative effectiveness of all of the possible improvement strategies. This chapter will describe why connectivity should be an important focus for transit agency planning and policy making. It will also provide an overview of some of the factors that affect service connectivity quality. Later sections describe the objectives of this research, introduce the research methodology, and provide a brief overview of the rest of this thesis.

1.2 Importance of Connectivity

As shown in Table 1-1, a large portion of transit trips involve transfers, and given the significant influence a transfer has on the overall quality of a transit trip, the quality of transfers has a large effect on total ridership and customer satisfaction. In cities like Chicago and Montreal where both bus and rail services are utilized throughout the city, about half of all passengers make a transfer. Considering just these two modes, there will be bus-bus, bus-rail, and rail-rail transfers. Considering other modes and service providers, there will be even more types of transfers. Good connectivity is essential to a healthy system because it means that people are able to easily access a much greater number of destinations than if their travel was limited to destinations on the routes they have direct access to.

Table 1-1 Percentage of Trips with Transfers

Transfer Type	Boston[1]	Chicago[2]	Washington, DC[3]	San Juan[4] (anticipated)	Curitiba[5]
Bus-Bus	7%	10%	12%	4%	40%
Bus-Rail	17%	32%	6%	31%	-
Rail-Rail	16%	5%	18%	-	-
Commuter Rail/Bus– Bus	<1%	4%	2%	-	-
Commuter Rail/Bus– Rail	3%	4%	<1%	-	-
Percent of All Trips Involving a Transfer	43%	55%	38%	35%	40%

1. based on 1994-1995 Customer Survey 2. From 1999 Customer Satisfaction Survey of CTA Riders 3. based on data from Ralph Frisbee of WMATA 4. based on Cambridge Systematics ridership forecasts for Tren Urbano's opening year, includes bus and TU riders 5. URBS Passenger Survey

The number of transfers that take place in a system is highly dependent on the system design and land use patterns. In cities where land use is linear, there may be less need for transferring because a large concentration of origins and destinations can exist on a single transit line. Other cities, such as Chicago, may have bus-rail interchanges at almost every rail station and bus-bus interchanges throughout the system. The combination of a grid bus system and radial rail system allows for efficient operation and direct service to the central business district (CBD), but it doesn't provide direct trips between many non-CBD origins and destinations. Other systems, such as pre-Tren Urbano San Juan, are built around a handful of bus-bus interchange facilities at major activity centers. Networks based on transit centers aim to provide as many direct trips as possible by starting and terminating routes at the major activity centers. Still other cities, such as Boston and Washington, D.C., may concentrate the terminals of bus lines at a limited selection of rail stations. The transfer patterns at a particular transfer facility will be largely determined by network design.

Agencies take varying degrees of interest in connectivity. At some agencies, the revenue department takes the greatest interest in transfer volumes because this determines how fares will be allocated among connecting service providers. At some agencies, transfer data is mainly used for reporting the number of unlinked trips (boardings) to the Federal Transit Authority (FTA). However, in some agencies, connections are, in fact, central to planning, operation, and policy. Connectivity can have huge implications for customer satisfaction, ridership, and efficiency, as described in the next three sections.

1.2.1 Customer Satisfaction

Customers are disappointed when their transit needs are not met. People's travel needs include arriving at their destination at a specific time, comfort throughout the entire journey, reasonable travel times, and reasonable prices. Transfers add uncertainty, discomfort, waiting time, and cost to most transit trips, and so they increase the disutility of a trip. However, if connecting vehicles arrive and depart with more certainty, the transfer can be made under more comfortable conditions, the connection time can be minimized, or the cost of a transfer can be diminished or eliminated, then the disutility of the transfer can be reduced.

Most transit agencies state a commitment to the needs of their customers. These needs are often described as some variation of the CTA's "on-time, clean, safe, and friendly" service pledge. Connectivity plays a large role in determining whether a trip is on-time, safe, fast, comfortable, and affordable, so in improving connectivity, an agency can better fulfill its commitment to serving its customers well.

1.2.2 Ridership

It is important for transit agencies to provide good transfer facilities and develop connection-friendly operations and policies in order to retain their existing transferring customer base. An unpleasant transfer experience has the potential to turn a person away from using transit. A transferring passenger subjected to freezing conditions, excessive wait times, or crime may choose to make all of his or her subsequent trips by car.

Improving connectivity also has the potential to attract new riders, in addition to retaining current ones, by making transit more convenient. Transfers can be made more attractive on a system level through better information or lower transfer fares. On a facilities level, agencies could take the approach of improving those transfer facilities that are already attracting high volumes of passengers, with the assumption that demand will grow as a percentage of the base transfer volumes with improved services. Alternatively, they could take the approach of improving transfer facilities that aren't heavily utilized, under the assumption that they are underutilized because they fail to provide transfer conditions that are desirable to passengers. Similarly, on a service level, services that are currently attracting a lot of passengers could be improved to attract even more transferring passengers, or less popular services could be improved for their potential ridership gains.

Attracting passengers to feeder bus trips that may compete with walk or park-and-ride access to transit is a scenario for ridership gain. Passengers will only choose feeder services over the alternatives if the connections are very fast and if fare payment is neither a hassle nor a financial burden.

Improvements to transit service connectivity have the potential to retain existing customers, attract new riders, and encourage more trips by current users. However, there is evidence that the potential ridership improvements are limited. Better transfers may cause passengers to take a different route to their destination rather than generate new trips, as trip assignment models for timed transfer transit systems suggest (Shih, Mahmassani, and Baaj, 1997). Furthermore, a stated preference survey of car drivers whose most common trip would require a transfer if taken by transit showed that while parking cost increases might make them choose transit, very little could be done to the transit services themselves to give them incentive to take transit (Wardman, Hine, and Stradling, 2001). Surveys have also shown that people who do not use transit view transfers as being more onerous than passengers who actually make transfers (Balog, Morrison, and Hood, 1997), and this adds another challenge to attracting new riders to transit. Nevertheless, if people have good experiences with their transfers, they are more likely to be retained as passengers, and if an agency can maintain a high quality of connectivity over a long enough period of time, non-users might be convinced to use transit.

1.2.3 Efficiency

Improving connectivity has the potential to improve efficiency in a system. If passengers using a system take advantage of connections, then there don't have to be as many routes. Connectivity also allows the more expensive, high-capacity lines to carry more passengers, making them more worthwhile investments (Lee and Schonfeld, 1991).

If better connectivity attracts more riders, then passengers per vehicle kilometer will rise, making a system more efficient by that measure. Also, if loads on connecting vehicles can be more equally distributed through connectivity improvement efforts, then extreme peak loads may be avoided. As a result, passengers will be more comfortable on transit vehicles and there will be fewer delays caused by overcrowding. There may be situations where service changes may not increase the efficiency of a transit system, but they will improve the level of service that passengers receive.

Improving connectivity through infrastructure enhancements also has the potential to improve efficiency. If transferring passengers can board transit vehicles more quickly (if they don't have to pay again, for example), or if buses exiting a transfer facility are not subjected to delay (if they are given traffic signal priority, for example), then it is possible that connectivity improvements could lead to running time improvements.

However, certain connectivity efforts have the potential to worsen efficiency, at least from the agency's perspective. Often routes are rerouted in order to connect with a transfer facility, which means higher running times and more resources will be needed to maintain the same service levels. Other efforts may involve increasing a route's slack time in order to improve the chances of making a connection. If this reroute or schedule modification does not attract more passengers, then efficiency will drop in terms of passengers per vehicle hour.

Knowing how, when, and where passengers are transferring can help an agency better plan its routes and reduce redundancy in the system. It can also help agencies make appropriate service management, fare policy, scheduling, and passenger information decisions that balance customer and agency needs.

1.3 Transfer Attributes

The focus of this thesis is the transfer, also known as the connection or the interchange, and there are many factors that affect its quality. Access and egress play a part in the overall attractiveness of a transit trip, but they do not have a direct effect on the quality of the connection. Trips that require two vehicles require a connection. Trips that require three vehicles require two connections, and so on. The following figures describe a generic one-connection trip, first in space, as shown in Figure 1-1, and then by the disutility and time of different trip components, as shown in Figure 1-2.

Figure 1-1 Physical Components of a Generic One-Connection Trip

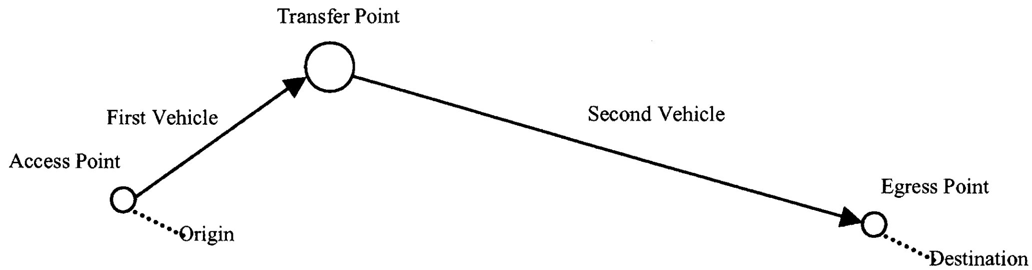
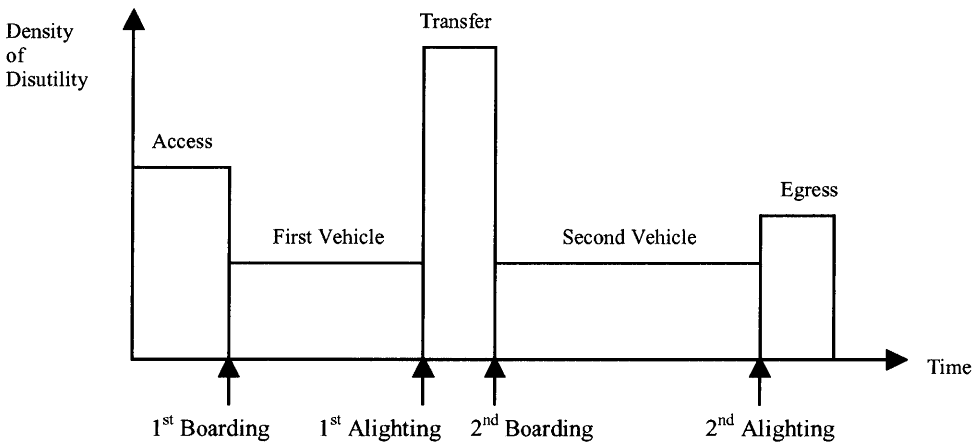


Figure 1-2 Relative Weights and Time Lengths of a Generic One-Connection Trip



In Figure 1-2, the area under the curve represents the total disutility of this trip. The greatest disutility per time occurs at the transfer point in this example. The disutility per time for trips does not necessarily have a constant value over each trip segment; it might increase or decrease over the course of the segment. There may also be components of disutility that are independent of time.

The quality of connections will vary throughout the day as the number of people using the system fluctuates and the level of service changes. There may be fewer people traveling at night, in the evening, and on weekends. As a result, the waiting time may be more stressful, as there are fewer people available to increase the sense of security at a transfer location and to provide distractions while waiting for the bus. At certain times of year, transfers may be more onerous because they will involve waiting under less comfortable conditions. Another consideration is that supervisors typically only monitor transfer points at certain hours of the day, and so if connectivity quality depends on supervision, then connectivity may suffer when the supervisors are not on duty or are busy attending to other matters.

While connections are of particular concern in the off-peak, given the longer headways and longer average wait times, the peak period also poses some problems for certain types of connections. Planned connections are threatened by peak-period traffic and a lack of substitute vehicles in case of a breakdown.

The factors that affect connectivity are rooted in the relative service levels on the two connecting routes, as well as in the level of service at the transfer point. There are also system factors, independent of both the services and transfer point, which may affect the quality of a transfer. These factors are described in the following sections.

1.3.1 Multiple Vehicles

Most passengers would prefer to have a one-seat ride to their destination, but for many trips, more than one service must be used, and so a transfer becomes necessary at a point where a second service intersects the first service. However, two services have to do more than intersect if there is going to be an adequate connection. The connection quality depends heavily on the relative frequencies, speeds, spans of service, loads, and reliability of the two services. It also depends on the degree of fare integration and schedule coordination between the two services and the amount that passengers are forced to deviate from the shortest path to their destination to access the transfer point.

Relative Frequencies

The relative frequencies of connecting links will affect the wait time at the transfer point. As shown in Table 1-2, when transferring between high-frequency services, the waiting time at the transfer point is generally short, and passengers feel relatively confident that their connecting vehicle will arrive soon. A similarly pleasant situation occurs when transferring from a low-frequency route to a high-frequency route. However, problems can occur when transferring to a low-frequency route. When transferring from a high-frequency route to a low-frequency route, the waiting time can vary greatly, but passengers with information about the departure times on the connecting route can minimize their waiting time by catching an appropriate first vehicle. For transfers between low-frequency routes, the waiting times can be very long or vary greatly, unless there is coordination between the arrival and departure times of the connecting services, as there might be in a timed-transfer system (TTS).

Table 1-2 Transfer Times between Routes with Short and Long Headways

	To Short Headway	To Long Headway
From Short Headway	<u>Case A</u> Always short, convenient	<u>Case C</u> Varies greatly Information about the departure time of the connecting trip gives passengers the ability to reduce transfer waiting time
From Long Headway	<u>Case B</u> Always short, convenient	<u>Case D</u> Variable depending on headways: (1) Equal and coordinated – all transfers convenient (TTS) (2) Integer multiples and coordinated (3) Different – difficult to coordinate; long transfer times

Adapted from Vuchic and Musso (1992)

With different frequencies on different routes, it is often easier to make a transfer in one direction than the other. For example, if getting from one's home to a shopping destination requires transferring from a low-frequency route to a high frequency route and the return trip requires a transfer from a high-frequency route to a low-frequency route, then the trip to shopping is likely to be more convenient than the return trip. This is because passengers generally consider the waiting time at the transfer point to be more onerous than the initial waiting time (Wardman, Hine, and Stradling, 2001), and given that a larger fraction of the expected waiting time on the return trip is at the transfer point, the waiting component of the transfer will be considered worse for the return trip.

People will generally transfer to a high-frequency route if they have the choice, as this will probably reduce their transfer waiting time. Because of this, passengers may trade proximity to their destination for higher frequencies.

The frequency of service on a line usually varies over the day in response to demand, and so the quality of connections will also vary over the day. Connections tend to be better in the peak periods because more routes are operating at high frequencies, and so fewer passengers are forced into long waits. Connections are more problematic for passengers in the off-peak, when the headways can be large. Connections may also be of lower quality at transfer points that aren't used very heavily, as it is unlikely that the services would be coordinated.

Relative Speeds

The relative speeds of different services will influence how worthwhile a wait is perceived to be and what fraction of total travel time the transfer takes. Being able to access a higher-speed route, such as a commuter rail, metro, or express bus line is advantageous because it minimizes travel time, and people will transfer from a slower mode, such as a bus, to access these faster modes. A transfer in the opposite direction, to a slow mode, may not seem worthwhile, particularly if a passenger thinks she can walk to her destination faster than she can get there by transit. Having a range of speeds is important in a transit network, and research shows that speeds in the various networks should triple with each layer to maximize accessibility in the entire system (van Ness, 2000).

Like frequencies, the relative speeds of services may also depend on time of day. Services that have to share the roadways with other forms of traffic may be subjected to rush-hour congestion. Even services with their own rights-of-way are subjected to longer dwell times and more congestion – which leads to longer running times – when usage is high.

Relative Spans of Service

The relative spans of service on connecting routes, modes, and service providers determine whether or not a transfer is available. The span of service for a given transfer is the intersection of spans over which the two connecting routes operate. What this means is that if one bus route operates 24 hours a day, while a connecting bus only operates during peak hours, then the span of the connection is only the peak hours. The span of service affects when a connection can be made, and if a connection is not available for a return trip, then passengers may not even make the first trip by transit.

Deviation from Shortest Path

When people travel, they generally want to take the shortest route to their destination. In a grid system, it is generally possible for transit routes to follow the shortest path to a destination. However, transit lines and transfer points may be situated such that passengers have to deviate from the shortest path if they want to make a trip by transit.

Relative Loads

The relative load affects what actions can reasonably be taken to facilitate planned connections, as shown in Table 1-3. If a passenger is transferring to a route where vehicles carry large loads, then it is unlikely that holding vehicles on that route for transferring passengers will be viable; too many people would be inconvenienced for the sake of a few. On the other hand, if the vehicle loads on a route are relatively low, then holding for transferring passengers becomes a reasonable option, especially when transferring passengers will make up a large percentage of the riders on any given vehicle.

Table 1-3 Holding Options Between Routes with Large and Small Vehicle Loads

	To Vehicle with Large Load	To Vehicle with Small Load
From Vehicle with Large Load	- holding only an option if there are many transferring passengers	-holding an option, but only worthwhile if there are transferring passengers
From Vehicle with Small Load	- holding not an option	-holding an option, but only worthwhile if there are transferring passengers

Reliability

At a given transfer location, the connecting routes will each have their own level of reliability; vehicles will arrive and depart from the location with varying levels of adherence to the schedule. This will affect passenger waiting time and stress levels at the transfer point. When transferring from a high-reliability route to a low-reliability route, waiting times can be variable. "Just misses," situations in which passengers just barely miss their connecting vehicle, can be avoided by introducing slack times into the second route's schedule and holding those connecting vehicles for the arriving high-reliability routes. An added benefit of holding low-reliability vehicles for high-reliability vehicles is that it can introduce more stability on the low-reliability route. When transferring between high-reliability routes, then there is a large potential for improving the quality of the transfer through schedule coordination. When transferring from a low-reliability route to a high-reliability route, slack time in the first vehicle's schedule can be used to avoid long wait times as a result of just misses; otherwise, wait times will be variable. However, if the frequency of the second route is high enough, there is no reason to have slack time or a planned connection, as waiting times are guaranteed to be short, no matter what time the first vehicle arrives. When transferring between low-reliability routes, the waiting times will be variable.

Table 1-4 summarizes the effects of variability on wait time.

Table 1-4 Waiting Time, Holding Options, and Schedule Needs for Connections Between High and Low-Reliability Routes

	To High-Reliability	To Low-Reliability
From High-Reliability	- waiting times known - short waiting times possible with coordinated scheduling	-variable waiting times -long waiting times avoidable with slack times and holding of connecting vehicle
From Low-Reliability	-variable waiting times -long waiting times avoidable with sufficient slack times	-variable waiting times

Payment Systems

Payment systems affect activity required at the transfer point. Such activities might include pulling a fare or transfer card out of one's wallet or pocket and swiping it through an automatic farecard reader or showing it to a bus driver. The payment for a transfer can be especially time-consuming and expensive when transferring to a service operated by a different service provider. Each provider is concerned about receiving revenue, and this makes coordination of revenue collection something that often has to be initiated by a third party. The cost and time of having to pay again may cause a system to lose riders, especially if a person has the choice of walking or driving.

Different Planning Institutions

When different planners are responsible for planning the different services, they may institute changes to the schedule at different times of the year, making coordination of schedules more problematic. They may also be unable to coordinate arrival and departure times because they do not have access to information about each other's services (MTC, 1988). Other challenges might include different facilities, different service standards, and different communication systems.

1.3.2 Transfer Facilities

Transfer facilities may vary from simple intersections to billion-dollar, multimodal structures. While the relative levels of service of the connecting links are important, the physical characteristics of the transfer point are equally important. At these points, the different services can be accessed and connections made. There are many factors that determine how well transfer points provide for the needs of transferring passengers. When 70 potential objectives for intermodal facilities were rated, those objectives related to the transfer were rated second in importance only to safety and security (Horowitz and Thompson, 1994).

Areas for Waiting

Transfer facilities need areas for waiting, as this is often the main activity of passengers who are transferring. These waiting areas may include benches, heating, and protection from wind and rain. Some waiting areas have artwork or advertisements. Waiting areas range in comfort from the sidewalk at a bus stop intersection to a waiting lounge at a commuter rail station.

Paths for Movement

Transfer facilities also need paths for moving between the different modes, routes or service providers. At a typical on-street bus interchange, the path may be the crosswalk. While this is one of the most simple transfer situations, up to eight different transfer movements could exist. In more complicated intermodal facilities, the walk may require changing elevations or following signs in order to navigate the facility. In some cases it may simply mean getting off one vehicle onto a platform then getting onto another vehicle that arrives later at the same platform. In general, the path to a connecting service should be as short, unconstrained, and safe as possible.

Goods and Services

Transfer points may also offer diversions, such as shops or food stands. Some transfer points may provide enterprises that people need for the errands they must run, such as shoe repair, bill payment, or child care. These types of enterprises are generally more accessible to people transferring to or from a bus, commuter rail line, or tram, as opposed to between metro lines, because to access them, one usually has to leave the paid area, which is something metro passengers usually can't do when they transfer between subway lines.

Aides

Navigational aides are also important at transit facilities. These include maps, schedules, street signs, and signage throughout the station. Maps and signs are useful for new or infrequent riders, but are of limited use for those passengers very familiar with a given transfer. However, real-time travel updates have the potential of being useful to experienced and inexperienced riders alike.

1.3.3 System Effects

There are some factors that influence transfers throughout the system, independent of transfer point facilities and services. They include factors related to the fare policy and pre-trip information.

Fare

The price passengers have to pay for their transfer will depend on what kind of fares the agency or agencies make available to them. Some transfers will require the payment of a full new fare, or the transfer may be discounted or free as an incentive for people to transfer. Many agencies offer a choice of passes, some that are more expensive but offer unlimited riding privileges, and others that are less expensive but require that every trip or boarding be paid for. Passengers benefit from the choice because it allows them to choose the fare option that is most economical to them given their expected travel behavior.

Pre-Trip Information

This is the information passengers have access to before they start their trip. It may be available in the form of a system map, web services, a trip planner, or through customer service telephone numbers.

1.4 Objectives of Research

There are three main objectives of this research. The first is to develop a better understanding of what good connectivity means and what it requires. The second is to develop a process any agency could use to assess its current connectivity and to improve it, and the third objective is to apply this process to Chicago.

1.4.1 Define the Meaning of Good Connectivity

Determining the meaning of good connectivity is an important part of this thesis. Knowing what good connectivity is will help agencies select the most effective actions for improving connectivity. The quality of a connection is dependent on the relative levels of service of the connecting vehicles, features of the transfer facilities, and system-level factors, as described in earlier sections, but there are also human factors. How familiar people are with the system, how often they make a given transfer, how much of a hurry they are in, how secure they feel, and how mobile they are, all help determine their satisfaction with a given connection.

There are no universally accepted measures for connectivity quality, although some of the measures people have used to analyze transfers are total passenger waiting time and loading levels on vehicles. Because connectivity covers so many facets of service, its quality needs to be measured in more ways than these. Connectivity will be measured in this thesis according to a system of tiers developed for elements important to connectivity.

1.4.2 Develop A Process for Assessing and Improving Connectivity

This thesis develops a process that agencies can use to guide them in their connectivity assessment and improvement efforts. Since there are many ways that connectivity problems can arise and be addressed, it is useful to have a systematic way of addressing the topic so the most effective and sustainable solutions can be identified. Connectivity is influenced by policy and operational decisions made throughout the agency, and so an agency-wide approach to connectivity is most appropriate.

1.4.3 Recommend Strategies for Improving Connectivity in Chicago

The process will be applied to Chicago, leading to recommendations for improvement. This system poses interesting challenges to providing good connectivity. With a large number of transferring passengers, a wide distribution of transfer points, and several other agencies with which it needs to coordinate, the CTA needs some way to determine what efforts are feasible and most cost-effective.

1.5 Methodology

Achieving good connectivity is a complex problem, and there is a shortage of literature on how to solve it. The research presented in this thesis first establishes a framework for transit service connectivity improvements. It then develops a process that corresponds to this framework. With the need to prioritize in mind, the process provides ways of assessing current connectivity performance, applying guidelines and standards to elements, considering different improvement strategies, and prioritizing improvements. Finally, the thesis will apply the process to Chicago.

1.5.1 Establish Framework

Establish areas. Each system is made up of facilities and services. Service connectivity problems and improvement strategies will affect the entire system, individual transfer points, or connecting services. Depending on what category it falls under, a connectivity element should be assessed differently and improvement actions should be considered under different prioritization schemas.

Determine elements within each area that are most important to connectivity and which lend themselves to improvement. There is literature available on what elements of a transit trip are the most important to transferring passengers. A good example of such literature is the Interchange and Travel Choice Study conducted by Wardman, Hine, and Stradling in 2001. This study provides information about the preferences of passengers who made bus-bus transfers in Edinburgh, rail-rail transfers in Glasgow, and car trips to work sites on the outskirts of Edinburgh. Their research is cited throughout this thesis because having a fundamental understanding of what transferring passengers care about is central to prioritizing improvement efforts. This thesis considers transfers as a given but aims to turn them into features of a trip that won't dissuade travellers from making a trip on transit. Another example of existing literature is a paper entitled "Generic Objectives for Evaluation of Intermodal Passenger Transfer Facilities" by Horowitz and Thompson (1994), who ranked 70 objectives for intermodal facilities by surveying transportation planners. The factors that were emphasized in these studies and which had a large impact on the quality of transfers on a system level, facility level, and services level were selected so that an assessment can be made of connectivity in a system and elements can be chosen for the potential for cost-effective improvement.

Rank elements within each area according to their importance. The ranking is done based on the literature on passenger preferences and intermodal facility objectives. Ranking within each of the areas is important because their relative importance is a factor in prioritizing actions within each of the areas. The areas can largely be improved in parallel, and this is why the rankings can be done within each area, but there will be a need to prioritize the improvement options across areas in the case of limited resources.

Establish a quality tier for each element. The best level of the tier should represent the state of an element that is best for connectivity, and the worst level should represent the quality of an element that will be most detrimental to connectivity. There might also be mid-levels that are neither egregiously bad for connectivity nor particularly good for it. These tiers will be used in the process to assess connectivity in a system and frame improvement options. Categorizing passengers in a higher level in the tier represents a connectivity improvement, and these improvements should be tied to specific connectivity improvement strategies.

1.5.2 Develop a Process for Choosing Appropriate Solutions

The process will be based on the framework incorporating elements, areas, and tiers. The process should be applicable to any system. Its aim is to prioritize connectivity efforts, as transit agencies often aim to improve connectivity, but lack a clear sense of how to assess connectivity in a system or where to start making improvements. The process works by first establishing a system boundary that contains all of the transfers that will be considered. Then it assesses the quality of connectivity elements in a system. It then focuses the analysis onto the elements that have the potential for cost-effective improvement. Applicable system, facility, and service improvements are then evaluated in terms of their costs to the agency and benefits to passengers, and this will suggest which improvements should be prioritized. The next step will be to prioritize improvements across the areas. Finally, a monitoring plan will be set up to allow for the continual assessment of connectivity.

1.5.3 Apply Process to Chicago

This research originated in response to the challenges being faced by the transit system in Chicago. Chicago is a mature system with multiple modes, many services, and many facilities. The amount and types of transferring that occur are already roughly known, and a large percentage of riders make transfers on their typical trip – 55%. Of all trips, 32% transfer between a CTA bus and a CTA train, 15% transfer between vehicles of the same mode, and 8% transfer between a CTA service and either the commuter rail (Metra) or commuter bus (Pace) system (Northwest Research Group, 1999).

The CTA would benefit from an improvement in connectivity not only because it would lead to higher levels of customer satisfaction, but also because such improvement would help the CTA attain some of its other goals. For example, it already recognizes the benefits of having more off-peak riders; it makes the system feel more secure and makes use of excess capacity, and connectivity improvements could potentially lead to ridership gains in the off-peak. Also, the CTA recognizes that there are a growing number of riders from the suburbs, and the majority of these suburban riders have to make a transfer in order to access the CTA. Lastly, bus ridership is not enjoying as strong growth as rail ridership, and the CTA will have to raise the quality of its bus service if it wants bus ridership to increase. Building system connectivity for the bus system is one tactic the CTA could use to promote its service more effectively.

The CTA is an old system; so much of its infrastructure has to be upgraded. Incorporating transfer-friendly design into infrastructure improvements should be a priority. Chicago has quite different travel patterns now from when its routes were established, and so the operations plan should respond to these changes in travel patterns. Passengers are changing, and the CTA is changing, too. A system attribute that may change in the near future is the fare price, and with discussion about adding rail lines and extending rail lines, the services offered by the CTA are also likely to change.

1.6 Thesis Organization

Chapter 2 will discuss the connectivity framework. Chapter 3 will present the process that is central to this thesis. Chapter 4 will apply this process to Chicago. Finally, Chapter 5 is a concluding chapter that summarizes the findings of the research, presents recommendations, and suggests areas for further research.

Chapter 2. Service Connectivity Framework

This chapter will introduce the framework for understanding transit service connectivity. It will describe the system, facility, and services areas. Then it will describe the elements, their tiers, the synergies they may have with other elements, and potential strategies for bringing elements to higher-quality levels in the tiers.

2.1 Framework Introduction

Connectivity is a complex transportation issue since there are many elements that influence the quality of a transfer. Each element is categorized as a system, facility, or service element, depending on the range of its influence in a transit network when there is an improvement, the scale of the problem when there are weaknesses in that element, and the ways in which its improvements can be prioritized. A tier is then developed for each element. A tier represents the range of states in which an element can exist, from those states that are unsupportive of connectivity to those states that are supportive of connectivity and contribute to high-quality transfers. The ranking of the elements and the development of these tiers is a major part of the first objective of this research – defining the meaning of good connectivity. These tiers and this entire framework also provide a foundation for the second objective of this research – the development of a process for improving service connectivity.

Figure 2-1 summarizes the framework that is described in the rest of this chapter. The elements are categorized according to area and are listed in descending order of importance. Tiers are shown beneath each element, with the best levels listed first, through to worst levels listed last. It should be noted that even within a given level, there may be yet another range of qualities. For example, even if a trip planner is a component of pre-trip information at its best level, a trip planner may be very good if it is accurate and easy to use or very bad if it supplies inaccurate information and is difficult to use. The framework is useful because is explores the many opportunities for connectivity improvement and provides a basis for assessing the quality of connectivity in a public transportation system. This may not be a perfect framework, but it serves as a basis for studying connectivity and a starting point for further studies.

Table 2-1 Transit Service Connectivity Framework

System Elements

Transfer Price	Pre-Trip Information	Fare Media	In-vehicle Information	Fare Control
Free	System Information with Trip Planner	Same	Real-time and Connecting Route Info, Transfer Announcements	No Validation Needed and Can Leave Public Transportation Space
Discounted	System Information		Connecting Route Info, Transfer Announcements	No Validation Needed if Remain in Public Transportation Space
	Route Information		Connecting Route Information	Validation Needed, but No Delay Added to Trip
Full Additional Fare	No Information	Different	No Information	Validation Adds Delay to Trip

Facility Elements

Weather Protection	En-Route Information	Changing Levels	Road Crossings	Walking Distance	Concessions
Fully Protected Connection	Real-time, System, Facility, and Schedule Information	No Vertical Separation	No Road Crossing Required	No Walking Required	Large Selection
Covered Connection	System, Facility, and Schedule Information				
Covered Waiting Area	Facility, and Schedule Information	Vertical Separation with Assistance	Road Crossing Required, but Assisted	Short Walk Required	Small Selection
	Schedule Information				
Open Waiting Area	No Information	Vertical Separation without Assistance	Unassisted Road Crossing	Long Walk Required	None

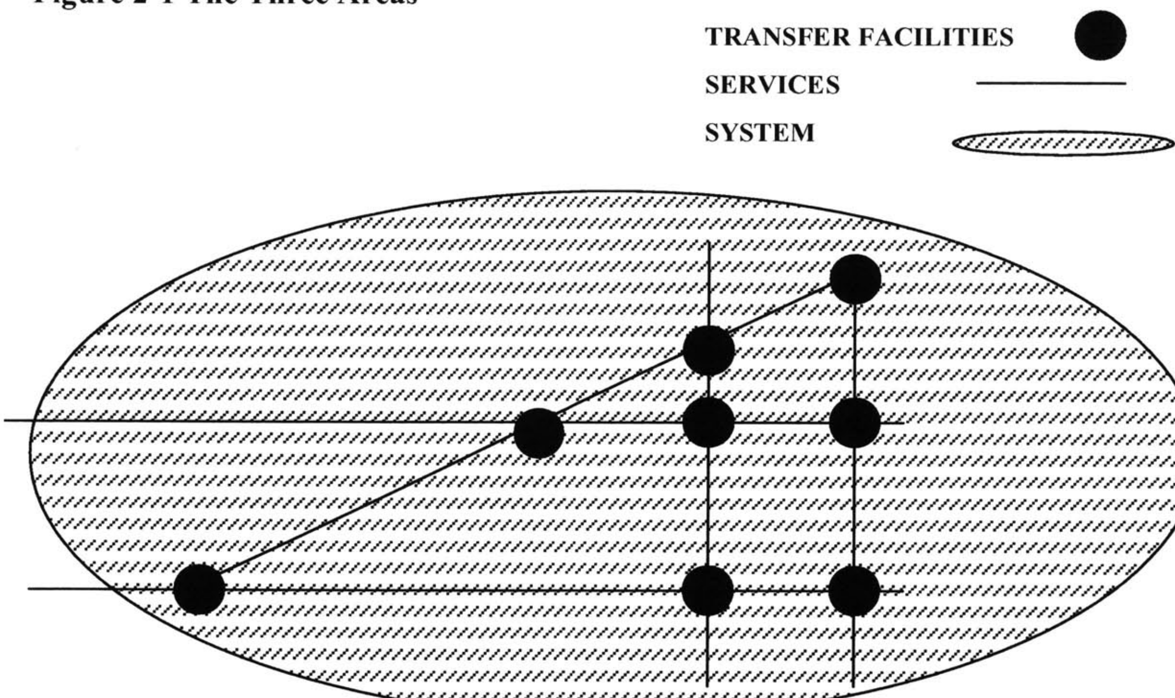
Service Elements

Transfer Waiting Time	Span of Service
High Frequency	Matched
Matched Headways and Coordinated Arrivals and Departures	
Coordinated Arrivals and Departures	
No Coordination	Unmatched

2.2 Areas: System, Facility, and Services

The system, facility, and service areas provide a tidy categorization of the different elements that can affect a transfer. Figure 2-1 shows how the three areas are related; every system is composed of transfer facilities, and every transfer point has at least two services. Consider a trip that includes a transfer and the elements that would affect that trip. If an element affects all transfers, or at least a large subset of the transfers, then it is a system element. If an element affects only the infrastructure at a single transfer point, then it is a facility element. If it affects the services that the passenger receives at the transfer point, especially in terms of how long he or she has to wait for a connecting vehicle, then it is a service element.

Figure 2-1 The Three Areas



The different areas can also be thought of as a categorization of the different ways in which an agency can bring about connectivity improvements in their system. Table 2-2 shows how changes in each of these areas can affect different transfer markets. System improvements can affect all transfers or all transfers of a given type (e.g. bus-bus, rail-bus, rail-rail), regardless of location or time of day. Facility improvements only affect individual transfer points. If more than one type of transfer occurs at a given transfer point, for example, then a given improvement to the facility might only affect a fraction of the passengers transferring there. A service improvement could affect all transfers at a single location, a fraction of passengers transferring at a single location, all transfers on a route, or all transfers on a route during a certain period of the day. All improvements can affect non-transferring passengers, especially facility element improvements.

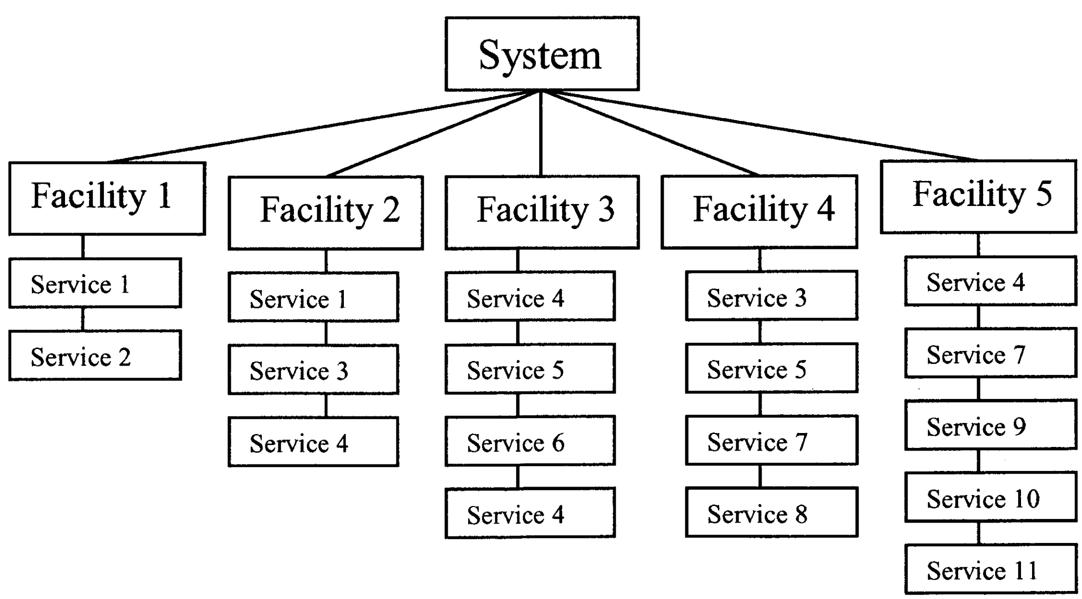
Table 2-2 Impact Levels for Different Improvements

	All Transfers	All Transfers of a Given Type	One Transfer Point	A Fraction of Transferring Passengers at One Transfer Point	All Transfers on a Route	All Transfers on a Route Within a Certain Span of Time
System Improvement	X	X				
Facility Improvement			X	X		
Services Improvement			X	X	X	X

The ordering of the system, facility, and service areas is based on their complexity. System elements are relatively simple because the number of options to be analyzed is small. However, this is not to say that system elements can be improved quickly or at a small cost to the agency; in fact, they are often quite difficult to change, given the inertia of change and political conditions. Facility elements are more complex. The larger the system, the more transfer facilities, and knowing which kinds of improvements are most needed at a given transfer facility may not be straightforward, as the cost of different improvements may vary greatly. There are often many transfer points competing for a limited amount of resources, and an agency has to choose which ones merit the improvements. Facility improvements are generally long-lasting, but they are susceptible to the negative effects of time, vandalism, and breakdowns. Service elements are the most complex. While there is only one system, and there may be hundreds of transfer facilities that could be improved, there are likely to be thousands of services that could be improved, and so the scope of the problem of services is large. Agencies provide many trips each day, and there are innumerable ways in which these trips could better interact to provide better connectivity. Services have temporal and probabilistic qualities that facility and system elements do not have. Furthermore, a service element improvement often comes at a cost to some passengers, and so any improvements have to be carefully considered so that the net benefits to passengers are positive and significant enough to justify the scheduling and service management efforts. Service improvements are generally not long-lasting because demand, running times, and schedules are continually changing throughout the system, and this can eventually negate the service improvements unless they are regularly monitored and updated. In addition to the fact that service improvements are probably the most complex of all the types of improvements, the service elements of the transfer are often the elements with which passengers are least content, partly because it is clear that the agency directly controls the service and changes could be made immediately and without major new investment.

Figure 2-2 shows the relationship of the system, facility, and service areas to each other. System improvements affect the entire system but are largely independent of service and facility improvements. Exceptions might arise when dealing with fare control, which is a system attribute but which affects the facility requirements. Facility improvements affect physical attributes of the transfer points, and in some cases, may have an effect on the services. Service improvements have an effect on the quality of transfers at specific transfer points, and these effects may carry over to other services, as well.

Figure 2-2 Relationship of System, Facilities, and Services



The different areas of improvement are often approached in different ways. System improvements are often prompted by organizational or mandated changes or external pressures. In some cases, though not all, they will be very costly for an agency. Facility improvements may be included in capital improvement programs, a portion of which (in the US) may be financed by the federal government, not just the agency. If it weren't for federal funding, some facility improvements might be prohibitively expensive and agencies would have more difficulty with deferred maintenance and affording the construction or reconstruction of facilities to comply with ADA requirements. In transit agencies, there are often departments that have the responsibility for the infrastructure. Services are included in the operating budget, and some agencies might be under constraints to cover a certain percentage of their operating costs with fare revenue. While some service improvement costs are quite high, there are also some that can be made at little or no cost but which would benefit transferring passengers. Services are the responsibility of the planning and operations departments at most transit agencies.

Due to their differences in complexity and ranges of influence, system, facility, and service improvements should be prioritized separately. The costs to the agency and benefits to the passengers of system improvements should be compared and the long term effects considered. As for facility improvements, they should generally be prioritized according to how the most benefits can be brought to the most people in a cost-effective way. This is because improvements can only be made incrementally, so those that bring the most benefits to the most people should be made first. Service connectivity improvements should generally be prioritized according to where they can be made at little or no extra cost to the agency, since agencies are responsible for both providing good service and keeping their costs down. Many service improvements can be made by making simple adjustments to the services that are already provided.

Prioritizing elements across areas is more difficult, given that it involves comparing dissimilar actions. However, there may be instances in which two actions interact such that they have to take each other into consideration or there will be trade-offs between them. For example, an agency might decide that it would like to reduce the transfer fare.

But the loss in revenue might make it impossible to add new service, which would increase frequencies along certain routes and improve the quality of transfers to these routes. In another example, an agency might want to share a fare medium with another agency, but there might not be very many shared facilities at which people can transfer between the two systems. In this case, the decision to integrate fares might hinge on whether or not more facilities are built to accommodate transferring between the two systems. Such decisions will be difficult to make but should consider the relative costs and benefits.

2.3 Elements

Within each of the three areas there are elements that are important to every transferring passenger and that the transit agency can do something about. The elements in the connectivity framework should be relevant for most transit agencies and transferring passengers, although there may be situations where a given element is not important to a particular agency, perhaps because the agency already has effectively dealt with that element. Elements that were neglected in the past could be added to the list, provided that there is evidence of potentially cost-effective improvements. Additional elements should be placed in the most reasonable area.

These elements are listed by area and ranked according to their importance to passengers and potential passengers. The elements need to be ranked because in the process, the elements that are most important to passengers and relatively easy and inexpensive to improve need to be identified. The major source of these rankings is the Interchange and Travel Study. This survey was very useful because prior to it, most travel surveys treated the transfer as a variable that affected mode choice, but did not explore how the details of the transfer affected mode choice. The results of the survey answered many questions about what features of a transfer passengers valued and what they found unsatisfactory. An explanation of the rankings this study helped determine is provided in the following sections.

2.3.1 System Elements

Table 2-3 shows how passengers responded to questions about the importance of the top three system elements in the Interchange and Travel Choice Survey. Price is a major motivator for many things, not just transferring. Passengers want value for their money, and about 90% of transferring passengers listed "the fares are good value" as something important to them when they traveled. Knowing beforehand about routes and schedules is also very important to transferring passengers. About 90% of transferring passengers listed "finding out about routes and services is easy" as something important to them when they traveled. While pre-trip information and price might appear to be equally important to rail and bus passengers who transfer, more car drivers viewed price as more important than information, and so this suggests that transfer price is more important than information overall. 87% of rail transferring passengers and 82% of bus transferring passengers valued "ticketing arrangements are simple" as being important. Interestingly, only 27% of car drivers considered this feature something that would persuade them to use public transportation more often, perhaps because they are not aware that ticketing is ever a hassle, given that they don't have experience with purchasing tickets. Ticketing arrangements pertain mostly to fare media, but also fare control to some extent.

In the study, there were no categories that referred directly to in-vehicle information or fare control and the ease with which passengers could get their tickets validated, and so they are considered less important than the other elements; otherwise they would have been included in the survey. However, information generally tends to be more highly valued than other elements, and in-vehicle information might help people find out about routes and services, so it is ranked above fare control.

Table 2-3 System Elements and Their Importance

	Percentage of Passengers Making Rail-Rail Transfers for Whom this is Important	Percentage of Passengers Making Bus-Bus Transfers for Whom this is Important	Percentage of Car Drivers who would Commute by Public Transportation More Often if this were True
Fares Are Good Value	90%	89%	56%
Finding Out About Routes and Times of Services is Easy	90%	89%	51%
Ticketing Arrangements are Simple	87%	82%	27%

from Interchange and Travel Choice Survey, 2001

2.3.2 Facility Elements

A project to develop objectives for the design of intermodal transfer facilities gathered and ranked 70 objectives for transfer facilities (Horowitz and Thompson, 1994). The applicability of the results for the use of ranking the six facility elements is questionable because the study was considering major facilities, as opposed to the smaller facilities that make up the majority of transfer points in most systems. However, the results will be used to provide some sense of the relative rankings for facility attributes that weren't addressed in the Interchange and Travel Choice Survey.

In the Interchange and Travel Choice Survey, weather protection is very important to the comfort and health of passengers. 96% of transferring rail passengers and 94% of transferring bus passengers agreed that weather protection was important to their trip. 55% of car passengers said that better weather protection might be an inducement for them to use public transportation more often.

En-route information appears to be ranked after weather protection. In the interchange study, shelters with lighting and weather protecting roofs and end panels were given a value of 1.7, while the availability of real-time, up-to-date information about bus arrival times had a value of 1.4, showing that passengers value good shelters more than they value real-time arrival information. These values are the equivalent minutes of in-vehicle travel time, i.e. a good shelter would be the equivalent of shortening the travel time by 1.7 minutes, while real-time information would be the equivalent of taking 1.4 minutes off the travel time. There are other types of en-route information available that would add to the value of this information. En-route information can help with trip planning and with informing passengers that a connecting service is operating on schedule – or otherwise. In addition to real-time information, en-route information can help passengers navigate a transfer facility, as well as be in the form of schedules, maps, and customer assistants available to help passengers at transfer points with their journeys.

The Interchange and Travel Choice Study does not provide much information on other aspects of transit infrastructure, but the ease of level changing is a large component of the convenience of changing services, which is considered important to 88% of transferring bus passengers and 94% of transferring rail passengers. In the intermodal facility study, the objective of minimizing exertion is ranked #33 out of 70 elements.

The last three elements are road crossings, walking distance, and concessions. In the intermodal facility study, road crossings fall under the general category of Safety/Security, walking distance falls under the general category of Efficiency, and concessions fall under the general category of the Passenger. Of these three groupings, Safety/Security is ranked first, Efficiency is ranked second, and the Passenger is ranked third. This is also a logical ranking because safety is a trip need, short walking distance a trip preference, and concessions a trip luxury.

Road crossings are very important to the feeling of personal safety. Road crossings are the most difficult part about making horizontal movements when transferring. However, the importance of safe road crossings is assumed to be less than the importance of weather protection, en-route information, and vertical assistance because it is not a survey question. However, this may have been a flaw in the way that the survey was set up, and improving street crossings may not have been considered because the survey-makers did not consider it to be an element that had very much bearing on the quality of an intermodal transfer facility or on the quality of a transfer.

Walking distance can be a concern for certain transfers. If the time required to walk to a connecting mode adds so much time to a trip that connections may be missed, passengers may choose to walk to their final destinations rather than to the second vehicle.

The last element is concessions. This is listed last because concessions are often not a requirement for transfers, but they may have a large impact on how passengers are able to use their time at the transfer point and whether or not passengers can add utility to their transfer trips. Concessions may affect the activity-level of a transfer point, which is something that passengers value for the safety and entertainment it brings.

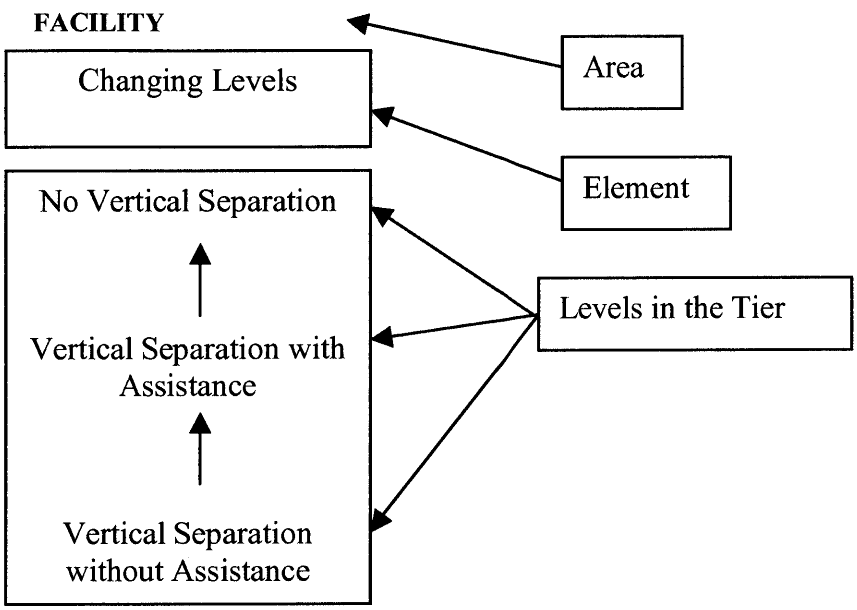
2.3.3 Service Elements

Many aspects of service affect connectivity, but one of the most critical aspects is how long a passenger has to wait for a transfer. There are many factors that go into determining what the transfer waiting time will be, such as the frequency of the connecting route, the regularity of the schedule, the reliability of the route, and the degree of coordination between the arrival and departure times. The second most important element is span of service. This determines whether or not a connecting service is available at a given time of day, and this is vital to ensure that passengers are not stranded at the transfer point, where they enjoy neither the comfort of their origin nor the satisfaction of having reached their destination.

2.4 Element Tiers

Now that the elements and their rankings within their respective areas have been determined, each element will be described in more detail. A discussion of the problems each can cause, the markets they can discourage from taking transit, and potential strategies for their improvement help shape the tiers. Figure 2-3 shows the relationships between an element, its area, and its associated tier. The tiers have a best level, a worst level, and in some cases one or more mid-levels. An improvement from one level to another level will imply an associated strategy or strategies.

Figure 2-3 Areas, Elements, and Tiers



2.4.1 System Elements

<u>Transfer Price</u>

Revenue is a major concern to transit agencies, particularly those that have to exceed a certain farebox recovery ratio; as a result, they may be unwilling to reduce or eliminate any fare revenue. They may not be able to provide free or discounted transfers within their system or provide discounts for passengers transferring from other systems, as this would translate into the daily loss of thousands of dollars. With no fare reduction, passengers have little incentive to transfer. When passengers have to pay full fare or even a reduced fare for their transfer, they may not feel as if they are getting their money's worth, particularly if it is a short trip they could make on foot, by bicycle, or by car, for which the out-of-pocket cost might be nothing.

Despite the associated problems of providing reduced or free transfers, lowering the cost of a transfer is an obvious way to induce transfers. Many agencies provide a reduced fare for all, or most, transfers within the system. Many agencies also provide free transfers, either through offering farecards with unlimited usage or through allowing free transfers within an hour (or two) of the first boarding. Table 2-4 shows the tier for transfer price. From the passenger's perspective, a free transfer is the best level, a full additional fare is the worst level, and a discounted fare lies somewhere in between. Improvements to transfer price will probably be costly for an agency, given the loss in potential revenue. And even if a fare reduction leads to an increase in ridership resulting in extra revenue, there might be a need to increase service, and this will come at a cost to the agency.

Table 2-4 Transfer Price

Best Level: Free Transfer
Mid Level: Discounted
Worst Level: Full Additional Fare

In New York, there was an 11% increase in subway ridership and a 20% increase in bus ridership as a result of making transfers between the bus system and rail system free in 1997 and by providing bulk discounts in 1998 (Tri-State Transportation Campaign, 1998). Fare improvements do not have to be a jump from the worst level to the best level of a tier, as they were in New York; an agency can provide discounts on transfers that currently require a full fare or they may make discounted fares free. Both still have the advantage of providing financial incentives to transfer and giving passengers a sense that there is coordination between services. The range of available strategies for reducing the transfer price for passengers is rather limited, but there is some flexibility in terms of what the actual discounted price is.

An agency might be in a position to change the price of a transfer if it hasn't increased fares in a long time. A fare increase and the associated expected revenue increase would provide an opportunity for lowering the price of services other than the basic fare, such as the transfer. Providing free transfers would be something that an agency could offer in exchange for approval of the fare increase. An agency would not need to consider the price element if the service it provided was free.

In many cases, transfer price is not only a matter of revenue, but also strongly tied to other system decisions, such as how fares are collected and what kinds of fare options are available. Systems that require payment or evidence of payment upon entry into the public transportation space are more likely to require payment for a transfer. On the other hand, proof-of-payment systems are more likely to allow free transfers, and payment is dependent on the number of zones traveled through rather than the number of services used.

Pre-trip Information

Passenger information has a large effect on how easily passengers can make a transfer. However, agencies may not always get information to the people who need it most. It may be hard to convey all the necessary information in the space that is available on a typical system map. There may not be a customer service telephone number, or the customer telephone number may be understaffed, making it difficult for people to get their questions answered. A website might not be useful or might not even exist. The agency may not believe that the schedules are ever actually adhered to, or the work involved in keeping the schedules current may be too difficult, and so they may not even publish them. Names, facilities, and operations might have changed in the recent past, and so the pre-trip information might not be current.

However, improving pre-trip passenger information could affect every transfer in the system in a positive way. If there is a website with schedules, service announcements, maps, and a trip planner, passengers can get information about any planned trip. With service announcements, passengers can modify their trips if necessary. With schedules, passengers can plan their trips in advance and find out when they should leave and when they can expect to arrive. With a trip planner, a potential passenger enters an origin and destination, and the program returns a travel itinerary. Itinerary planners are available at 7.6% of agency websites (Transitweb, 2001). Real-time information has some value for pre-trip information, but the benefits are more significant at the transfer point or very close to the starting time of the trip, when waiting time is the pressing problem; in the pre-trip stage, other factors, such as connection availability, are of greater importance.

However, if real-time arrival time is accessible on the website, there are an increasing large number of ways that passengers can get access to this information when they need it during the course of their transit trip.

System maps provide useful information about available transfers. If the transfers are clearly labeled on the map, as they are on 31.8% of transit agency maps (Transitweb, 2001), and it is clear what the transfer policy is and how transfers can be made, then passengers would generally be willing to make such a transfer, if they are planning their trip using the map. They will still need some information about hours of service and approximately how long the entire trip will take, and some maps provide this information.

All passengers can also be helped when a customer hotline is set up. Traditionally, one of the largest sources of complaints for transit agencies is not being able to reach customer agents by phone (Golob, 1972). Other forms of pre-trip information might include advertising on television, radio, billboards, or in work locations.

Route schedule information is also useful for transferring passengers. It can allow a passenger to plan his or her trip to a certain route well. Guaranteed connections can be denoted on schedules. For example, on some MTBA schedules, there is a "w" after the departure time of the last bus of the evening, denoting that this bus will wait for the last train before departing.

Table 2-5 shows the quality levels for pre-trip information. A passenger with no information about services is unlikely to use them. If a passenger at least has information about a route, then he or she may feel some reassurance that there is a connection available somewhere on that route. However, with system information, passengers are provided with complete information about all of the connections that can be made. With a trip planner, passengers do not have to go through the trouble of reading the schedules, as their trips can be planned for them. While the quality levels are based on the quantity of information available to transferring passengers prior to their trip, there should be an understanding that there is a range of qualities within each level. The information provided has to be accurate and easy to understand; otherwise, it will be of little use to passengers. The cost of pre-trip information provision is generally small compared to other agency costs.

Many agencies have taken steps to improve their pre-trip information. WMATA has instituted a voice-activated customer service telephone system to take care of as many calls as possible. They also make use of a trip planner, and this serves many passengers every day. Most agencies now have websites, and system maps have long been a good way of disseminating passenger information.

Table 2-5 Pre-trip Information

Best Level: System Information with Trip Planner
Mid Level (A): System Information
Mid Level (B): Route Information
Worst Level: No Information

It is difficult to estimate how many potential passengers do not use transit due to a lack of pre-trip information, but one could assume that it is rather high. Public transportation is a product that needs to be sold, and there is very little marketing compared to other products. Marketing to transferring passengers is especially important because while they may know about services close to their home or work, they may not be aware of connecting services. Tourists, or any passengers new to the transit system, similarly need a good deal of pre-trip information before they use transit, and if they can't find it, they will be unable to use transit, and the transit agency will suffer from not having reached certain markets.

Fare Media

Fare media is related to connectivity in that the more modes and services in a system that share the same fare media, the easier it will be to transfer. Table 2-6 shows that the best level is when transfers can be made using the same fare media and the worst level is when it requires two different media. When people can use the same fare media for different services, there are time and comfort benefits. When fare media differ across services, there usually isn't any discount on the transfer, payments have to be made more frequently, and there are more limitations on travel. Passengers value fare media integration because of the convenience, and fare media are a relatively small expense for an agency.

The fare media also have indirect consequences for connectivity. Some allow for easy collection of data on transfer patterns, which can be used to facilitate connectivity analysis. Others may also be more easily reprogrammed to allow for different fare structures.

Table 2-6 Fare Media

Best Level: Same
Worst Level: Different

The technology available for fare media is well established and there are many benefits to having a high quality fare medium in addition to the fact that it improves the quality of transfers for passengers. However, some transit agencies might resist fare integration, as it requires that they share revenues with other agencies. Agencies may also not be convinced that many of their passengers use connecting services, and therefore may be unwilling to undertake the cost of changing or modifying their fare control equipment.

In-vehicle Information

In-vehicle information can be very useful for passengers on the first leg of their trip needing information about their transferring service. It is often useful to have system or connecting route information in the transit vehicles in the form of maps, printed schedules, and real-time information about connecting services so people will know how they can best complete their trip. Announcements are particularly useful on buses since bus stops, even if they are transfer points, are often unlabeled or not easily visible from the bus. In-vehicle announcements are also an ADA requirement. Improving in-vehicle announcements is relatively inexpensive compared to the other services that an agency provides. As shown in Table 2-7, the worst situation occurs when there is no information available and passengers may be forced to ask the driver for information, which makes driving unsafe and slows boarding. The best situation is when there are announcements, real-time information, and connecting route information available in the vehicles for passengers. Mid levels exists for passengers who just have connecting route information and possibly announcements in the vehicles.

Table 2-7 In-Vehicle Information

Best Level: Connecting Route and Real-time Information and Announcements
Mid Level (A): Connecting Route Information and Announcements
Mid Level (B): Connecting Route Information
Worst Level: No Information

There are opportunities for improving in-vehicle information if there are efforts to upgrade the quality of bus service and announcements are a part of that improvement. Many agencies now provide stop announcements to comply with ADA legislation, and this also provides a way for transfers to be announced. Also, if maps and schedules are not provided in the vehicles or stations, then providing them there is a way to improve in-vehicle information at a relatively small cost.

Fare Control

Fare control affects what passengers must do to validate their fare payments when making a transfer. It may require that they go through certain barriers, wait in lines, or pull out items from their wallet. These activities may add delay and inconvenience to their trip.

As shown in Table 2-8, the worst situation is when the fare control system adds delay to the trip, as they generally do on bus trips and in rail systems during the peak periods. The fare control system could be greatly improved if it did not delay the trip. This could be achieved through the use of contactless farecards, which allow speedy movement through fare barriers. However, even if they don't cause significant delays, barriers still hinder completely free movement. This is why transfers that don't require validation are valued. These types of transfers are only possible when passengers can remain in the paid space when they transfer. However, a maximum amount of convenience is provided to passengers when their transfers do not require any validation and passengers can leave and return to the public transportation space without incurring additional cost. Passengers may want to leave the public transportation space to run an errand, so if they are not required to get validation they can run errands quickly and cheaply. Changes to fare control are generally a major expense for an agency.

Table 2-8 Fare Control

Best Level: No Validation Needed and Can Leave Public Transportation Space
Mid Level (A): No Validation Needed if Remain in Public Transportation Space
Mid Level (B): Validation Needed, but No Delay Added to Trip
Worst Level: Validation Adds Delay to Trip

If an agency is acquiring new fare control equipment, renovating a station, or changing the fare medium it uses, then there may be opportunities for improving the fare control system by eliminating its impacts on transferring passengers. The issue of fare control would not be an issue for an agency if it relied completely on proof-of-purchase.

2.4.2 Facility Elements

Weather Protection

Weather protection may not be sufficient or may not exist at transfer points because the additional infrastructure can be costly and require a lot of maintenance. However, passengers value weather protection very highly. To improve the conditions under which passengers transfer, weather protection can be provided in several different forms. The form depends on what type of weather passengers need to be protected against – wind, rain, snow, extreme cold, or extreme heat.

Awnings, bus shelters, covered walkways, and enclosed platforms are all forms of weather protection that can protect passengers against the rain or sun. Awnings are structures extending from a building that cover a sidewalk or waiting area. Bus shelters are small shelters for covering passengers at bus stops. Covered walkways provide continual coverage over the path passengers take between connecting vehicles. Enclosed walkways are tunnels that passengers can use to get from the alighting area of one trip to the boarding area of another trip.

Air conditioning and heating protect passengers from extreme heat or cold. Some indoor transfer facilities provide air conditioning or fans in the summer months, and heaters are provided in some systems for use in the winter.

People may choose their transfer points, and therefore their trip paths, based on what kind of weather protection exists at each point. If the transfer points they would have to use to complete their trip don't provide weather protection, then certain riders will be lost when the weather is extreme. They will drive, take a taxi, or forgo the trip altogether.

Table 2-9 shows the quality tiers for weather protection between services. A completely open area is the worst possible condition at a transfer point, as people will inevitably be waiting for at least some amount of time, and they will not want to wait out in the open if it is raining or if direct sun makes it very hot. Many bus-bus transfer points provide no covering at all. This situation can be improved by installing bus shelters at transfer points. The interchange study suggests that a good shelter alone provides benefits equivalent to reducing the in-vehicle time by 1.7 minutes, while even just a very simple shelter provides the equivalent of 1.2 minutes of in-vehicle travel time savings per trip. In general, weather protection improvements will be expensive.

Table 2-9 Weather Protection Between Services

Best Level: Protected Vehicle-to-Vehicle Connection
Mid Level (A): Unprotected but Covered Vehicle-to-Vehicle Connection
Mid Level (B): Covered Waiting Area Only
Worst Level: Open Area

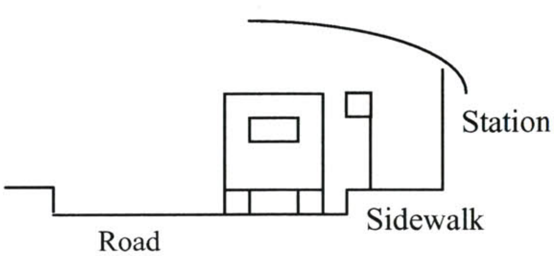
An even better alternative to providing just a shelter is to cover the entire vehicle-to-vehicle pathway. This is achievable at many bus-rail connections, where the buses stop very close to the station entrance, and constructing an awning would not require great investment. However, many people will still have to cross the street as they transfer, and even though it would have great benefit, covering a crosswalk is more challenging than building an awning over the sidewalk. The streets have to allow for the passage of large trucks, so the covering would have to be high. Being higher, they would require more lighting and they would have to be wider to cover passengers walking under it. Being wider, they would have to be heavier, and therefore uglier, more expensive, and harder to maintain (Abou-Sabh, 2002). Despite the costs, one study suggests that covering the walkways between connecting services is worth 16 minutes of in-vehicle time (Horowitz and Thompson, 1994), which is significant. Some weather protection options are shown in Figure 2-4.

Figure 2-4 Weather Protection Options for Transfers to Bus

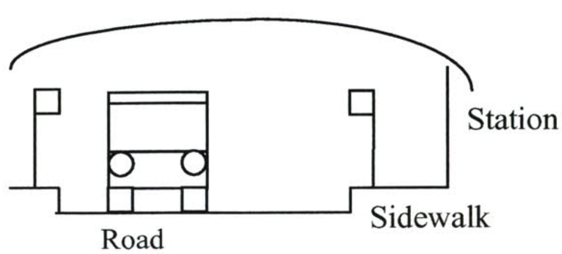
Simple Bus Shelter (Portland, Oregon)

Deluxe Bus Shelter (TCRP Report Example)

Awning



Crossing Covering



Due to the potential for extreme weather conditions, the ideal transfer condition is one in which the vehicle-to-vehicle connection is fully covered and protected. This can often be achieved for subway-subway transfers, which can generally be made completely indoors. There is no need to pull out an umbrella or be exposed to wind, rain, or heat, as would be the case at an unprotected transfer point.

Supplying the same weather protection quality as the subway connection to other transfer points is desirable but may not be feasible for most transit agencies. Enclosing platforms is an expensive option, particularly considering the maintenance that would be required. Maintenance would be especially difficult at stations in highway medians, due to the exhaust particles and the lack of easy access for cleaning, yet it is at these stations that enclosures would provide the most benefit because passengers want to be protected not only from the weather, but also from the smell and noise of cars.

Weather protection improvements can be made whenever an agency is renovating stations, an agency has funding available for station enhancements, when communities want to get involved in improving the quality of transportation, or when companies are willing to supply street furniture such as bus shelters in exchange for advertising space. Given that weather improvements can be made on a very small scale, there will usually be opportunities for improving weather protection that are inexpensive and yet will still improve the transferring conditions for many people.

<u>En-route Information</u>

En-route information is located at a bus stop or at a station platform, or even on a sidewalk somewhere near a transit facility. It provides information on what kind of service is available and how long the wait will be. En-route information can also include information for trip planning and reassurance that there is service coming soon. Without information, passengers may not know when connecting vehicles are expected to arrive, and so they may get nervous and choose not to wait. The waiting often causes anxiety, and good information tends to reduce this anxiety. However, even if there is some static information, passengers know that transit doesn't always operate exactly according to schedule, and this is why they highly value real-time information. Real-time information was the second most highly valued interchange attribute for bus riders according to the interchange study.

There are many ways in which en-route information can be improved beyond the schedules and route maps that are typically found at train and bus stops. System-wide information is beneficial because it helps people who need to transfer find out about all of their transferring options. There can also be facility information that shows passengers how to navigate a facility.

Understandable infrastructure is another important part of en-route information. It provides passengers with the comfort of knowing that they are going in the right direction when they make a transfer. It can be achieved through good design and positioning of services. Transferring to a subway line is not always intuitive because many of the stations may appear as little more than holes in the ground. Transferring to buses is not always intuitive, either, because buses share the roadways with cars, and they generally do not have exclusive bus lanes to give some sense of presence to the bus line. And often, if there is not even a bus shelter, there is little evidence besides a bus stop sign that there are buses operating. Bus-bus transfers are often considered easy to navigate because they happen in a relatively small space, but those bus-bus transfers that are not made at an intersection, but which require walking a half-block or more, pose a more challenging problem in terms of making the infrastructure understandable.

Table 2-10 shows the different quality levels for en-route information. The worst situation exists when there is absolutely no useful information at a transfer point. The next best level is when there is route information, which consists of the route number and some indication of where the route goes, but no information on the transfer facility itself or the expected waiting time. An improvement occurs when there is information about the waiting time, because this provides some assurance to the passengers about the arrival of services. The next best level is the provision of facility information. Facility information might be useful when a person needs directions on how to navigate a certain transfer point. If a transfer point has route, facility, and waiting time information, then the next item that passengers could benefit from is system information. Finally, the best level occurs when there is real-time arrival information in addition to all of the other information. Real-time information cannot substitute for static schedule and route information because the displays could malfunction, passengers need them to plan future trips, and they can make operators more accountable for their delays and early departures. En-route information is relatively inexpensive compared to other facility elements.

Table 2-10 En-route Information

Best Level: Real-time, System, Facility, and Waiting Time Information
Mid Level (A): System, Facility, and Schedule Information
Mid Level (B): Route, Facility, and Schedule Information
Mid Level (C): Schedule Information
Worst Level: No Information

Given all of the information passengers could use while accessing their transit vehicles, there are many ways in which en-route information can be improved. Schedules, maps, and navigational aids can all be added at minimal expense, and as the technology improves, real-time arrival displays may also be installed with relatively little cost. Furthermore, projects to provide real-time information are often undertaken in conjunction with projects to upgrade the service management and supervision capabilities, as they all rely on Automatic Vehicle Location (AVL) systems. With an AVL system, multiple functions that would better serve transferring passengers become possible.

Changing Levels

Trains and buses usually operate at different levels, which means that passengers transferring between these two modes have to descend or ascend a staircase or escalator when changing services. A lack of escalators might not be a major problem for passengers who are mobile, however, it can deter many passengers from using transit. A person going to the airport carrying heavy luggage may not be able to get there by transit if making the transfer requires climbing a flight of stairs. Also, passengers with certain disabilities know that they won't be able to make their trip if it requires a transfer without an escalator or elevator, and so they'll either have to stay home, get a ride, or take some other transit service to get to their destination. The physical strain of changing levels may also deter parents who would have to carry their children up the stairs.

Whether or not elevators assist most transferring passengers is debatable. In some senses, boarding an elevator is like making another transfer; a person has to wait for a service and ride in another mode. Escalators, on the other hand, provide continuous service. Even so, for people in wheelchairs, people with strollers, or people carrying cumbersome luggage, an escalator is not sufficient. However, most able-bodied people would walk or take an escalator instead of taking an elevator. This is partly because there is a sense that the elevators should be saved for those truly in need, and partly because people may feel that there are faster and more reliable ways of changing levels. Unfortunately, elevators can also be foul smelling and dirty, and this might be another reason many people do not ride them for their typical transfer. Elevators will probably only be of use to able-bodied people if they provide the shortest trip between the alighting and boarding points of a transfer.

Even if a person doesn't need assistance with their transfer, having well-functioning escalators may also help retain passengers as they get older and have more difficulty walking. Also, passengers may have temporary handicaps, and if they know that they can still manage the transfer as their injury is healing, they may continue to use transit during these periods.

If connecting vehicles operate at different levels, changing the configuration of the transfer point such that the services are operating at the same level is likely to be very expensive. There are many advantages to having the trains below or above grade, such as securing a dedicated right-of-way, that make it unlikely that trains would be placed at the same level as the connecting bus service. However, in designing a transfer point, providing transfers that don't require a change in levels should be considered.

The worst condition is when a transfer point does not provide any assistance for moving between different levels. However, if there are no level changes, then this element is at the best level. A mid-level exists when there is vertical separation of services but there is assistance between them. Even if a transfer point has escalators or elevators, they are prone to failure and they add to the transfer time. Table 2-11 summarizes the tier.

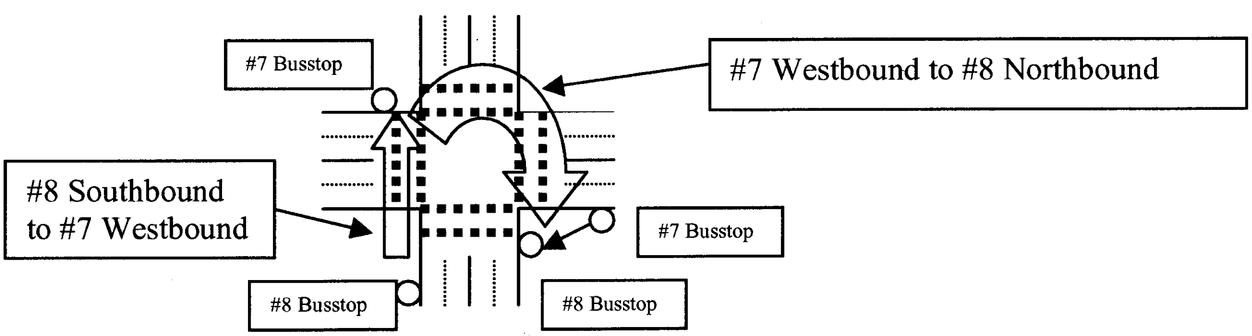
Table 2-11 Changing Levels

Best Level: No Vertical Separation
Mid-level: Vertical Separation With Assistance
Worst Level: Vertical Separation Without Assistance

Road Crossings

People often have to cross four, or even eight, lanes of traffic during a transfer, as shown in Figure 2-5.

Figure 2-5 Street Crossings at a Typical Bus-Bus Transfer Point



A major issue with the horizontal separation of services is that a transfer may require passengers to move through an intersection, which may pose safety concerns and which may add time to a transfer. In many systems, the major bus routes operate along busy roads, as demand is expected to be largest along these routes. However, automobiles are the major users of these roads, and so buses and their passengers compete with these vehicles for space. Many rail lines also operate in busy corridors, and as a result, when people transfer, they may have to cross a busy road.

In any transit agency, a trade-off must be made between efficient operations and customer convenience. When buses operate along the street and do not make turns or pull into bus depots, this allows for lower capital and operating costs, but it requires passengers to share the street with cars. However, there are some things that can be done to mitigate this situation. At some major bus-rail transfer points, there can be entrances on both sides of the street, so no matter which way passengers are transferring, they will never have to cross the street, assuming they've kept their fare card. Passengers transferring between bus lines may not even have to cross the street, if it happens that the connecting route's stop is around the corner. If there is a dominant transfer movement at the intersection of two bus lines, then the bus stops can be placed such that passengers traveling in these major transfer will not have to cross the street. If the transfers are equally distributed among all of the transfer movements, then if all four bus stops are far-side or near-side, this would eliminate the potential for any passenger to have to cross two streets to make a transfer. Alternatively, there may be off-street bus terminals where most passengers do not have to cross a street to transfer to a bus or train.

Road crossings make transfers dangerous for children who would need to transfer, and parents who don't want their children crossing busy intersections by themselves may not let them ride transit. The elderly and handicapped, if they do not move very fast, may not want to cross streets, either.

Table 2-12 shows the quality tier for road crossings. The worst situation occurs when there is an unassisted road crossing. This means that passengers have to dart across traffic to make their transfer. A much better situation can be achieved if a pedestrian crossing or a pedestrian crossing light is installed. There is some debate over which option is better. Some argue for stoplights that regulate the flow of pedestrians and automobiles, while others argue for a pedestrian crosswalk where cars are notified of the crosswalk and are expected to stop if pedestrians are present. Non-signalized crosswalks have the advantage of being cheaper to build than a controlled crossing and allow pedestrians to cross without having to wait for the walk light. The disadvantage is that not all cars stop for pedestrians, due to negligence or ignorance of pedestrian priorities. An even better situation can occur if the road crossing is completely eliminated for transfers, either through the construction of a second rail station entrance, off-street transfer facilities, or an overpass or underpass that can provide a safer alternative to pedestrians than walking across a busy intersection. Road crossing improvements will often be expensive.

Table 2-12 Road Crossings

Best Level: No Road-Crossings Required
Mid Level: Road Crossing Required, but Assisted
Worst Level: Unassisted Road Crossing

If passengers have to cross roads when they transfer, then this should be a concern for agencies, as there are usually actions that can be taken to improve the transfer, even in small ways. The crosswalk could be marked more clearly, the street could be narrowed, or the stops could be rearranged to maximize the ease of transferring. Alternatively, there may be cost-effective ways of eliminating the need to cross the street, if land is available for an off-street bus depot or if a rail station can be accessed from both sides of the street.

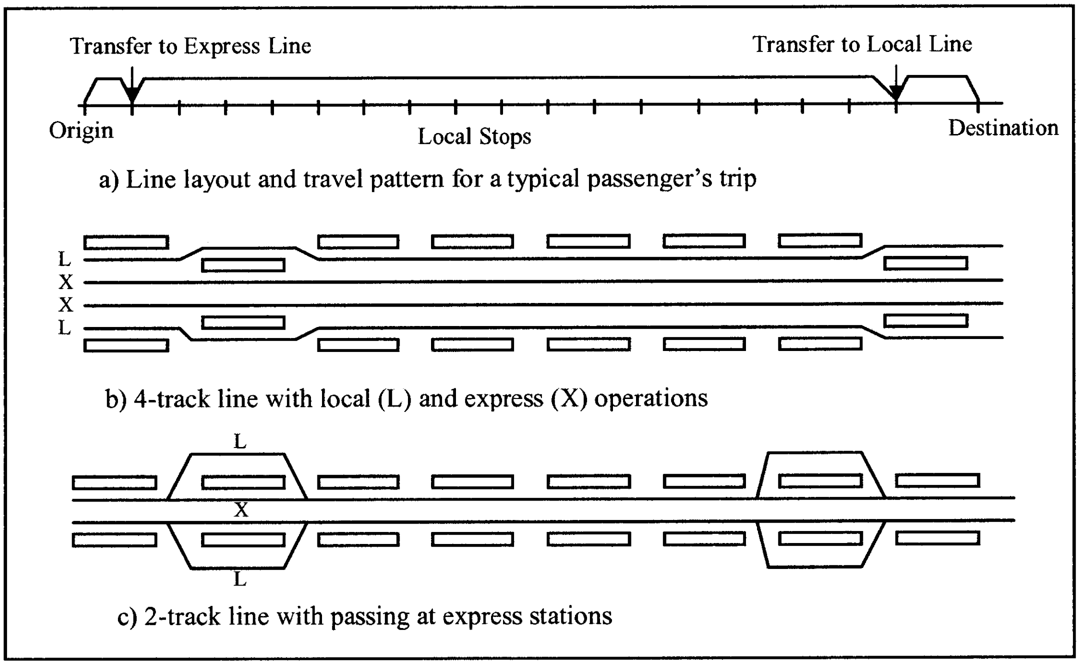
Walking Distance

The distance people have to walk to make a transfer affects the quality of the transfers; the longer the distance, the less happy passengers are with their trip. This is because they are less sure they are going to be able to make their connections, more uncertain about their travel time, and under greater physical strain.

If the routes along which the services operate are flexible or if stop locations can be modified, then there might be opportunities for reducing the walking distance. With fixed route service, reducing walking distance might be more challenging. If walking distances throughout the system are already short, this element will not offer any opportunities for improvement.

There are some creative ways for providing no-walk transfers. Cross-platform transfers offer ideal transfer environments because there is no need to climb stairs or navigate a station, and the opportunities for timed-transfers are high when the transfer time is essentially zero. Furthermore, the cross-platform transfers are usually protected from the rain. Cross-platform transfers come in several different varieties. The first, which is common in New York, is the cross-platform transfer between an express and local train. This can be done with either a 4-track or a 2-track alignment, as shown in Figure 2-6.

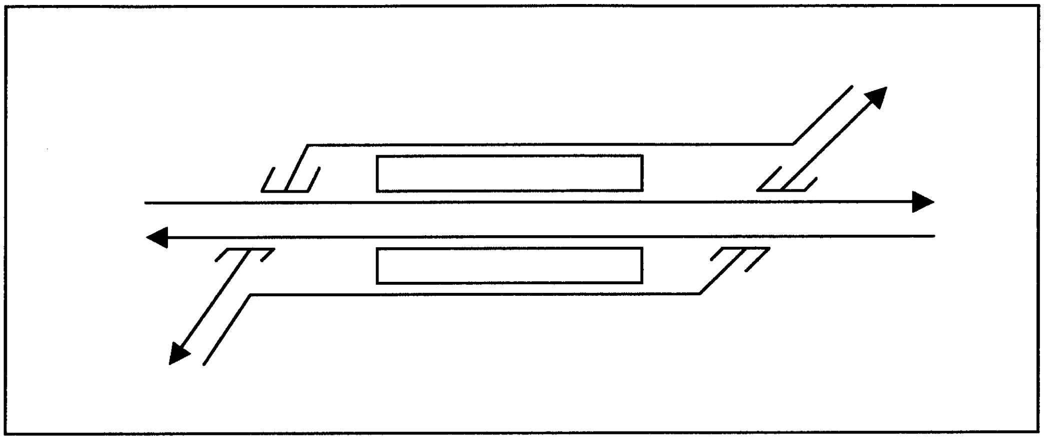
Figure 2-6 Cross-Platform Transfers for Local/Express Transfers



From Vuchic and Musso

Cross platform transfers can also be provided for connections between intersecting routes, as shown in Figure 2-7. Transfer points with woven tracks are used in Hamburg for timed transfers. The schedules are such that trains are scheduled to arrive at the same platform at the same time so that transfers in both directions can occur simultaneously. This infrastructure and timing mechanism allow for the optimization of 4 of the 8 possible transfers that exist when two routes intersect. In most situations, however, not all 8 of the transfers experience high volumes of flow, and so it may not be necessary to provide cross-platform transfers to all transferring passengers at a 4-way intersection.

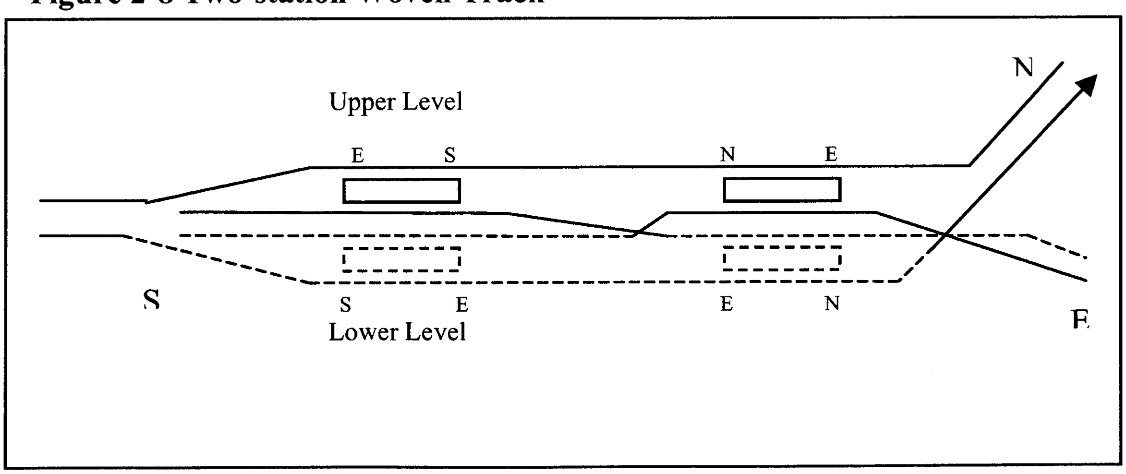
Figure 2-7 Woven Track to Accommodate Transfers



From Vuchic and Musso

The platform and track alignment shown in Figure 2-8 is another option available for improving the quality of transfers. It uses two stations, one to provide cross-platform transfers for passengers coming from the East and traveling South and passengers coming from the South and traveling East. The second station provides cross-platform transfers for those passengers coming from the East and traveling North and those passengers coming from the North and traveling East. Given that the line that goes out to the East terminates at this two-station transfer facility, there are only 4 possible transfers, and they are all provided with cross-platform transfers. This arrangement can be found in the Hong Kong Metro.

Figure 2-8 Two-station Woven Track



From Vuchi and Musso

Table 2-13 shows the quality tier for walking distance. The worst situation occurs when passengers must walk a long distance to make a transfer. The degree to which a long walk will bother passengers depends on cultural norms, climate, and fitness levels. A better situation occurs when the walking distance is short. If no walking is required, this is the best situation. Improvements to walking distance will probably be expensive.

Table 2-13 Walking Distance

Best Level: No Walking Required
Mid Level: Short Walk Required
Worst Level: Long Walk Required

Concessions

Concessions at a station might include things like a coffee shop, a newspaper stand, or soda machines. A small selection might be one or two shops, while a large selection might be more than two shops. An advantage of concessions is that they make the stations less dull by providing color, activity, and personality, thereby making the waiting time feel shorter. However, for bus-bus transfers there is often no transfer infrastructure, and so getting more concessions is not an improvement an agency can pursue. However, a shop unassociated with the transit service at an intersection may provide the same benefits.

Another aspect of concessions is how close they are to the flow of transfers. Only those concessions that the passengers pass by on their transfer path are considered, although some passengers might be willing to walk an extra block to get coffee or a donut when transferring.

Table 2-14 shows the quality tier for concessions. The worst situation occurs when there are no concessions. A person may really want something to eat or something to read, but a station might not provide these. If there are at least some concessions provided, then some passengers will be better served. These concessions might cause some maintenance and security concerns for an agency, but they might also enhance the security of a station, and actions can be taken to minimize the maintenance problems, such as providing more garbage receptacles. If there is a large selection of concessions, then even more passengers will be able to enjoy the convenience of concessions in the public transportation space. Too many concessions might be a problem if they obstruct the transfer walk, but the design of intermodal transfer facilities generally gives greater weight to shortening the walking distance than to positioning concessions in a transfer facility, so this generally isn't a problem. Concessions are generally inexpensive for an agency as long as space exists.

Table 2-14 Concessions

Best Level: Large Selection
Mid Level: Small Selection
Worst Level: None

If rail stations have enough space, then there may be opportunities for increasing the availability of concessions. This is more difficult for bus-bus transfer points, because there often isn't any built infrastructure, but infrastructure or services could be established with the intent of serving transferring passengers.

2.4.3 Service Elements

Transfer Waiting Time

Transfer waiting time is the result of both the operations plan and service management, and it is a function of reliability, frequency, and coordination. Transfer waiting time is generally wasted time, from the perspective of passengers, and the transit agency has the responsibility to make sure that passengers don't have to wait too long for their transfers. However, transfer waiting time is not always addressed in service design guidelines. Different people, for varying trip purposes, value time differently and may define "too much time at transfer point" differently.

Reliability is a major service issue for many transit agencies. Agencies know that guaranteeing smooth transfers has the potential to introduce delay into the system and decrease reliability. This is a common occurrence in airline networks, in which delays at one airport can result in system-wide delays due to the need to wait for connecting passengers at other airports. Train connections in the Netherlands are also a major source of delays (Goverde, 2001). Low service reliability also makes planners less interested in coordinating transfers, since they don't want to plan for and promise service connections that aren't possible. These problems lead to scheduled transfers being uncommon in many large transit agencies.

The reliability of transfers tends to be poor when the connecting vehicles are early, late, or if there are large gaps in the service. An early connecting vehicle might lead to a missed connection. A late connecting vehicle or a gap in the service will cause the transfer waiting time to be longer than it should have been. The best situation occurs when the connecting services are punctual. However, when there is high-frequency service, the passengers will not care about the lateness or earliness of vehicles; as long as a connecting vehicle arrives soon after they arrive at the waiting area, their waiting times will be short. Improving reliability should not be expensive for an agency, at least compared to adding more service. There are opportunities for increasing reliability when schedules, communication, supervision, and equipment can be improved.

The higher the frequency of connecting service, the sooner a connecting vehicle will arrive, on average. Higher frequencies will generally lead to better connections, unless the route already has matched headways with another route. In systems where all services are operating on short headways, transfer waiting time is a relatively minor concern because there is an expectation that a connecting vehicle will be there shortly. With high frequency service, scheduling meets becomes unnecessary, and doing so might increase passenger waiting time, because it would require more slack time in the schedule. Because high frequencies are so good for connectivity, an agency might do just as well to speed up service along its major corridors such that running times are cut and higher frequencies can be provided with the same number of vehicles.

There are several ways in which agencies can attempt to reduce transfer waiting time for their transferring passengers through schedule coordination. Coordination aims to make the connection times acceptable or to eliminate the wait completely, where possible. Two of the major scheduling tactics are to introduce a timed-transfer system or to attempt transfer optimization. Avoiding just misses, which happen when passengers just miss their connecting vehicle by approximately a minute or less, is another potential strategy. Matching headways, on either a large scale or a small scale, also has the potential to reduce transfer waiting times. There are also service management techniques that can be used to reduce transfer waiting time.

Timed-transfers are a common way of reducing waiting time for passengers in many transit agencies, as shown in Table 2-15. However, the use of the timed transfers are often limited to certain times of day and certain locations, and so not all transferring passengers benefit from this practice. This is understandable, given that there are limitations to the cost-effectiveness of timed transfers. One study (Abkowitz,1987) tested four different scheduling and holding strategies for transfer conditions and determined the conditions they would work best under with the use of a simulation model. In his model, vehicles were dispatched at different distances from the transfer point to account for the loss of schedule adherence as vehicles move along the route. Vehicles were also dispatched with different headways. The first case considered was the unscheduled connection case. While it was determined that the unscheduled case never minimized transfer times, it was often better than the application of a poorly structured holding strategy. The second case considered was the scheduled case, which provided the most benefits when the frequencies of both routes were low. The case where vehicles on the lower frequency route wait for vehicles on the higher frequency route provided the most benefits when the waiting time imposed on non-transferring passengers might be very high. Double holding is particularly useful when the headways of intersecting routes are compatible. The results depend heavily on the distribution of passengers transferring, making through-trips, and waiting downstream, so the results of their simulation are not conclusive, but provide guidelines to steer future studies.

Table 2-15 Use of Timed Transfers by System Size

	Under 50 Buses	51 to 200 Buses	201 to 500 Buses	501 to 1,000 Buses	Over 1,000 Buses	Total
Use	20	16	5	4	3	48
Don't Use	15	15	9	5	7	51
Total	35	31	14	9	10	99

Bus Route Evaluation Standards Survey, 1994

The TCRP Scheduling Manual (TCRP, 1998) suggests that timed transfers are beneficial only when service is infrequent (20 minutes or more between vehicles) because for more frequent service, untimed transfers are adequate for passenger needs. This doesn't recognize that wait times of 15 minutes might be too long for some passengers, particularly those traveling at night or in neighborhoods where there is not very much activity. Nor does it mention the benefits of matching the schedules of high-frequency routes in order to balance loads. Nonetheless, the document lists timed transfer scheduling as a basic scheduling practice.

Transfer optimization differs from scheduling timed-transfers in that it does not require that vehicles meet at a single point for the exchange of passengers. Rather, transfer optimization determines the optimal set of departure times of all trips so that the total transfer waiting time, or whatever function is chosen to represent passenger cost (and/or operator cost), is minimized. An advantage to transfer optimization over timed transfers is that slack time does not have to be introduced into the schedule to increase the probability that a certain connection can be made (Bookbinder et al., 1992), nor does it require the same kind of service management as timed transfer systems.

Schedules accounting for transfers can be optimized considering deterministic running times between transfer points. This was the approach taken when trying to optimize a train network timetable for a part of the Netherlands using max-plus algebra (Goverde, 2001). Transfer optimization considering probabilistic arrival times has also been investigated (Bookbinder et al., 1992). The results of optimizing some networks show that a solution based on assuming deterministic arrival times can actually be worse for passengers, and so there are benefits to considering probabilistic arrival times if it more accurately reflects the real situation. The results show that transfer optimization can reduce the expected waiting time by more than 20% on some systems, but often at the cost of increasing their variability. The more the arrival times vary, the smaller the benefits of transfer optimization. Larger headways increase the benefits that can be gained from transfer optimization. Optimizing directional transfers produces more benefits.

Just misses are vehicles that leave a transfer point just as passengers coming from another mode arrive. This is a very frustrating experience for passengers, and efforts should be taken to avoid just misses whenever possible. Just misses can often be found in the schedule, and departure and arrival times can be modified so that they are eliminated. There are many advantages to matching headways. If headways of two routes are matched, then planning consistent transfers between them will not be difficult. Matched headways generally mean shorter connection times, more even headways, and easier service management.

When headways are matched on a large scale – at many transfer hubs -- then integrated timed transfer (ITT), also known as Taktfarplan, result. Integrated timed transfers are different from a timed transfer because they are much more extensive. Reinhard Clever (1997) describes the use of ITT in Europe and considers its applicability in the United States. ITT provides an opportunity for faster transit trips and allows more areas to become accessible. Integrated Timed Transfer networks can address many of the items that motorists cite as reasons they do not use transit, such as a lack of flexibility and destinations available on the transit system. Another advantage is that the network need only be optimized for one short time period, as the cycle repeats itself on a regular basis.

Clever also makes the interesting observation that building a high speed rail line is of little help for some people if they still have to wait 40 minutes for a connection in order to finish their trip, and if a slower mode could be utilized in an integrated timed transfer system, then travel times could be more effectively reduced.

Clever also points out a disadvantage to matched headways: they do not allow for much flexibility on the route if demand rises beyond the capacity that the operating plan provides. A way of getting around this difficulty is to invest in some additional vehicles and dispatch multiple vehicles at certain times. He also mentions that some systems that have instituted timed transfer systems, such as the Austrian railroad, have added service beyond what they provided before, but ridership and revenue increases did not meet service increases. There is also the reliability problem: a delay on one line may spread to the entire system, which is dependent on connections and timing for good performance. Another complaint is the timed-transfer systems are not a good use of existing facilities. While the hubs may be full of vehicles and passengers during the transfer windows, they are empty at all other times. Another consideration is that when a system is based on a fixed headway, the network is supply rather than demand driven. To deal with this, capacity has to be expandable or shrinkable in order to save money, and yield management techniques have to be used to best spread out passengers.

If entire regions commit themselves to one or two headways, then this is an important step toward integration. This technique seems particularly applicable to intercity travel.

Another important component to the schedule-making process for connections, in addition to setting the frequencies and departure times, is establishing the slack times at transfer points. Due to the variability in running times, slack times are required to make sure that vehicles will be present for a given connection with a high degree of certainty. One study aimed to find the optimal slack time that would minimize the total expected transfer cost (Lee and Schonfeld, 1991). The transfer cost in their model was the sum of scheduled passenger waiting time, unscheduled passenger waiting time, and missed connection penalties. Under typical conditions, the optimal slack time was about five minutes, meaning that the vehicles on the route with lower reliability should be scheduled to arrive 5 minutes before they would have to arrive to allow more passengers to make their transfer and to make sure that the vehicle doesn't have to wait too long at the transfer point for the passengers making a transfer movement in the opposite direction.

Table 2-16 shows the tier for passenger waiting time. Each passenger has a threshold for what constitutes waiting time that is too long. This might depend on the time of day, mood, degree of lateness, presence of company, or a host of other factors. By definition, an acceptable amount of waiting time is a compromise level. The best situation occurs when a person does not have to wait at all for a transfer. Most strategies for reducing transfer waiting time require little cost if they involve schedule modifications and don't involve adding additional service.

Table 2-16 Transfer Waiting Time

Best Level: High Frequency
Mid Level (A): Matched Headways and Coordinated Arrivals and Departures
Mid Level (B): Coordinated Arrivals and Departures
Worst Level: No Coordination

Service management is required to support any scheduling efforts on behalf of transferring passengers. One study establishes a model for finding holding times that minimize passenger waiting time (Dessouky and Hall, 1999). They point out that if the arrival time of the incoming vehicle is known, then the connecting bus should either be dispatched immediately or held for the incoming vehicle. If the arrival time of the incoming vehicle is not known, however, there may or may not be a holding time that will minimize the expected passenger waiting time. The general equation used is:

$$\min W(t_d) = t_d B + \sum_{t_i \le t_d}(t_d - t_i)M_i + \sum_{t_i \ge t_d}(\tau - t_i)M_i$$

where τ is the next departure time on the route of the held bus, t_d is the decision variable, and $\tau \ge t_i$ for all t_i, which are the arrival times of the late vehicles. B represents all non-transferring passengers, either going through the transfer point, boarding at the transfer point, or waiting for the bus downstream. M represents transferring passengers, who may either catch the held bus or the next bus on its route.

Dessouky and Hall's model doesn't consider a few important points. The first is that the amount of time that a bus is held will have an effect on the likelihood of it being able to start its next trip on time. It also doesn't recognize that passengers who miss their connections will probably be more displeased than passengers who have to wait but still make their connections, and the model doesn't consider that the value of time may be different for passengers undergoing different connection experiences. The model also does not consider the variability of the times needed for people to move through the transfer point.

In summary, Dessouky and Hall conclude that the best circumstances for holding exist where a large fraction of passengers are transferring and the time until the next departure is large.

Dessouky and Hall's research touches on the issue of knowing where the connecting bus is located and how this should affect a holding decision. Knowing bus location and load through rail and bus tracking have the greatest impacts when there are major delays and the number of connecting vehicles is small (Dessouky, 1997). The research also shows that the technologies for both locating vehicles and estimating passenger loads exist, but their usefulness may be limited because it is still often best to hold for all connections, which means that the technology would not be helpful. There are also concerns about the accuracy of the information provided by location trackers and load counters.

While it is useful to determine what should be done in the event of delays, a better area for agency focus may be how to reduce the number of such delays that occur. This reduces waiting time for everyone, and so keeping all service on schedule should always be the main focus of service management.

Much of the responsibility for making connections lies within the control of operators. They may have to wait for the last train and respect the slack time in the schedule and not run ahead of schedule.

Bus holding lights are used in many transit agencies to inform bus operators that a train will be arriving soon and that that they should wait for any transferring passengers. The way that these holding lights generally work is that an approaching train trips a switch along the track, and this switch activates a bus holding light. Adjustments can be made to where these switches are located, and the amount of time that the holding light remains lit can be programmed. Problems with bus holding lights are that they often fail and they may not be set to optimal parameters. They may also be of limited use if only a small fraction of buses are actually at the stations to get the information about the train arrivals, and many drivers may have no incentive to obey the bus holding light and wait for the transferring passengers, particularly if their scheduled departure time has already passed.

Bus holding lights exist at many of the major transfer stations in the MBTA system, such as Sullivan Square, and the CTA system, such as Pulaski Station on the Orange Line. They are also used at some stations at BART.

Train holding lights are used in the New York City subway system to provide several functions. During the rush hour, the main objective is to maximize capacity by evening out the loads on the trains. During the non-rush periods, the main purpose of the lights is to provide even headways and to provide desired connections. Generic stations are considered – Midway In, Gateway In, Center CBD, Gateway Out, and Midway Out, and whether or not the trains should be held for connections is determined for different times of day (New York City Transit Authority, 1987). No trains are held for connections in the AM peak. Only trains at "Midway Out" stations are held in the PM peak, and trains at all stations can be held for connections in the off-peak.

Operators can also communicate with each other directly when there is a transfer that needs to be made. In Tempe, passengers can tell the bus driver that they want a transfer to a given route. If the operator knows that it will be a close connection, he or she will turn on a transfer light at the top of the bus to alert the connecting bus operator that there is a passenger who wants to transfer (Valley Metro, 2002).

Span of Service

The span of service element refers to the existence of a transfer at a given point at a given time of day. Two services need to be operating for there to be a transfer, and connection availability can be determined from the schedules.

Table 2-17 shows the quality tier for span of service. The worst level is when the spans of service are not matched. Passengers are either stranded at a transfer point, or they never make the trip by transit if they know they won't be able to complete it. In some cases, they may not make two trips, given that they'll know that they shouldn't make the initial trip if they know they won't be able to make the return trip. The number of passengers who don't have a connection cannot be measured, and so the assessment of this element will need to be based on schedule information rather than passenger information. When both services are operating, the best level is achieved. However, expanding the availability of connections is generally expensive and may conflict with a transit agencies service design guidelines.

Table 2-17 Span of Service

Best Level: Matched
Worst Level: Unmatched

A common way of increasing connection availability is increasing the span of service of a given route. Another strategy would be to guarantee that a bus will meet the last train of the evening or vice versa. There are opportunities for increasing span of service for connections whenever there are route pairs with service spans that don't match.

Chapter 3. A Process for Improving Transit Service Connectivity

This chapter will describe a process for assessing service connectivity in a transit system and guiding efforts for improving the quality of transfers. The major steps of the process are shown in Figure 3-1. The process presents some of the major decisions that an agency will have to make in order to develop a strong connectivity improvement plan and guidelines for how these decisions should be made. The first such decision is what the agency is going to consider as its system boundary for this process. Then it will present a way of using the available data to assess connectivity in the system. Using the results of the assessment and estimates of the costs and benefits of various improvements, the applicable parts of the framework will be considered for further analysis. The next step in the analysis is determining the different ways in which the improvements would be applied to a system and the costs and benefits of such an application. The next step will be to consider how these improvements should be prioritized across areas. Finally, a plan for monitoring transfer volumes, service quality, and customer satisfaction will be developed to monitor how the implemented service connectivity improvements are affecting passengers and their willingness to transfer.

Figure 3-1 Process for Improving Transit Service Connectivity

Step 1: Define System Boundary
Step 2: System Element Assessment
Step 3: Facility Element Assessment
Step 4: Service Element Assessment
Step 5: Tailor System Element Analysis
Step 6: Tailor Facility Element Analysis
Step 7: Tailor Service Element Analysis
Step 8: System Improvements
Step 9: Facility Improvements
Step 10: Service Improvements
Step 11: Cross-area Prioritization
Step 12: Monitoring Plan

3.1 Define System Boundary

The purpose of this step is to determine the set of transfers and potential transfers the process should assess and consider improvements for. If an agency is concerned with its ridership in general, it might start by considering the limits of its service area as the system boundary and focus on improving transfers within the established network. If the agency believes that it can increase ridership by attracting riders from outside the service area, then it should consider those transfers that occur on the edges of the service area or anywhere outsiders might access the system. If a new line is being built and new transfers will be introduced, then these new transfers should be the focus of a study to make sure that the new service is well integrated into the existing service. Once the new connections have been successfully established, the process could be repeated with an extended system boundary that includes both the new and the existing transfers.

3.2 Element Assessment

In this section, methods for assessing system, facility, and service elements will be described.

3.2.1 System Element Assessment

Table 3-1 shows an assessment of system elements for a hypothetical transit agency. Such an assessment requires transfer volumes by transfer type: in this transit system, there are four transfer types. The transfer from the bus to the rail is considered separately from the transfer from the rail to bus because in many agencies, the transfer policy is not symmetric. Transfer volumes could be calculated from a number of sources. They often come from the fare collection system, but they could also be estimated from passenger surveys. Counting passengers through the fare collection system is preferable because it provides complete information about the transferring population, but for systems that do not have an automatic fare collection system that records transfers, surveys will be necessary. If parts of the system are not yet operational, then the transfer volumes can be forecast.

The distribution of transfers among the different tier levels is generally quite easy to determine for system elements. The fare policy will determine whether the transfer price is full fare, discounted, or free. Data from an automatic fare collection system may be the most accurate source of information on how much passengers are paying for their transfers if different passengers are eligible for different fares. The scope of information available on the agency website (if there is one), on the customer service hotline (if there is one), and from distributed system maps and schedules determines how much pre-trip information transferring passengers have available to them. However, the information may not be reaching very many existing and potential passengers, and so passengers should be surveyed about their awareness of pre-trip information. Whether or not a single fare medium can be used for particular transfer types is a component of a system's fare policy. Even though a single fare medium might be available for monthly pass holders, it may not be available for passengers who buy their fare passes on a per-trip basis. The assessment of in-vehicle information depends on whether the vehicles have announcement systems and whether information is distributed or displayed in vehicles. The fare control system should also be rather straightforward in a system, as it is largely tied to the fare policy and the fare media. When no passengers are experiencing the lower levels of an element's tier, the lower levels do not have to be listed, as the improvements that are considered will not involve these levels.

As shown in Table 3-1, rail-rail, bus-bus, and rail-to-bus transfers are free in this hypothetical transit authority. Bus-to-rail transfers require a full additional fare. This system does not have a trip planner, but it provides passengers with system-wide pre-trip information. A single fare medium can be used when transferring between rail lines, since there is no need for fare revalidation, and passengers can use evidence of their rail trip to board buses. Bus-bus transfers can be made with a transfer slip they receive when the pay on the bus. Passengers transferring from bus to rail cannot use a single fare medium, which may be due to the fact that the rail system fare collection system is relatively high-tech and does not recognize the bus system's fare media. There is no in-vehicle information in this system, and there are barriers that add delay to all transfers except those between rail lines.

Table 3-1 System Element Assessment – Hypothetical Transit Authority

	Transfer Type	Bus-bus	Bus-rail	Rail-bus	Rail-rail
	DAILY TOTAL	300,000	200,000	200,000	150,000
Transfer Price	Free	100%	0%	100%	100%
	Discounted	0%	0%	0%	0%
	Full Additional Fare	0%	100%	0%	0%
Pre-trip Information	System and Trip Planner	0%	0%	0%	0%
	System	100%	100%	100%	100%
Fare Media	Same	100%	0%	100%	100%
	Different	0%	100%	0%	0%
In-vehicle Information	Connecting Route and Real-time Information with Transfer Announcements	0%	0%	0%	0%
	Connecting Route Information with Transfer Announcements	0%	0%	0%	0%
	Connecting Route Information	0%	0%	0%	0%
	No Information	100%	100%	100%	100%
Fare Control	No Barriers	0%	0%	0%	0%
	No Barriers if Remain in Paid Area	0%	0%	0%	100%
	Barriers do Not Add Delay	0%	0%	0%	0%
	Barriers Add Delay	100%	100%	100%	0%

3.2.2 Facility Element Assessment

The assessment requires knowing the status of the facilities throughout the system. A survey of stations may be required, but there may be a lot of information already available in the form of GIS data and station designs. Information is needed on what is available in terms of weather protection, en-route information, changing levels, road crossings, walking distance, and concessions for transferring passengers. Table 3-2 shows the evaluation of four major transfer facilities in the hypothetical transit agency.

Table 3-2 Facility Element Assessment – Hypothetical Transit Authority

	Transfer Type	Rail-bus	Bus-Rail	Bus-bus	Rail-rail
	Location with highest volume	Terminal Station A	Terminal Station A	Hub Transfer Center A	Central Station A
	DAILY TOTALS	5000	5000	4000	10,000
Weather Protection	Protected vehicle-to-vehicle connection	0%	0%	0%	100%
	Unprotected but covered vehicle-to-vehicle connection	100%	100%	100%	0%
	Covered Waiting Area	0%	0%	0%	0%
	Open Area	0%	0%	0%	0%
En-route Information	System, waiting time, and real-time arrival information	0%	0%	0%	100%
	System and waiting time information	100%	100%	100%	0%
	Route and waiting time information	0%	0%	0%	0%
	Route Information	0%	0%	0%	0%
	No Information	0%	0%	0%	0%
Changing Levels	No Vertical Separation	0%	0%	100%	0%
	Assisted movement	100%	100%	0%	100%
	Unassisted vertical movement	0%	0%	0%	0%
Road Crossings	No road crossing	100%	100%	100%	100%
	Assisted road crossing	0%	0%	0%	0%
	Unassisted road crossing	0%	0%	0%	0%
Walking Distance	No walk	0%	0%	0%	0%
	Short walk required	100%	100%	100%	100%
	Long walk required	0%	0%	0%	0%
Concessions	Large selection	0%	0%	100%	0%
	Small selection	100%	100%	0%	100%
	None	0%	0%	0%	0%

Such an assessment does not necessarily have to be done for every transfer facility within the system boundary. Transfer facilities with very low transfer volumes do not need to be included in the analysis because they will not have a large impact on the system-wide assessment, and it is unlikely that many facility improvements can be justified at facilities with small transfer volumes. Those facility improvements that can be justified at the smaller transfer facilities are likely to be improvements that are so cost-effective that they can be recommended for nearly every transit facility.

Table 3-3 shows the hypothetical distribution of passengers among the different facility level elements. This is for all transfer facilities assessed within the system boundary. The assessment process can be greatly simplified by the fact that certain transfer types often share the same characteristics throughout the system. For example, bus-bus transfers are almost always made at an intersection, where there is no need to climb stairs or an escalator, and so the bus-bus transfer facilities do not need to be assessed individually for the changing levels element.

Table 3-3 Summary of Facility Level Assessment – Hypothetical Transit Agency

Elements	Best Level	Mid Levels	Worst Level
WEATHER PROTECTION	Protected Vehicle-to-Vehicle Connection 0%	Unprotected but Covered Vehicle-to-Vehicle Connection 50% Covered Waiting Area Only 40%	Open Area 10%
EN-ROUTE INFORMATION	System, Facility, and Waiting Time Information with Real Time Arrival Displays 10%	System, Facility, and Waiting Time Information 20% Route, Facility, and Waiting Time Information 70% Route Information 0%	No Information 0%
CHANGING LEVELS	No Vertical Separation 30%	Vertical Separation with Assistance 60%	Unassisted Vertical Movement 10%
ROAD CROSSINGS	No Road-Crossing Required 50%	Road Crossing Required, but Assisted 50%	Unassisted Road Crossing 0%
WALKING DISTANCE	Long Walk Required 0%	Short Walk Required 86%	No Walk Required 14%
CONCESSIONS	Large Selection 12%	Small Selection 8%	None 80%

To assess facility elements, transfer volumes are needed for the transfer facilities being considered for improvement. If an agency knows where each of its passengers enters and leaves the system, it can make assumptions about where passengers transfer. Similarly, if an agency knows when passengers have used multiple services consecutively and what these services were, it can make estimates about where passengers are transferring. These kinds of data usually come from the fare collection system. In the case of transfers that aren't taking place yet, this process will be undertaken with forecast data. In the case of agencies that have fare collection systems that don't collect data or systems that use a proof-of-payment system, passenger surveys will generally be necessary to find out about the distribution of transfers in the system.

3.2.3 Service Element Assessment

The schedules are the main source of this data, although schedules are often not met. AVL data could be used to determine the real connection time between services at a particular transfer facility and to see if the scheduled connections occur as planned. The assessment of the route pairs with the highest transfer volumes for each transfer type in a hypothetical transit system is shown in Table 3-4.

If two routes have been jointly scheduled for the purpose of minimizing the waiting time for transferring passengers and the service management supports what the schedules are aiming to do, then passengers who travel during this time are transferring under mid level (B) conditions. In this hypothetical transit agency, this is done for the connection between the Red and Yellow lines for all hours of operation. If the two routes are coordinated and have matching headways and service management is ensuring that the transfers are occurring as planned, then passengers under these conditions are transferring under the mid level (A) conditions. This is done for the connection between the Red Line and the #4 for 60% of the hours that the connection is available. If passengers transfer to a high frequency route and the service management is successfully keeping the headways even and avoiding gaps in the service, they are experiencing the best level. None of the routes are operating at a frequency to justify putting them in the best level.

The hours per week that the spans of service are matched is calculated by counting the hours during which both routes are serving a particular transfer point. In this hypothetical transit authority, the Red, Grey, and Yellow Lines operate 24 hours a day and 7 days a week, so connections between them are available 168 hours per week. The #4 bus only operates about 20 hours a day, and this leads to the connection between the #4 and the rail lines being available 140 hours per week. The #7 operates 20 fewer hours per week than the #4, and so the connection between the #7 and #4 is available 120 hours per week.

Table 3-4 Service Element Assessment – Hypothetical Transit Authority

	Transfer Type	Rail-bus	Bus-Rail	Bus-bus	Rail-rail
	Transfers with highest volume	S Red Line to N #4	S #4 to Grey S Line	N #4 to E #7	N Red Line to N Yellow Line
	DAILY TOTALS	5500	5000	3000	8000
Transfer Waiting Time	High Frequencies	0%	0%	0%	0%
	Headways matched and arrival and departure times coordinated	40%	0%	0%	0%
	Arrival and departure times coordinated	0%	0%	0%	100%
	No coordination	60%	100%	100%	0%
Span of Service	Matched	140 hours per week	140 hours per week	120 hours per week	168 hours per week
	Unmatched	28 hours per week	28 hours per week	20 hours per week	0 hours per week

Table 3-5 is a summary chart for the hypothetical transit agency that shows that no passengers are transferring to high frequency service. Different agencies might define high-frequency service differently, but it should generally be less than 5 minutes between arrivals given that passengers often feel that a five-minute wait is too long, especially when waiting for a connecting service. In this hypothetical transit agency, for half of the connection times, arrival and departure times are coordinated, and for 10% of the connection time, the headways are matched and coordinated. The rest of the time, the schedules are not coordinated.

Table 3-5 Summary of Service Element Assessment – Hypothetical Transit Agency

Elements	Best Level	Mid Levels	Worst Level
TRANSFER WAITING TIME	High Frequency 0%	Headways matched and arrival and departure times coordination 10% Arrival and departure times coordination 50%	No coordination 40%
SPAN OF SERVICE	Matched Average route-pair: 100 hours per week		Unmatched Average route-pair: 40 hours per week

3.3 Element and Tier Tailoring

As information is gathered about the different elements, it might become clear that certain element improvements are not relevant to a particular system. Only those element improvements that will attract more riders, improve customer satisfaction and which will benefit passengers more than they will cost the transit agency should be considered for improvement. And even those that are potentially good elements for improvement may have different degrees of cost-effectiveness. It might even be the case that a certain element needs to be added to the list of elements that need improvement if it shows up as a major concern for transferring passengers in surveys or from observations. The remaining elements then need to be reprioritized according to their cost-effectiveness, not just their importance to passengers.

The tiers may also require revisiting if they don't properly reflect the way in which a given element is valued in a particular agency. For the most part, the tiers won't change from agency to agency, however, due to the fact that climates vary, the weather protection tier might differ slightly from agency to agency. For example, in warm climates, a fully covered vehicle-to-vehicle connection might not be preferable to a vehicle-to-vehicle connection that is covered but allows the air to circulate.

In the following sections, the costs and benefits of various improvements will be considered, and the improvements will be ordered according to their cost-effectiveness. These new rankings will differ from the rankings used in Chapter 2 that listed the elements according to their importance to passengers. By using cost as part of the prioritization, an agency will potentially be able to afford more projects for improving connectivity in the transit system than if they prioritized projects simply according to passenger benefits.

3.3.1 System Element Tailoring

In this section, the costs and benefits of different system element improvements are considered so that decisions can be made about whether or not a particular improvement is worthwhile in a given agency and how those that are worthwhile should be prioritized.

Transfer price improvements will almost always be cost-effective, in the sense that they provide passengers with more benefits than costs to the agency. However, a transfer price reduction may not always be affordable to an agency. This is why transfer price reductions make the most sense in conjunction with an increase in the base fare, as the fare increase can compensate for the transfer revenue loss. Transfer price reductions should not be undertaken if they lead to a loss in revenue that forces the agency to cut service or if the agency is currently operating at capacity and cannot carry any more passengers.

If pre-trip information about transfer trips can be improved, it will almost always be a cost-effective improvement, due to the fact that pre-trip information improvements are relatively inexpensive for the transit agency and highly valued by passengers. Improving pre-trip information generally requires one large effort – the creation of a system map or a trip planner, for example – followed by the regular maintenance of whatever was created.

If fare media can be improved, by making it possible for more passengers to use a single farecard for multiple trips or even for purposes other than transit, then this element should be addressed due to its relatively low cost and relatively high importance to passengers. The improvement to this element would require a large initial effort, but generally no maintenance would be required.

In-vehicle information, in the form of announcements, is valued by riders with sensory disabilities or unfamiliar with the route. However, in-vehicle announcements are relatively expensive in relation to their importance to passengers, and so it will not always be a candidate for improvement. Nonetheless, in-vehicle announcements are an ADA requirement, so they are likely to become a system feature eventually, and so efforts should be made to ensure that transfer options are included in the announcements. In-vehicle information also refers to schedules and maps distributed on the bus. These are highly valued and relatively inexpensive, and since they provide information that passengers can take home with them, they also serve as pre-trip information. Real-time information in vehicles is another form of in-vehicle information that would inform passengers about arriving connections, delays on connecting routes, and the expected waiting times for connecting routes.

Solutions for improving fare control are often expensive. Increasing the public transportation space to allow for more free transfers would be costly in terms of construction and revenue loss. Proof-of-payment systems are effective in many European systems, eliminating the need for fare control, but most U.S. agencies have invested in fare control systems, and not using them would be a waste of investment. Fare control wouldn't need to be addressed if there are no transfer facilities with transfer volumes high enough to justify the expensive infrastructure changes or if the current fare collection system is performing well.

Once system elements with the potential for improvement have been selected, they will be prioritized according to the cost-effectiveness of their improvements. In this chapter, it will be assumed that all elements have the potential for improvement, for the purpose of addressing all of them. However, this won't be the case for most applications of this process, given that some agencies may already perform at the best level for certain elements or certain improvements may not be justified, if there are a small number of beneficiaries or if a particular improvement would be too expensive for their system. Table 3-6 shows the relative costs of different system improvements, as suggested in the previous paragraphs. Three dollar signs symbolize improvements that are relatively expensive, while those elements with only one dollar sign are considered relatively inexpensive. The purpose of this chart is to rank elements by their cost-effectiveness. The determination of the costs of different improvements may be more detailed when applying this process to a real agency, and this may result in a different cost-effectiveness ranking.

Table 3-6 Relative Costs of Different System Improvements

Transfer Price	$$$
Pre-Trip Information	$
Fare Media	$
In-vehicle Information	$$
Fare Control	$$$

Table 3-6 leads to the following ranking of cost-effectiveness for system elements:

Pre-trip Information
Fare Media
Transfer Price
In-vehicle Information
Fare Control

3.3.2 Facility Element Tailoring

Given the relatively low costs of weather protection improvements and their relatively high benefits to passengers, even transfer facilities with relatively small volumes could be candidates for improvements, as shown in Table 3-7. The bus shelters should be able to pay for themselves in 1 year and the covered walkways to pay for themselves in two years. The time periods are relatively short because there is often a concern that bus shelters and any on-street infrastructure will get destroyed or vandalized. According to the study "The Role of Passenger Concessions and Transit Vehicle Characteristics in Building Ridership" (TCRP, 1998), bus shelters cost approximately $1000 for a simple model and $5000 for a fancier one. The cost of the covered walkway cannot be determined because it often depends on the situation at a particular transfer facility, but an attempt has been made to provide a figure that is the correct order of magnitude. Similarly, the cost of a fully-enclosed walkway is highly dependent on the situation, but in general, it would be an expensive improvement, and each enclosure would cost approximately $2 million dollars. However, because of the greater investment, it is likely that the enclosure would last longer than a bus shelter or covered walkway, the cost of the enclosure can be spread over more years.

The Transit Station Renovation and Pedestrian Walkway Survey suggests that a basic shelter is worth 2.5 cents per trip. A fancier bus shelter is likely to be worth 3 cents, based on the relative values of a basic shelter and a fancy shelter as described in the Interchange Study. Horowitz suggests that a covered vehicle-to-vehicle connection is worth 16 minutes of in-vehicle time, which would be equivalent to about $1.60, but to be very conservative and to keep the values somewhat in line with the other values, a covered walkway will be valued at 10 cents per trip. Fully enclosed platforms are valued twice as highly as the covered walkway because they prevent the exposure of passengers to any of the elements.

These calculations find usage standards for facilities, regardless of whether the users are transferring or non-transferring passengers. If total boardings are known at a particular transfer point, this can be used to determine whether or not a transfer point is a candidate for a weather protection improvement. If only transfer volumes are known, then a factor can be chosen to relate transfer volumes to total boardings. If two is chosen as the factor, then if a particular facility had a volume of 70 or more transferring passengers per day, it could be assumed that more than 140 passengers use that shelter every day. As a result, it is a candidate for a simple bus shelter, as suggested in Table 3-7.

Table 3-7 Candidate Transfer Points for Weather Protection Improvements

Item	Value per trip	Cost	Payback Time	Minimum number of people needed to justify per day
Simple Bus Shelter	2.5 cents	$1000	1 year	140
Fancy Bus Shelter	3 cents	$5000	1 year	560
Covered Walkway	10 cents	$100,000	2 years	1680
Enclosed Walkway	20 cents	$2,000,000	3 years	11,100

Table 3-8 shows how much use a particular transfer facility should get for it to be considered as a candidate for en-route information improvements. The value of three cents for the printed timetable comes from the Interchange Study, which shows that printed timetables are valued a bit more than a basic shelter, which was determined to be valued at 2.5 cents in the Transit Station Renovation and Pedestrian Walkway Survey. In the Interchange Study, signs have approximately the same value as schedules, as does real-time information and system maps, so all of these en-route information forms are assumed to have the same value per trip. Therefore, if all of these items were added to a transfer facility that currently had no en-route information, there would be approximately 12 cents in benefits for every passenger using that facility. It is important to note that not all passengers will value each item of information uniformly. For example, a commuter who uses a given transfer point regularly will become familiar with the schedule and will not value the posted timetable. However, a passenger unfamiliar with the transfer point will not be aware of the schedules and will benefit from having them posted. It will be assumed that only half of all passengers will find the maps, schedules, or facility signage useful and receive benefits from their presence. Because it may change from day to day, real-time information has the potential to benefit all passengers.

The cost of printed schedules and system maps should be fairly low for a basic bus stop. Based on a recent project to display schedules along a bus route through Cambridge and Boston, the cost per schedule display was about $150 per unit, including the material and labor costs (Barr, 2002). Assuming that quarterly schedule updates would be necessary to keep the information up-to-date, the additional labor costs might be $20 every three months. This would make the cost of displaying a schedule $210 per year. Presumably, the cost of displaying a system map would be approximately the same. Real-time arrival displays are more expensive, but if installed at many points in the system, the unit cost might be approximately $6000. This figure is based on estimates from Tri-Met. As part of their Intelligent Transportation System Plan, they are installing Transit Trackers at rail platforms, along the downtown Portland bus mall, at transit centers, in high-capacity bus shelters, and at many bus stops. The cost of the project is approximately $2.5 million over five years, and the number of units they are aiming to install is 390 (Tri-Met, 2001). This figure can only serve as a guide for estimating the cost of other real-time information projects if there are a high enough number of displays being considered, as there are likely to be economies of scale for such a project. It can also be assumed that this is only the cost of the equipment and its installation – the system will have to have an AVI system for the real-time information displays to work. The cost of signage depends on the complexity of the facility, but $1000 is chosen as an approximation. Signs cost approximately $200 apiece (Barr, 2002), and a transfer facility may need on average five signs. As with weather protection, en-route information benefits transferring as well as non-transferring passengers, so total boardings at a transfer facility should determine whether or not the improvements can be justified.

Table 3-8 Candidate Transfer Points for En-route Information

Item	Value per trip	Cost	Payback Time	Minimum number of people needed to justify per day
Printed Timetable	3 cents	$210	1 year	21
System Map	3 cents	$210	1 year	21
Real-time Arrival Information	3 cents	$6000	1 year	560
Facility Information	3 cents	$1000	1 year	90

Given the costs of escalators and their benefits to passengers, a much smaller number of transfer facilities will be candidates for escalators than weather protection or en-route information, as shown in Table 3-9. The value of 2 cents is an approximation from the Transit Station Renovation and Pedestrian Walkway Survey. An escalator is a more permanent addition to a facility than information, so its payback time is longer than that given to the en-route information or most of the weather protection improvements.

Table 3-9 Candidate Transfer Points for Escalators

Item	Value per trip	Cost	Payback Time	Minimum number of people needed to justify per day
One escalator	2 cents	$1 million	3 years	55,600

The benefit of improved road crossings is estimated to be 2 cents per trip. This is an estimate based on the ordering of importance of different elements as explained in Chapter 2, and since changing levels and road crossings are ordered next to each other, they should provide similar benefits per passengers. These improvements are shown in Table 3-10.

Table 3-10 Candidate Transfer Points for Better Road Crossings

	Value per trip	Cost	Payback Time	Minimum number of people needed to justify per day
Off-street bus depot	2 cents	$1 million	3 years	55,600
Improved Crosswalks	2 cents	$100,000	3 years	5,560

The cost of changing the walking distance can vary greatly from transfer facility to transfer facility, so it is difficult to place a numerical value on it. In general, it will be very expensive for a given transit agency, and the benefits per trip might be based on the time savings. If the value of time is estimated to be $0.10 per minute, then if 30 seconds were eliminated from the transfer time due to modifications to the transfer facility, then this would be the equivalent of a benefit of 5 cents per trip.

Concessions essentially cost the transit agency nothing, so if there are any concessions that can be brought to a transfer facility, it is likely that the benefits to passengers will outweigh the costs to the agency. Concessions may also bring an agency additional revenue.

The approximate costs of different element improvements are shown in Table 3-11.

Table 3-11 Relative Cost of Different Facility Improvements

Weather Protection	$$
En-route Information	$
Changing Levels	$$$
Road Crossings	$$
Walking Distance	$$$
Concessions	$

Table 3-11 leads to the following ranking of cost-effectiveness for system elements:

En-route Information
Weather Protection
Concessions
Road Crossings
Changing Levels
Walking Distance

3.3.3 Service Element Tailoring

There are many inexpensive opportunities for improving transfer waiting time, so potential improvements to this element should be explored. The improvements might include things like changing the arrival and departure times of vehicles and modifying the recovery times to reduce the transfer waiting time at a particular transfer facility. It might also be the application of different control strategies that better serve transferring passengers.

Reducing transfer waiting time will not necessarily be expensive because it can be achieved by modifying services that already exist. Increasing the span of service of the connections will cost more money because it requires the agency to operate more trips (assuming that the frequencies will remain the same) and to pay employees for more hours of work. It should only be considered if it is expected that enough passengers will make use of the extra service to justify the additional cost and if the service extensions comply with the service standards. The relative costs of transfer waiting time and span of service improvements are shown in Table 3-12.

Table 3-12 Relative Costs of Service Element Improvements

Transfer Waiting Time	$
Span of Service	$$

3.4 Consider Improvements

This section will consider the elements that have been prioritized for improvement in the previous section and examine their costs and benefits in more detail. The major purpose of this section is to identify the improvements that might be carried out at an agency.

3.4.1 System Improvements

Regardless of the current status of pre-trip information in a system, it is always worthwhile to provide all of the basic components of high quality pre-trip information – a system map, a website with a trip planner, and a customer service telephone number. The improvements and their effects on the agency and passengers are shown in Table 3-13.

Table 3-13 Improvements to Pre-trip Information

Improvements	Strategies	Agency Effects	Passenger Effects
System Information to System Information with Trip Planner	Add trip planner feature to website and phone service	Cost of program design and maintenance	Better trip planning ability Faster access to information
Route Information to System Information	Create and distribute system maps, build an informative website, and provide customer services by phone	Cost of map-creation and printing Cost of website design, maintenance, and construction Cost of phone service staffing	Better trip planning ability
No Information to Route Information	Create and distribute route Information	Cost of schedule-creation and printing	Better trip planning ability

The potential improvement to fare media is given in Table 3-14. Being able to use the same fare medium on different services and modes will make transferring faster and more convenient for passengers. To decide whether or not a change in the fare media is necessary requires the consideration of many things. One of the fare media has to conform to the other, and this change might require a change in fare collection equipment or fare structure for one of the agencies. Giving an agency an incentive to change its fare collection system may be necessary, as changing its fare medium may not bring it any direct financial gain. All of these considerations make the use of smartcard technology an attractive solution to the problem of multiple fare cards, as smartcards are very flexible and relatively inexpensive to produce.

Table 3-14 Improvements to Fare Media

Improvements	Strategies	Agency Effects	Passenger Effects
Different to Same	Have a single fare medium for all services operated by Agency A Have a single fare medium for services operated by Agency A and Agency B	Cost of additional or replacement fare control equipment Cost of changing fare structure	Shorter transfer time

The potential transfer price improvements are shown in Table 3-15. To determine whether or not to undertake a given improvement in terms of the transfer price, an agency would have to determine whether or not it could afford the loss in revenue, even if more riders started to transfer. Another consideration is whether or not the loss of revenue can be compensated for, in some way. If there is going to be a fare increase at the same time as the removal of the transfer fare, then the agency might not lose revenue. However, the passengers would benefit directly from reduced transfer fares. Free transfers could speed boarding and lead to travel time savings. There is also the benefit that a transfer price change would make the fare policy more consistent throughout the system, and this has the benefit of making the system easier to understand.

Table 3-15 Transfer Price Improvements

Improvements	Strategies	Agency Effects	Passenger Effects
Discount to Free	Provide or reduce the cost of unlimited ride passes Make all transfers to mode A free Make all transfers to agency B free	Loss of revenue; amount depends on the number of transfers affected Revenue from additional passengers	Greater financial incentive to transfer May speed boarding System consistency
Full Additional Fare to Discount	Reduce fare for those who show a proof of purchase Discount all transfers to Agency C	Loss of revenue; amount depends on discount selected and the number of transfers affected Revenue from additional passengers	Greater financial incentive to transfer System consistency

The loss of revenue can be determined by multiplying the number of people making a particular transfer by the amount that the transfer price is going to be reduced. The cost reduction may not apply to passengers who travel on unlimited ride cards. The revenue earned by additional transferring passengers might make up for a portion of the revenue losses. When the cost of travel goes down, travel demand generally rises. For public transportation, the elasticity is typically about –0.4 (Victoria Transport Institute, 2002). This means that if there is a 10% reduction in the price of a trip, there would be a 4% increase in demand. That is, if the total price of a trip was \$2.00 and 1000 people were making this trip, and then the price dropped to \$1.75 as a result of eliminating the cost of a transfer, and there would be about 50 additional people who would make that transfer. The original revenue would be \$2000, and the resulting revenue would be \$1837.50.

Table 3-16 shows some of the in-vehicle information improvements that can be made. Installing an announcement system may be a requirement for ADA compliance, and so adding announcements for transfers shouldn't be a major additional cost, but it probably couldn't be justified for the sake of improving connectivity alone, given the costs. To keep costs down but still provide passengers with the same benefits, drivers would ideally announce the transfers. Distributing schedules for the routes that passengers connect to is an easy way of providing information to riding customers, and it is in the category of improvements that should be pursued. Improved in-vehicle information will be particularly valued on routes that carry a lot of tourists or infrequent riders. Real-time information about connecting routes would also be valuable to transferring passengers.

Table 3-16 In-vehicle Information Improvements

Improvement	Strategy	Agency Effects	Passenger Effects
Real-time Information	Provide real-time information displays in vehicles	Display costs Operation costs	More information
Connecting Route Information	Put connecting route schedules or system maps in vehicles	Printing Schedule delivery	More information
Transfer Announcements	Install an announcement system Require drivers to announce transfer	Installation Training	More information

The potential improvements to fare control are given in Table 3-17. Many of the issues related to fare control could be avoided if an agency relied on proof-of-payment, but many agencies are hesitant to do this because of the fear of fare evasion or because they have already invested a lot of money in the fare collection equipment. Taking advantage of smartcard technology, which reduces the hassle of negotiating a fare control system, is another option that agencies should strongly consider.

Table 3-17 Improvements to Fare Control

Improvements	Strategies	Agency Effects	Passenger Effects
No Validation Required if Remain in Public Transportation Space to No Validation Required and Can Leave Public Transportation Space	Move to a proof-of-payment system		Convenience Shorter Travel Times
Validation Needed, but Adds no Delay to Trip to No Validation Needed if Remain in Public Transportation Space	Increase public transportation space	Cost of station remodel	Convenience Shorter Travel Times
Validation Adds Delay to Trip to Validation Needed, but No Delay Added to Trip	Use Smartcards	Cost of new fare collection equipment Shorter running times	Faster boarding times Convenience

When deciding among the different options for improving system elements, an agency should keep in mind that the benefits are going to reach many people, and no passengers are going to be harmed by the improvements, at least directly. The improvements to system elements have to be thought about together, as they are tightly related. Most of the elements are related to fare – its cost, how it is paid, how people find out about it, and how it affects the physical nature of the transfer. Changing one element often has consequences for the other elements. For example, removing a fare barrier implies free transfers, no need for a second fare medium, and changing the information that passengers will receive about transferring in the system.

3.4.2 Facility Improvements

The purpose of this step is to consider those improvements that would affect transfer facilities. The improvements will benefit all or a large fraction of passengers passing through a particular transfer point, and so the major questions an agency has to answer are how many transfer points should be improved and what should be the extent of the improvements at each transfer facility.

Improvements to en-route information are described in Table 3-18 for a hypothetical transit authority. Providing real-time arrival information at a transfer facility, where there currently isn't any, is clearly the most ambitious of all of the strategies, and given the importance passengers place on knowing when the next vehicle will arrive, the benefits of this improvement are likely to exceed the costs at some of the more heavily used transfer points. Because it is assumed that only half of all transferring passengers will make use of the posted schedule map, the benefits are half of what they are for the real-time information. To save costs, multiple improvements could be undertaken at a time. The values in the chart suggest that if a particular transfer facility is provided with real-time arrival information and system information, there would be a benefit of 4.5 cents per trip.

Table 3-18 En-Route Information Improvements

Improvement	Strategy	Agency Effects	Passenger Effects
Achieve Best Level	Provide real-time arrival displays at 36 transfer facilities	Approximately $6000 per unit, 4 units per transfer facility $864,000 annual costs	Approximately 3 cents per trip, 100 million trips per year $3 million annual benefits
Achieve Mid Level (A)	Provide system information at 300 transfer facilities	Approximately $210 per unit, 4 units per transfer facility $252,000 annual costs	Approximately 3 cents per trip, 100 million trips per year $1.5 million annual benefits

Improvements to weather protection at a hypothetical transit authority are listed in Table 3-19. To improve weather protection, an agency could construct fully-enclosed transfer environments, install covered walkways, or install shelters at the waiting area. Construction of fully covered transfer walkways might be justified at transfer points where there are high volumes of transferring passengers. Covered but unenclosed walkways might also be justified at transfer points that have significant transfer volumes. Building shelters is relatively inexpensive, and given that the benefits accrue quickly, especially on rainy days, shelters could be justified at transfer points with only modest transfer volumes. Using the guidelines suggested in the tailoring section, an agency should be able to determine how many of its transfer facilities are candidates for each type of improvement, and this will allow them to seek an appropriate amount of money to make those improvements. Even if it can't get money to cover all of the cost-effective projects, it can still bring the improvements to the facilities where they will bring the most benefits. The costs and benefits suggest that at a transfer point that gets 1000 users per day going in one direction, the costs of a basic shelter could be matched by its benefits in 40 days. It would take 40 days to offset the costs of a fancy shelter at a transfer spot that receives 5000 users per day.

Table 3-19 Improvements to Weather Protection Between Services

Improvements	Strategies	Agency Effects	Passenger Effects
Open Area to Covered Waiting Area Only	Build basic shelter at 250 transfer points	About $1000 for a basic shelter, 2 per transfer point $500,000 annual costs	Approximately 2.5 cents per trip, 24 million trips per year $600,000 annual benefits
Open Area to Covered Waiting Area Only	Build fancy shelter at 10 transfer points	About $5000 for a basic shelter, 1 per transfer point $50,000 annual costs	Approximately 3 cents per trip, 2 million trips $60,000 annual benefits
Open Area to Covered Walkway	Build covered walkway at 5 transfer points	About $100,000 per walkway, over two years $250,000 annual costs	Approximately 10 cents per trip, 3 million trips $300,000 annual benefits

The improvements that could be made for changing levels are described in Table 3-20. The table shows that there are several potential strategies for bringing about this improvement, but the most obvious one is the construction of an escalator at transfer points where transferring passengers have to walk up stairs. For ADA compliance, the mechanism of this assistance might have to be an elevator, given that using escalators is difficult for passengers in wheelchairs. A ramp is an option at some stations, but this often takes up too much space and may make the movement between vehicles too circuitous.

Table 3-20 Changing Levels Improvements

Improvement	Strategy	Agency Effects	Passenger Effects
Vertical Separation without Assistance to Vertical Assistance	Build an escalator, elevator, or ramp . . . at 2 transfer points	Approximately $1 million per station, over three years $666,700 annual costs	Approximately 2 cents per trip, 34 million trips per year $680,000 annual benefits

Road crossing improvements are shown in Table 3-21. Eliminating the road crossing has the benefit of improving the safety of a transfer, but it may be expensive to find the space to build off-street transfer facilities. Furthermore, a new transfer facility might increase running time, which would lead to additional operations costs. The street could also be reconfigured to improve the safety of the crossing, and such an improvement might fall under the jurisdiction of a public works agency.

Table 3-21 Road Crossing Improvements

Improvement	Strategy	Agency Effects	Passenger Effects
Road Crossings Required, but Assisted, to No Road Crossings Required	Build off-street transfer facilities Build underpass or overpass Build additional station entrance . . . at 3 transfer points	Land Acquisition, Construction. And Longer Travel Times $1 million per transfer point, over 3 years $333,000 annual costs	Safety, more weather protection Approximately 2 cents per trip, 60 million trips per year $1.2 million annual benefit
Unassisted Road Crossings to Assisted Road Crossings	Add a crosswalk Add a signal . . . at 3 transfer points	Approximately $100,000, over 3 years $33,000 annual costs	Safety Approximately 2 cents per trip, 60 million trips per year $1.2 million annual benefit

Walking distance improvements are shown in Table 3-22. Improvements to minimize walking distance have the potential of being quite expensive, given that they might require that the alignment of a route be changed. For a bus route, this may not be a problem, but for a subway line, such an improvement would be prohibitively expensive and disruptive to a downtown area. In some circumstances, the walking distance can be reduced by moving a far-side stop to a near-side stop, or vice versa, allowing a transfer to be made on a single street corner.

Table 3-22 Walking Distance Improvements

Improvement	Strategy	Agency Effects	Passenger Effects
Short Walk Required to No Walking Required	Change alignment at one transfer point	Construction Increased running time Approximately $3 million, over 10 years $300,000 annual cost	Travel time savings for 800,000 trips per year@ 30 seconds per trip $400,000 annual benefit

Table 3-23 shows the passenger and agency effects of several improvements that can be made to the concessions element. There are several benefits in addition to customer satisfaction that these concessions can bring, such as greater security in the station area and rent revenue for the transit agency. It must be noted that businesses will only locate at transit stations if they feel there is a good chance of having a profitable enterprise.

Table 3-23 Concessions Improvements

Improvement	Strategy	Agency Effects	Passenger Effects
Small Selection to Large Selection	Provide space for many more vendors at 2 transfer points	Rent revenue	Security Convenience Approximately 1 cent per trip, 3 million trips per year $30,000
No Selection to Small Selection	Provide space for a vendor at 12 transfer points	Rent revenue	Security Convenience Approximately 1 cent per trip, 4 million trips per year $40,000

The benefits of facility improvements are large, and improvements can be experienced day after day and generally don't come at the expense of other passengers. This suggests that the agency should try to improve as many of its facilities to as high a level as it can. However, attaining the highest quality level at every facility is not always crucial because mid levels will be highly valued in some cases. The needs of transferring passengers should be considered in facility design guidelines.

A summary of the results of considering improvements at individual transfer facilities is shown in the next few figures. More costly improvements are shown in Figure 3-2, and the less costly improvements are shown in Figure 3-3. Generally, the improvements that are the least costly and which produce a significant amount of benefits should be a priority for the agency. Therefore, for this hypothetical transit authority, en-route information improvements should be the first priority, as well getting more concessions. The next priority should be weather protection improvements. The improvements should be applied at those transit facilities where they will have the largest impact first.

Figure 3-2 Costs and Benefits of Individual Facility Improvements – Hypothetical Transit Authority (Major Cost Improvements)

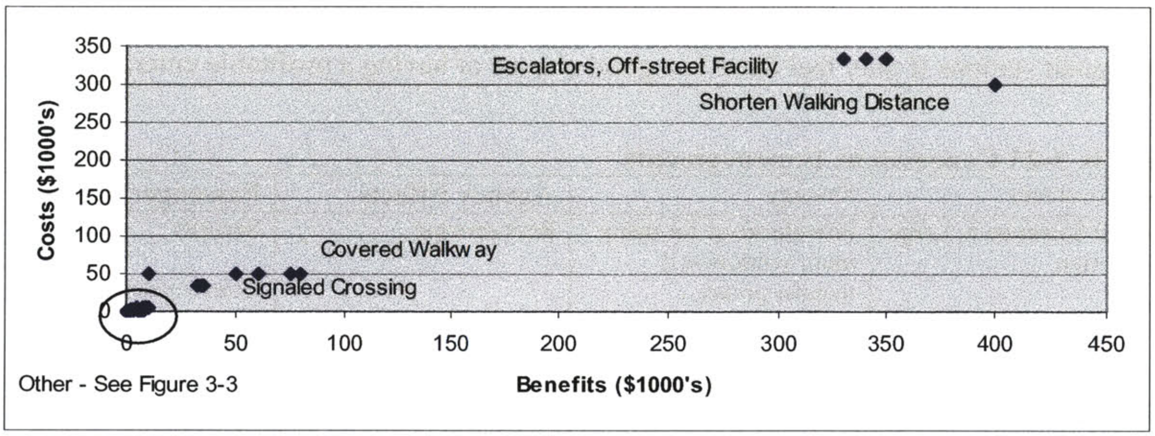
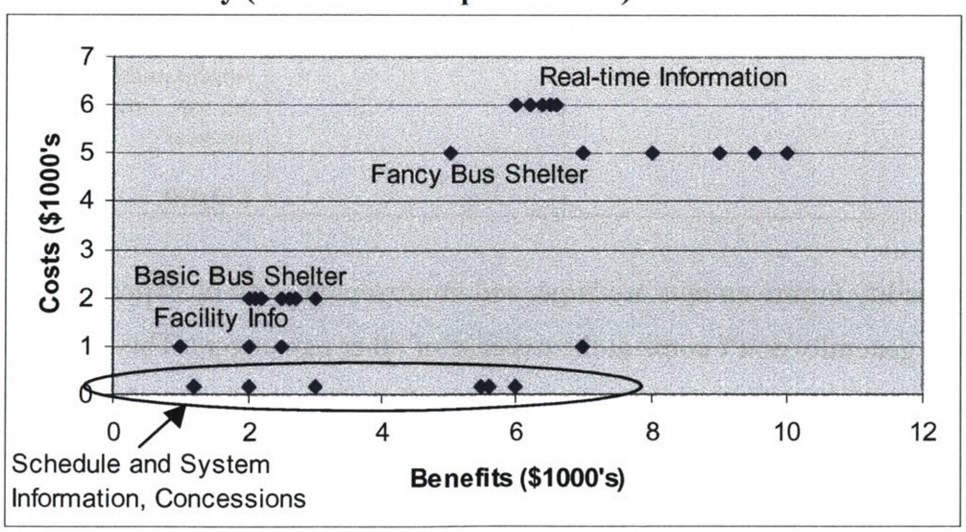
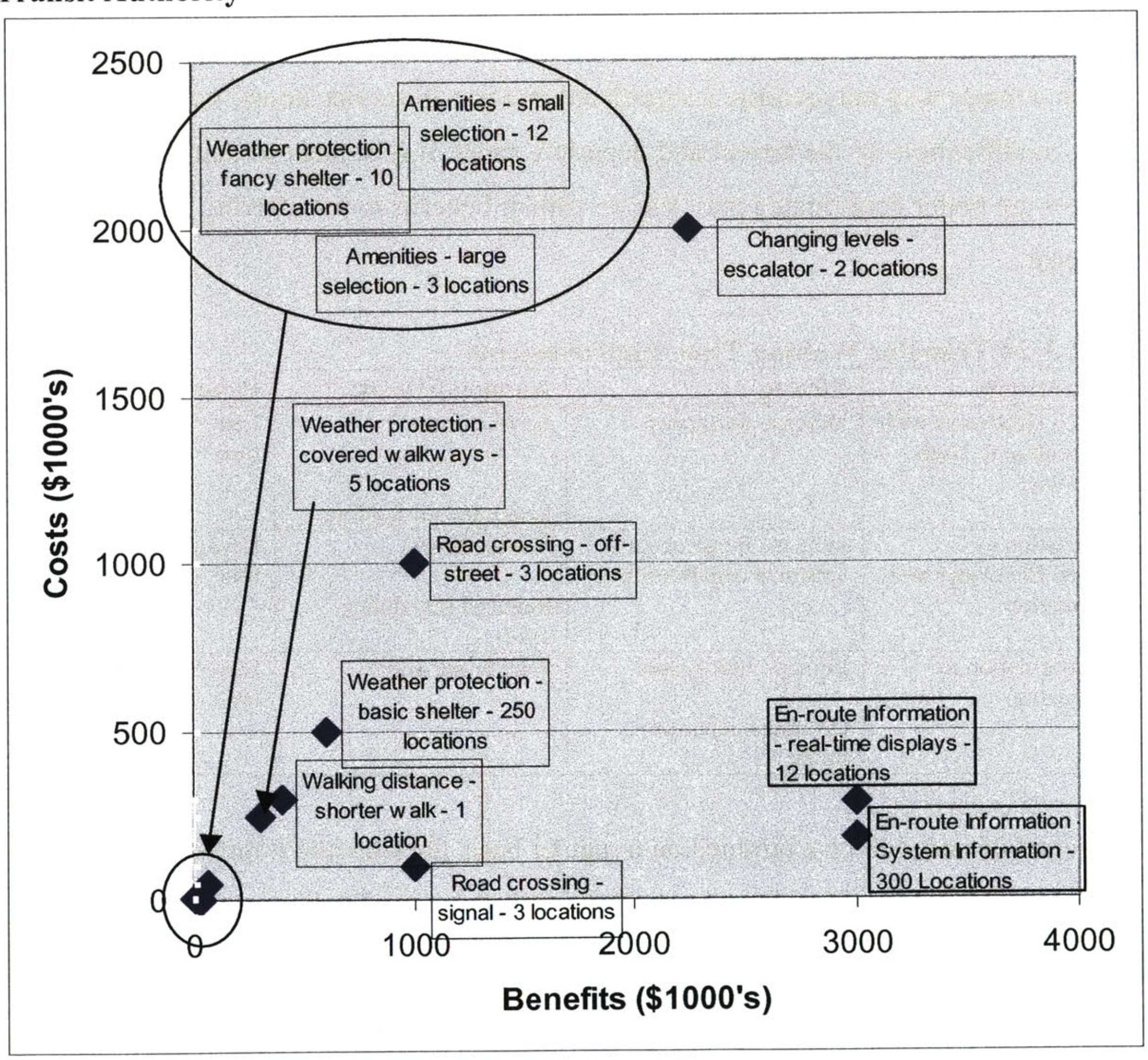


Figure 3-3 Costs and Benefits of Individual Facility Improvements – Hypothetical Transit Authority (Minor Cost Improvements)



Figures 3-4 shows the costs and benefits of collective facility improvements. This chart is potentially more realistic because it would be unlikely for an agency to make connectivity improvements one at a time. There are economies of scale in doing multiple improvements at once. In general, an agency would consider inexpensive improvements before the expensive improvements and the more beneficial projects before the less beneficial ones. Thus, projects to provide real-time and system information are the most attractive, followed by either the escalator project or the traffic signal project.

Figure 3-4 Costs and Benefits of Collective Facility Improvements – Hypothetical Transit Authority



3.4.3 Service Improvements

The purpose of this step is to consider improvements to the services that operate at the transfer points. The services affect how long passengers have to wait at a transfer point and the times of day during which a particular connection is available. Services are driven by the schedules, but service management also affects them. Services vary by transfer point and by time of day, and so improvements have to be tailored to individual transfer points, time periods, and in some cases, to individual trips.

Transfer waiting time improvements are shown in Table 3-24. Reducing transfer waiting time in a major way may require a significant increase in service hours, but in some cases, modifications to the arrival and departure times of schedules so that connecting services are better coordinated may lead to similar benefits to transferring passengers at little cost.

Table 3-24 Transfer Waiting Time Improvements

Improvement	Strategy	Agency Effects	Passenger Effects
Matched Headways with Coordination to High Frequencies	Increase frequency	Service hours Less need for holding	Less passenger waiting time
Coordination to Matched Headways and Coordination	Increase frequency and optimize departure times	Service hours Reduced scheduling effort	Less passenger waiting time
No Coordination to Coordination	Remove just misses Optimize departure times	Scheduling effort	Less passenger waiting time

The schedules need to be examined on a regular basis for schedule improvement opportunities, and service managers must play a large part in making sure that transfer waiting times are short, or at least not excessive. The best transfers are those that involve transferring to a route operating at a high frequency. To ensure the best quality transfers to such a route, the headways should be evenly spaced to reduce overcrowding. Additional consideration has to be given when two high-frequency routes intersect, because it is likely that there will be a high demand for transfers between them. Ideally, the departures of such routes from the transfer facility would be staggered to eliminate just misses, minimize the maximum wait time, and avoid excessive wait times. When two heavily loaded vehicles arrive at approximately the same time, there may be excessive dwell times as a result of congestion in the transfer facility, and this will harm operation on both routes.

The next best level is having connecting routes operating on identical headways. It is not as good as transferring to a high frequency route because if the first vehicle is delayed, the second vehicle might leave without the transferring passengers, and then these passengers may not have an optimal connection. However, when headways are matched, vehicles can be scheduled to arrive at approximately the same time in order to minimize transfer waiting time. It also makes the schedules easier to remember for passengers. To support transfers between routes with matched headways, service managers should consider single- or double-holding. With single-holding, vehicles on one of the routes might be held until transferring passengers arrive. With double-holding, the first vehicle to arrive waits until the second vehicle arrives, and both leave when transfers in both directions have occurred. Whether to use single-holding or double-holding depends on flow of transferring passengers. When there is a dominant direction of transfers, or the load on the first vehicle is high, then there should only be single-holding. However, when there are significant flows in both directions and the transferring passengers make up a large proportion of the routes' ridership, double-holding should be considered. Knowing the location of the next connecting vehicle through an AVL system would be useful for improving the holding decisions, particularly in circumstances where there are major delays on one of the routes.

However, headways cannot always be matched for connecting routes. There are a limited number of vehicles available for service, and it is difficult to justify increasing service when insufficient demand exists. An alternative is to coordinate the arrival and departure times such that the amount of time that passengers have to wait at a transfer facility is reduced. Schedulers can coordinate routes by listing the times that connecting vehicles arrive and depart from a transfer point. These times will give an indication of how long a passenger would have to wait for a particular transfer if he arrived on a particular vehicle. Doing such an analysis leads to the identification of waiting times that are unnecessarily long. To reduce the long waiting times, departure times from the terminals can be adjusted. This is usually feasible because there is flexibility in the layover time. Supporting such scheduling efforts requires that vehicles do not depart just before another vehicle with transferring passengers arrives, thus incurring just misses. Bus holding lights or supervision can also play an important role in ensuring that just misses are avoided. By notifying drivers that transferring passengers will be arriving soon, they will know not to depart and strand transferring passengers.

When connecting routes are operated by different agencies, there are additional considerations needed for the schedule coordination process. Coordination can be done unilaterally or bilaterally, and getting access to the most current schedules is important. The Metropolitan Transportation Commission sponsored a study in the late 80's on the schedule coordination of multiple transit agencies in the San Francisco Bay Area (MTC, 1988). This study assumed that improvements had to be made such that no additional service hours would be required, given the limited funding available for public transportation. It also did not consider route changes or extensions as strategies for improving interoperator schedule coordination. It considered a scheduled waiting time of 5-9 minutes as ideal, as it allowed for some variance in the actual arrival time but did not produce excessive waiting times. The studied looked in depth at 20 Transfer Point Locations and found that the scheduled waiting time could be significantly reduced through modifications to the schedules.

Achieving the best level, or even the next best level, for every transfer in the system will not be possible, given that services cannot always operate at high frequencies, given limited resources. Nor can services always operate exactly according to the schedule. Nor can every transfer service be optimally coordinated, given the coordination constraints of other transfers. The best approach to service improvements is to take improvement opportunities when there are few if any obstacles. Such improvements are of the type when departure times can be adjusted to reduce overall waiting time.

A question that has to be considered is whether schedule improvements are made by computer or by hand. An advantage to building the schedules with the aid of a computer program is that the connections might be more sustainable – that is, if one schedule changes, then there will be some indication that other schedules may have to be modified, too. Computer scheduling might also save time and have fewer mistakes. On the other hand, computer scheduling may put some constraints on the connections that can be planned. If the time points used in the scheduling program are not the transfer points, then this may make connection scheduling difficult. Learning how to use the computer program may also require more time that it would take to change the schedules by hand.

Table 3-25 shows the major service improvement of making more connections available. This can be achieved by extending the span of service on routes that passengers transfer to or from so that trips that require a transfer can be made at more hours of the day. Increasing the span of service is an option that will cost the agency money, but which will not hurt any passengers.

Table 3-25 Span of Service Improvements

Improvement	Strategy	Agency Effects	Passenger Effects
Unmatched to Matched	Increase Span of Service	Service Hours More passengers	More trips available

To help sustain improvements, changes could be made to the service design standards so that all future schedules are made with transferring passengers in mind. This would ensure that service connectivity continues to be an important part of the services that a transit agency provides. A possible standard might be lower load requirements if it means matching the headways of two routes, or allowing more flexibility in the standard recovery time if it allows for a better connection to be made. However, better service connectivity does not necessarily need more service – it also benefits from the simple modification of arrival and departure times, and these times should be inspected for the major transfer points to make sure there are no transfers that will be especially bad. The schedules could be written such that none of the scheduled waiting times are greater than half a headway.

3.5 Cross-area Prioritization

Once the top improvement options within each of the areas are identified as a result of considering their costs and benefits, both as individual improvements and as collective improvements, priorities have to be made across the areas. System improvements have the advantage that they have the potential to improve the transferring situation for many people. On the other hand, they have a great potential of being unaffordable to an agency, especially a reduction in price. Agencies should also consider the speed at which the improvements could be attained. Schedule improvements could potentially be realized quickly, and this might suggest that they be addressed before facility and system improvements, which will take much longer to plan and implement. Another important consideration for the prioritization across areas is whether or not there are windows of opportunities that the agency should be taking advantage of before they close.

There will not be conflict between some of the elements. In most U.S. agencies, no revenue goes towards capital improvements, and so the transfer fare price will not be in competition with any of the facility improvements. However, transfer price might be in competition with the amount of service that is provided. If an agency is trying to choose between improving service or reducing the transfer fare, they could calculate the amount of time that would be saved as a result of a given improvement, convert this to dollars (generally the conversion rate is about $0.10 per minute), and costs and benefits per day could be compared.

In general, service improvements will have the highest priority because they have the potential to bring the most benefits, at the least cost, and in the least amount of time. Agencies generally have the capability to reduce transfer waiting time but are not placing priority on this because of other pressing demands. An additional benefit of service improvements is that passengers can experience them almost immediately.

To get a sense of how the benefits of the different improvements compare with each other, the following situation can serve as an example. Suppose that the transfer waiting time of the 400,000 bus-rail and rail-bus transfers is reduced by one minute. Then assuming that there is a value of time of approximately 10 cents per minute, this amounts to passenger benefits of $40,000 per day. This is the equivalent to the cost of eight fancy bus shelters. And if the agency were considering making their bus-rail transfers free, this would lead to revenue losses of $200,000 per day, assuming the fare was a dollar. In this example, the service improvements appear much more attractive than either the facility or system element improvements. Even though passengers would benefit from the fare reduction, the transit agency might not be able to afford the cost. On the other hand, the $40,000 in passenger benefits could be provided to passengers at no cost to the agency apart from schedule production costs.

3.6 Monitoring Plan

The purpose of this step is to establish a monitoring plan for determining whether improvements are leading to higher levels of customer satisfaction and a greater willingness to transfer. Transfer volumes should be monitored at transfer points affected by system, facility, or service improvements. Monitoring can be done most easily if transfer volumes are collected automatically from AFC data. If an agency cannot gather adequate transfer volumes from AFC data, then passengers can be surveyed on their transit usage. If the number of people making transfers is increasing, this might suggest that the connectivity improvements were successful and they should be carried out at more locations. Customer satisfaction surveys should also follow connectivity improvements to find out if and how passengers are benefiting from them. This information can be used to improve the process by adding more importance to those improvements that have lead to improvements in customer satisfaction and trip-making and reducing the importance of improvements that don't increase customer satisfaction or trip-making as much. If available, AVL data could also be used to determine how closely the schedules are being met and how long passengers are really waiting for their transfers.

Chapter 4. Application of Process to Chicago Transit Authority

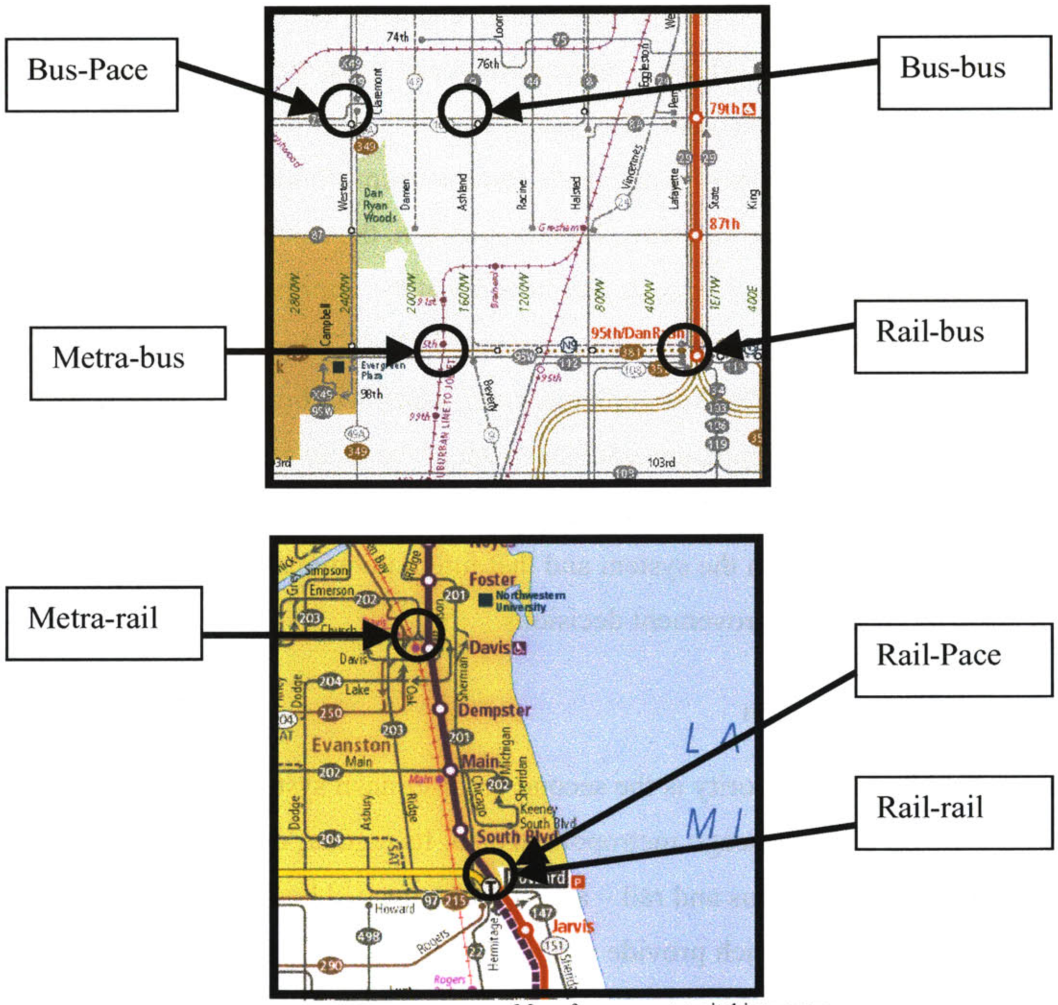
This chapter applies the process described in Chapter 3 to the Chicago Transit Authority – the third objective of this research. The purpose is to recommend strategies the CTA can use to improve connectivity in its system such that customer satisfaction will improve, more passengers will be willing to transfer, and system efficiency can be improved. A system boundary is established, and connectivity within this system boundary is assessed. Based on this assessment, elements will be divided into those that have the potential for cost-effective improvement and those that do not. Those that do are then considered for improvement. For system elements, improvements to specific transfer types are considered. For facility elements, improvements to individual transfer facilities are considered. For service elements, improvements to the connection between specific route-pairs are considered. The costs and benefits of the improvements are estimated and discussed so the different options can be compared. The CTA should be able to select those options that it can afford to implement and which will bring the most benefits in each area. Then the top improvements from each of the areas are compared and prioritized, and finally, a monitoring plan is established to make sure that connectivity continues to be assessed in the system and that future iterations of the process provide a good basis for further improvement decisions.

4.1 System Description

The Chicago Transit Authority is the second largest transit system in the United States serving the core of the Chicago metropolitan area. Its regular, directly operated service consists of two modes – bus and rail – and is supplemented by Pace bus and Metra commuter rail, both of which provide service within CTA's service area.

As shown in Figure 4-1, there are many different types of transfers in the CTA system. There are close to 400 bus-bus transfer points in the system that each handle more than 50 transferring passengers per day. These typically occur at the intersections of the major streets along which the buses operate. There are also many rail-bus transfers, which is unsurprising given that more than 90% of the 143 CTA rail stations have connecting bus service. Similarly, Metra has many stations in non-CBD neighborhoods where transfers can be made to the CTA network, and Pace buses operate out of many CTA rail stations. There are also many rail-rail transfers that occur in the downtown area and in the North, where the Purple, Yellow, and Brown Lines meet the Red Line. Transferring is spread throughout the city, although the highest concentrations of transfers are in the downtown area and at rail stations.

Figure 4-1 Some Typical Transfers in the CTA



Maps from www.transitchicago.com

More than 50% of CTA passengers transfer during their typical trip, as shown in Table 4-1, so CTA's ridership depends heavily on connecting services. The CTA is undergoing physical changes as a result of a major capital improvement program, and with an ever-expanding set of technologies available for the improvement of customer service, the CTA is in a strategic position to greatly improve its product.

Table 4-1 Services Used By Mode - 1999

	All Riders	Train Riders	Bus Riders
Transfer Within CTA	47%	45%	49%
Transfer From Another System	8%	7%	9%
Do Not Transfer	44%	47%	40%
Bus-Train or Train-Bus Transfer	32%	35%	29%
Train-Train Transfer	5%	10%	--
Bus-Bus Transfer	10%	--	20%
Only Ride CTA Train	23%	47%	--
Only Ride CTA Bus	21%	--	40%
Ride Metra/Transfer to CTA	4%	4%	4%
Ride Pace/Transfer to CTA	4%	3%	5%
Other	1%	1%	1%

From 1999 Customer Satisfaction Survey of CTA Riders

There is a good deal of transferring among Pace, Metra, and the CTA, but there are concerns that the services aren't well integrated. In response, the Regional Transportation Authority (RTA) hired Booz-Allen & Hamilton to create a transit coordination plan, focusing on the physical, service, fare, and information coordination of the three service providers (RTA, 2001). One of the main goals of the study was to determine which transfer points are the most critical for connections between the different service providers and where additional transfer points might be introduced. The study considered locations for an additional Metra station (or stations) within Chicago that would provide more direct service to passengers coming from the suburbs and going to non-downtown worksites.

The services that CTA provides are dictated in large part by service standards. In 2001, a new set of service standards was approved for the CTA. The service standards determine key features of the services that the CTA provides, such walking distance to the nearest transit stop, hours and days of the week a service will be available, frequency of a route, and how full the buses can be at the busiest point on the bus route (CTA, 2001). The service standards also define minimum productivity standards, so trips that get little usage become candidates for cancellation. The service standards also require estimates of the net cost per new passenger when proposing a service improvement. These place restrictions on the extent of the improvements that can be made.

The CTA is a good candidate for the application of the process described in Chapter 3 for the following reasons:

- Connectivity has not been a focus of planning in recent years, so there is room for improvement,
- The CTA bus system is largely based on a grid, which relies on high-quality transfers to be effective,
- Chicago is a dispersed city with many origins and destinations spread over a large area, and so the system depends on good connectivity to be effective,
- The agency needs to address its stagnating bus ridership, and improving service connectivity could play a large role in building bus ridership,
- There are multiple operators in the area, and
- There are multiple modes that have to work together to make the system function effectively.

4.2 System Boundary

The boundary of this analysis will be the CTA service area, which includes the entire City of Chicago and many of its suburbs. Ridership is a major concern at the CTA, particularly in the bus system, and given that transfers to buses can be made throughout the service area, it does not make sense to confine the study to transfers at a particular geographic location. Opening the analysis to all transfer points in the CTA service area means that many transfer points will be considered for analysis, and a system improvement has the potential to improve even the more remote and atypical transfers. Facility and service improvements, on the other hand, are unlikely to reach every transfer facility, as the process eliminates improvements that do not bring enough passenger benefits to justify the costs to the agency. While the CTA has primary responsibility for the coverage of its service area, Pace and Metra also provide service that is used by people within the service area, so transfers from Pace and Metra to the CTA should also be considered. Providing good connections for Metra and Pace passengers is also a good strategy for the CTA given the population growth of the Chicago suburbs and the growing percentage of CTA passengers who live in the suburbs (NRG, 1999).

4.3 Connectivity Assessment

In this section, system, facility, and service elements are assessed. The data used in the assessment is first described. System elements are assessed according to how many passengers experience the different levels of the system element tiers, with the assessment mostly based on survey data. Facility elements are assessed according to which levels in the facility element tiers passengers are transferring, with the assessment based mostly on AFC data. Service elements are assessed according to the schedules.

4.3.1 Data

The Customer Satisfaction Survey of CTA Riders is a useful source of information about CTA passengers. Every two years, a telephone survey is taken of people in the Chicago area. This survey provides information on how people perceive the CTA, how often they use it, what service features dissatisfy passengers the most, and other measures of performance. The results of the 1999 survey are used in this analysis.

In addition to surveys, the CTA has other ways of measuring the number of transfers. The CTA collects AFC data on bus-bus, bus-rail, Pace-bus, and Pace-rail transfers. This data gives information about the number of passengers transferring between pairs of routes. A shortcoming of this data is that there is no indication of the direction of travel. It records when a passenger boarded a bus or entered a rail station, but for the buses, it only records the route, and for the rail system, since there is no information about where passengers get off, there is no indication of which direction the passengers is traveling. CTA takes a cross-platform survey every year to determine how many people are making rail-rail transfers to provide the CTA a complete measure of annual boardings, since there are no AFC records for most rail-rail transfers. Booz-Allen & Hamilton's "Regional Transit Coordination Plan" provides transfer volume estimates between the three different service providers (CTA, Metra, and Pace) by location.

In the section on improvements, boardings are used rather than transfer numbers because many of the improvements being considered for transferring passengers will also benefit non-transferring passengers, and the benefits they receive have to be considered in the analysis. The number of rail boardings is known because entries are recorded at rail station entrances, but boarding numbers have to be extracted from the transfer volume data for transfers to the buses. For simplicity, it will be assumed that half of passengers boarding buses at transfer facilities are actually passengers making a transfer.

4.3.2 System Element Assessment

The percentage of transferring passengers of each transfer type who experience each quality level for each system element is shown in Table 4-2. The system elements were assessed using the transfer volumes suggested by the Customer Satisfaction Survey of CTA Riders (1999) and information about what passengers have access to what quality level for each element. There are about 1.5 million boardings a day, and with the transfer rate of approximately 50% suggested by the Customer Satisfaction survey, this means that there are about 1 million trips taken on the CTA each day, half of which are transfer trips.

For transfer price, rail-rail transfers are always free, but all other transfers in the system may be sold at a full or discounted additional fare. For bus-rail, rail-bus, bus-bus, Pace-CTA, and CTA-Pace transfers, the discount on the additional fare is $1.20, as transfers are sold for $0.30. This is a simplification of the real situation, given that 14% of bus and 11% of train users use a pass (NRG, 1999), allowing unlimited rides, and so for them, the transfer is essentially free. In the assessment, it is assumed that transferring passengers hold passes in approximately the same proportions as the surveyed sample, although transferring passengers have a greater incentive to buy a pass given their higher cost per trip compared to non-transferring passengers. An alternative to providing free transfers would be to encourage more people to use the unlimited fare cards. But it may not be the most economical choice for most people, or they'd be purchasing them already. The majority of the transfers made between Metra and the CTA are to and from rush shuttles, the buses that link the Metra stations and the downtown areas, and fares for the rush shuttles are only $1.00, so the discount on the additional fare is $0.50. Metra monthly pass holders also have the option of purchasing a Link-up Pass for $36, which allows them to ride the CTA during the peak periods.

Table 4-2 System Element Assessment – CTA

	Transfer Type	Rail-bus	Bus-bus	Rail-rail	Pace-CTA	Metra-CTA
	DAILY TOTALS	320,000	100,000	50,000	40,000	40,000
Transfer Price	Free	12%	14%	100%	12%	10%*
	Discounted	88%	86%	0%	88%	85%
	Full Fare	0%	0%	0%	0%	5%
Pre-trip Information	System and Trip Planner	100%	100%	100%	100%	100%
Fare Media	Same	100%	100%	100%	100%	10%*
	Different	0%	0%	0%	0%	90%*
In-vehicle Information	Transfer Announcements, Connecting Route Information, and Real-time Information	0%	0%	0%	0%	0%
	Transfer Announcements and Connecting Route Information	0%	0%	0%	0%	0%
	Transfer Announcements	0%	0%	100%	0%	0%
	No Information	100%	100%	0%	100%	100%
Fare Control	No Barriers	0%	0%	0%	0%	50%
	No Barriers if Remain in Paid Area	0%	0%	90%	0%	0%
	Barriers do Not Add Delay	0%	0%	0%	0%	0%
	Barriers Add Delay	100%	100%	10%	100%	50%

* No data was found on how many passengers use the Link-up Pass, so this is an estimate. From observation, most people transferring from Metra to the CTA pay with cash.

Pre-trip information is equally available to all transferring passengers, regardless of which services they use, given that CTA, Metra, and Pace schedules are available on the internet and that the RTA provides a trip planner that uses schedules for CTA, Metra, and Pace services. Even if pre-trip information is offered, there are concerns that it may not be in a form that is accessible to all people. However, more then 40% of CTA passengers have a system map (NRG, 1999). Access to system schedules and the trip planner is dependent on phone or internet access, but 90% of CTA passengers have internet access

(NRG, 1999), and presumably even more have telephone access. Therefore, it is assumed that all passengers have access to system wide information and the trip planner, even if they don't use them.

All passengers transferring within the CTA and between CTA and Pace use the same fare medium. Even transfers that are made between Metra and the CTA can be made with the same fare medium, if a passenger has purchased a Link-up Pass, which is the combined Metra monthly pass and CTA fare card. The fact that so many transfers can now be made on a single fare medium suggests that the benefits of further improvement in this area are not substantial.

Transfer announcements are not currently made in CTA buses, except occasionally by drivers, nor is printed information available inside the vehicles about connecting services. Announcements are made on CTA trains when there is an opportunity to transfer to another rail line, but not for bus transfers. An announcement system for CTA buses is currently planned, and certain types of announcements could be beneficial for some transferring passengers.

No validation is required for rail-rail transfers, as long as passengers don't leave the paid area. However, validation is required for most other transfers, and usually the validation process imposes some delay because passengers have to search for their fare card or pass and swipe it through the fare reader as they board a bus or enter a rail station. An exception is a transfer to Metra, where the fares can be paid onboard.

4.3.3 Facility Element Assessment

In this step, transfer volumes at individual transfer facilities are determined using AFC data and cross platform survey data. The top 300 bus-rail and the top 500 bus-bus transfers are considered in the assessment. This doesn't represent all of the transfers, and so the calculated distributions of passengers among the different transfer types and tier levels won't coincide perfectly with the real situation. Bus-bus transfers are probably more underrepresented because they are spread over a greater number of locations. Many of the transfers recorded from the AFC data were eliminated from the analysis because they weren't the type of transfer that this thesis is considering. For example, many people in the system get a transfer fare for a trip that is in the reverse direction on the same route, as opposed to a transfer to another service. Or people may be making a stop on the way to their final destination, and still can use a transfer fare when reboarding the same route, as the transfer is good for two hours after the time it was purchased. There is also evidence of people using parallel routes, which suggests that they use a second route for their return trip, or they are doing personal business en-route that brings them to another service to continue the trip to their destination. There may be some illegal distribution of fare cards with discounted or free transfers on them. Finally, some recorded transfers had to be eliminated because they were for routes that didn't even intersect or come close to each other. The source of this error is probably bus drivers improperly logging into their data terminals.

The number of CTA transfer facilities considered in each section of the service area is shown in Table 4-3: 469 transfer facilities in total. The most transfers occurred in the South, which also had the highest number of transfer points. There were nearly as many transfers in the downtown area, which are concentrated in only 31 transfer facilities.

Table 4-3 Transfer Facilities Considered in Facility Analysis - CTA

Transfer Facility Locations	Number of Transfer Points	Daily Transfer Volumes
Downtown	31	71,767
North	82	52,600
South	118	79,833
Northwest	87	45,400
Southwest	40	22,167
West	93	30,467
Suburbs	18	8,933
Total	469	12,447

Table 4-4 shows the top 30 transfer facilities by transfer volume. Many of the same transfer types share the same facility features, and this reduces the time it takes to determine the information about each transfer facility, which is important given the large number of transfer points in the CTA system.

Table 4-4 Top 30 Transfer Facilities by Volume – CTA

		Rail-bus	Bus-bus	Rail-rail	Pace-CTA	Metra-CTA	Daily Transfer Volumes
Downtown	Downtown Passenger Transfer Tunnels	0	0	29358	0	0	29358
Downtown	Lake/State	597	0	18691	0	0	19288
Downtown	Clark/Lake	582	0	16567	0	0	17149
North	Howard	1063	180	11658	1657	0	14559
South	95th/Dan Ryan	11184	612	0	1740	0	13537
North	Fullerton/North Main	1976	0	8850	0	0	10826
Northwest	Jefferson Park	4708	911	0	1339	0	6957
South	79th/Dan Ryan	6398	0	0	0	0	6398
South	69th/Dan Ryan	5312	400	0	0	0	5713
Southwest	Midway Airport	3357	219	0	1456	0	5032
South	Garfield/Dan Ryan	3817	0	0	0	0	3817
South	87th/Dan Ryan	3772	0	0	0	0	3772
Northwest	Belmont/O'Hare	3664	0	0	0	0	3664
Southwest	Kedzie/Midway	2427	1028	0	0	0	3455
Northwest	Rosemont/O'Hare	0	0	0	3149	0	3149
South	63rd/Dan Ryan	3114	0	0	0	0	3114
Downtown	Union Station	0	0	0	0	2846	2846
North	Belmont/North Main	2609	0	201	0	0	2810
Northwest	Irving Park/Pulaski	2352	450	0	0	0	2801
Southwest	Pulaski/Midway	2636	0	0	0	0	2636
North	Lawrence/Kimball-Homan	1916	683	0	0	0	2598
North	Western/Ravenswood	1668	796	0	87	0	2552
Southwest	Western/Midway	2415	0	0	0	0	2415
Southwest	Halsted/Midway	2129	201	0	0	0	2330
South	47th/Dan Ryan	1816	505	0	0	0	2321
South	63rd/Ashland	949	1337	0	0	0	2286
Northwest	Harlem/O'Hare	1197	435	0	591	0	2223
Suburbs	Forest Park/Congress	179	0	0	1866	0	2045
Northwest	North/Damen	1280	722	0	0	0	2001
Downtown	Oglivie Transportation Center	0	0	0	0	1943	1943

The assessment of transfer facilities with the highest volumes for each of the transfer types is shown in Table 4-5. This represents only a small fraction of all of the transfer facilities considered in the study. However, the results of the assessment of one transfer facility may be true at other transfer facilities with the same type of transfer, and in this way, the transfer facilities will not have to be assessed one at a time. Many of the bus-bus transfer facilities in the system are virtually identical, and so the assessment of one of them can serve as the assessment of all of the others.

Table 4-5 Facility Element Assessment for Top Transfer Facilities – CTA

	Transfer Type	Rail-bus	Bus-bus	Rail-rail	Pace-CTA	Metra-CTA
	Location with highest volume	95th/Dan Ryan	79th and Jeffery	Subway Connections	Rosemont/ O'Hare	Union Station
	DAILY TOTALS	11,200	1600	29,400	3100	2800
Weather Protection	Protected connection	0%	0%	100%	0%	0%
	Unprotected but covered connection	100%	0%	0%	100%	76%
	Covered waiting area only	0%	0%	0%	0%	12%
	Open area	0%	100%	0%	0%	12%
En-route Information	System, waiting time, and real-time arrival information	0%	0%	0%	0%	0%
	System and waiting time information	50%	0%	100%	0%	0%
	Route and waiting time information	0%	0%	0%	100%	50%
	Route information	0%	0%	0%	0%	0%
	No information	50%	100%	0%	0%	50%
Changing Levels	No Vertical Separation	0%	100%	0%	0%	0%
	Vertical separation, with Assistance	100%	0%	0%	100%	0%
	Unassisted	0%	0%	100%	0%	100%
Road Crossings	No road crossing	100%	100%	100%	100%	75%
	Assisted road crossing	0%	0%	0%	0%	25%
	Unassisted road crossing	0%	0%	0%	0%	0%
Walking Distance	No walk	0%	0%	0%	0%	0%
	Short walk required	100%	100%	0%	100%	100%
	Long walk required	0%	0%	100%	0%	0%
Concessions	Large selection	0%	0%	0%	0%	100%
	Small selection	100%	0%	0%	0%	0%
	None	0%	100%	100%	100%	0%

All transfers at 79th and Jeffery occur without any weather protection, and this is typical of most bus-bus transfer facilities. On the other hand, the transfers that occur between the Red Line and Blue Line are fully protected, but this is unusual in the CTA system. Many transfer facilities serve passengers movements between multiple route-pairs. As a result, different passengers may experience different levels in the tier at a given transfer facility. For example, some transfers at Union Station occur without weather protection, like those to buses that pick up passengers across the street from the station.

For the transfers between bus and rail at 95th/Dan Ryan, there is en-route information for those passengers transferring from bus to rail. This is because the bus stop route diagrams indicate that the bus is going to the rail station, and at the rail station, passengers have access to information about how long they'll have to wait for a CTA train. However, passengers transferring from rail to bus have no information. There is no indication of the availability of bus routes at 95th/Dan Ryan at any rail station where a passengers may have entered the system, and since there are no schedules available at the CTA bus stops at 95th/Dan Ryan, passengers don't know how long they'll have to wait.

Escalators or other forms of assistance are available at 95th/Dan Ryan, Rosemont/O'Hare, and Union Station. There is no need to change levels at 79th and Jeffery, but transfers between the downtown subways require climbing a flight of stairs. Passengers who really want to avoid the stairs can take the escalators to the mezzanine level and walk to the other subway through the mezzanine walkway. However, this is a longer trip than the tunnel that goes beneath the tracks, and there are no signs informing passengers about this alternative route that provides assistance with changing levels.

There are no road crossings at 95th/Dan Ryan, the connection between the downtown subways, or Rosemont on the O'Hare branch. Transfers at 79th and Jeffery do not require a road crossing because there is a station entrance on both sides of street. A fraction of the transfers at Union Station require a road crossing because a few of the routes load passengers across the street.

The walking distances at all of these stations are generally short, although the walking distance between the Blue and Red Lines is relatively long: more than a block.

A summary of the assessment of all transfer facilities is shown in Tables 4-6 to 4-11.

Weather protection varies from ideal to non-existent at the CTA, as shown in Table 4-6. There are protected vehicle-to-vehicle movements only for transfers between the Red and Blue Lines downtown, where there are multiple pedestrian tunnels between the subway platforms. Passengers who transfer at most rail stations have an unprotected, but covered, vehicle-to-vehicle connection. There are some bus-bus connections that can be made under complete cover, such as ones at Jefferson Park or Midway. Some connections have only a covered waiting area, and many, particularly transfers to buses, have no weather protection.

Table 4-6 Summary of Weather Protection Assessment – CTA

	Best	Mid Level (A)	Mid Level (B)	Worst
	Protected Vehicle-to-Vehicle Connection	Unprotected but Covered Vehicle-to-Vehicle Connection	Covered Waiting Area Only	Open Area
Total	**8%**	**37%**	**9%**	**47%**
Rail-bus	0%	57%	7%	36%
Bus-bus	0%	3%	3%	94%
Rail-rail	30%	51%	19%	0%
Pace-CTA	0%	78%	11%	11%
Metra-CTA	0%	40%	15%	45%

Rail-rail transfers have system and waiting time information because rail stations always provide a map of the entire rail system, which shows passengers where they have to transfer, and schedules, which tell them how long they have to wait for the next train (provided they are accurate and the trains are running on schedule). Connections from bus to rail can also be said to have system and waiting time information because the bus stop signs show where the route intersects the rail stations, and at the rail station, passengers know how long the wait will be because there are train schedules. No transfers to bus routes have any information, because bus connections aren't shown on any maps at rail stations, and the bus stops have no schedules. No transfers have real-time arrival information, as shown in Table 4-7.

Table 4-7 Summary of En-route Information Assessment – CTA

	Best	Mid Level (A)	Mid Level (B)	Mid Level (C)	Worst
	System and Waiting Time Information with Real Time Arrival Displays	System and Waiting Time Information	Route and Waiting Time Information	Route Information	No Information
Total	**0%**	**24%**	**22%**	**54%**	**0%**
Rail-bus	0%	0%	50%	50%	0%
Bus-bus	0%	0%	0%	100%	0%
Rail-rail	0%	100%	0%	0%	0%
Pace-CTA	0%	0%	94%	6%	0%
Metra-CTA	0%	0%	50%	50%	0%

All bus-bus transfers are made on-street or in an off-street bus facility, so there are no concerns with changing levels, as shown in Table 4-8. There are several at-grade rail stations, and transfers between the rail and the bus at these locations do not have a level separation, either. However, operations at some terminals are such that the trains sometimes arrive on the far platform, and so passengers have to climb stairs to the overpass that gets them over the track. Transfers between rail and bus, the most common type of transfer in the CTA, generally require a level change, given that much of the rail system is elevated or below the street level, where the buses operate. For transfers that require walking up stairs, it is assumed that gravity assists with the reverse transfer, which would involve walking down stairs. However, walking down stairs is still a problem for some passengers.

Table 4-8 Summary of Changing Levels Assessment – CTA

	Best	Mid Level	Worst
	No Vertical Separation	Vertical Separation, Assisted	Unassisted Vertical Movement
Total	**47%**	**32%**	**20%**
Rail-bus	1%	78%	20%
Bus-bus	100%	0%	0%
Rail-rail	39%	12%	49%
Pace-CTA rail	3%	87%	10%
Pace-CTA bus	100%	0%	0%
Metra-CTA	12%	33%	56%

Walking distance is generally quite short at most transfer points, particularly for transfers between bus and rail and between buses, as shown in Table 4-9. Rail-rail connections require no walk if they can be made without leaving the platform, but if they are made between the Red Line and the Blue Line in the Washington or Jackson St. tunnels, then the walking distance is rather long, requiring 2 to 3 minutes.

Table 4-9 Summary of Walking Distance Assessment – CTA

	Best	Mid Level	Worst
	No Walk Required	Short Walk Required	Long Walk Required
Total	**6%**	**87%**	**8%**
Rail-bus	0%	100%	0%
Bus-bus	0%	100%	0%
Rail-rail	32%	44%	24%
Pace-CTA	0%	100%	0%
Metra-CTA	0%	100%	0%

Road crossing assistance is provided at all bus-bus transfer points that are on-street, but at some of the bus-rail transfer points, particularly those where the rail line is operating in a highway median, the station exit is in the middle of a block, where there might not be a crosswalk. No road crossings are required for transfers that occur at dedicated bus facilities such as Jefferson Park or Midway or for most rail-rail transfers, as shown in Table 4-10.

Table 4-10 Summary of Road Crossing Assessment – CTA

	Best	Mid Level	Worst
	No Road-Crossing Required	Road Crossing Required, but Assisted	Unassisted Road Crossing
Total	**47%**	**48%**	**5%**
Rail-bus	66%	21%	14%
Bus-bus	2%	98%	0%
Rail-rail	80%	20%	0%
Pace-CTA rail	95%	1%	4%
Pace-CTA bus	52%	48%	0%
Metra-CTA	84%	16%	0%

Concessions are available at a few of the major transfer points, such as 95th/Dan Ryan, Midway, and Western on the Brown Line. They are available to most passengers transferring between Metra and the CTA, as shown in Table 4-11.

Table 4-11 Summary of Concessions Assessment – CTA

	Best	Mid Level	Worst
	Large Selection	Small Selection	None
Total	**1%**	**8%**	**91%**
Rail-bus	0%	17%	83%
Bus-bus	0%	2%	98%
Rail-rail	0%	0%	100%
Pace-CTA	0%	30%	70%
Metra-CTA	81%	0%	19%

4.3.4 Service Element Assessment

Service elements are assessed one route-pair at a time, using transfer volumes collected from the AFC data, cross-platform surveys, and RTA surveys. The number of each type of connection assessed in the service element assessment is shown in Table 4-12.

Table 4-12 Route-pairs Considered in Service Analysis

Transfer Types	Number of Route-pairs	Daily Transfers
Bus-rail	235	103,000
Bus-bus	448	117,000
Rail-rail	24	83,000
Pace-CTA	75	18,000
Metra-CTA	17	5,000
Total	799	316,000

The data shown in Table 4-12 is not consistent with the CTA Customer Satisfaction Survey data. Frequent riders and infrequent riders were considered together in the survey, which may skew the results. Passengers may also count return trips or continuing trips for which they've paid a transfer fare as a transfer, but those transfers have been eliminated from the transfers from the AFC data considered in this research. Also, there are many potential errors in the transfer data. Most notably, the survey suggests that there are a much higher number of bus-rail transfers than the AFC data suggests.

An assessment of the transfers with the highest volumes for each transfer type is shown in Table 4-13. The Red Line, Blue Line, #79 bus line, and #9 bus line are all 24-hour routes, so the transfers between them are available 24 hours a day. The #352 Pace line operates for 135 hours a week out of 95th/Dan Ryan and 141 hours a week into 95th/Dan

Ryan, and so its hours of operation determine the hours that the connection is available to and from the Red Line. Transfers to the #121 are only available for 7 hours per day, during the morning and afternoon rush periods, and so this connection between Metra and CTA buses is rather limited in terms of its availability.

Table 4-13 Service Element Assessment for Top Transfers – CTA

	Transfer Type	Rail-bus	Bus-Rail	Bus-bus	Rail-rail	Pace-CTA	CTA-Pace	Metra-CTA	CTA-Metra
	Transfer with highest volume	Red Line to #79	#79 to Red Line	#79 to #9	Red Line to Blue Line	#352 to Red Line	Red Line to #352	Metra to #121	#121 to Metra
	DAILY TOTALS	2500	2500	700	12,200	700	700	600	600
Transfer Waiting time	High Frequency	0	5 hours	0	5 hours	5 hours	0	0	0
	Headways matched and arrival and departure times optimized	0	0	0	0	0	0	0	0
	Arrival and departure times optimized	0	0	0	0	0	0	0	0
	No optimization	168 hours	163 hours	168 hours	163 hours	130 hours	141 hours	35 hours	35 hours
Span of Service	Hours per week Matched	168 hours	168 hours	168 hours	168 hours	135 hours	141 hours	35 hours	35 hours
	Hours per week Unmatched	0	0	0	0	33 hours	27 hours	57 hours	57 hours

A summary of the assessment of service elements for all of the route pairs considered is shown in Table 4-14. Connections are available when both routes are operating. The hours of operation of all of the routes were compared, and the hours of overlap were determined for each route. Route pairs in which both routes had 24-hour service had connections available 168 hours per week, and the average number of hours that transfers passengers have available connections is 133 hours. This number is quite high in part due to the fact that so many transfers are between rail lines and the key bus routes, which have 24-hour service or close to it. The schedules in general suggest a high level of connection availability, and the 1999 Customer Satisfaction Survey does not indicate that passengers feel that the CTA provides service over too few hours.

Frequencies on the rail lines are high at certain times of day with a lowest sustained headway being 3 minutes. It is impossible to make a good estimate of how many people transfer to the routes operating at high frequencies using the available data, but it is probably in the range of 10%. Therefore, the other 90% of passengers have to contend with potentially long transfer waiting times. Reducing transfer waiting time is not currently a planning priority at the CTA, nor are there any standards that schedules have to meet for connectivity, and that is why most of the transfers are at the lowest level for transfer waiting time. One exception is the night owl service, in which the headways of several routes are matched at 30 minutes and departures are coordinated from a downtown intersection.

Table 4-14 Assessment of Service Elements

Element	Best Level	Mid Levels	Worst Level
Transfer Waiting Time	High Frequencies 10%	Headways matched and arrival and departure times coordinated 0% Arrival and departure times coordinated 0%	No coordination 90%
Span of Service	Matched 133 hours per week		Unmatched 26 hours per week

4.4 Element and Tier Tailoring

As described in Chapter 3, the framework presented in Chapter 2 should be reviewed to make sure it accurately reflects the system conditions. Elements that are not on the list but are important for a given agency should be listed, but for Chicago, nothing seems to be missing. The elements of the framework are listed in Table 4-15, with those that are not likely candidates for improvement crossed out. The generic rankings and tiers established in Chapter 2 will be maintained for the application of this process for Chicago.

Table 4-15 Elements

System

Price
~~*Pre-trip Information*~~
~~*Fare Media*~~
~~*In-vehicle Information*~~
~~*Fare Control*~~

Facility

Weather Protection
En-route Information
~~*Changing Levels*~~
~~*Road Crossings*~~
~~*Walking Distance*~~
Concessions

Services

~~*Connection Availability*~~
Transfer Waiting Time

Of all the system elements, price is the only strong candidate for improvement. Pre-trip information ranks highly, as does fare media. In-vehicle information would be beneficial, but a project for announcing stops in buses is already underway for another purpose – ADA compliance. Fare control improvements do not appear likely. Increasing the public transportation space to allow for more free transfers would be costly in terms of construction and revenue loss, and it is unlikely that the CTA would choose to adopt proof-of-payment, given its large investment in an AFC system.

Due to the costs of weather protection improvements and their benefits to passengers, many transfer facilities are candidates for improvements, as shown in Table 4-16. The cost of covered walkways cannot be estimated accurately because they haven't been built anywhere in Chicago, but an attempt has been made to provide a figure that is, at least, the correct order of magnitude. Simple bus shelters can cost as little as $1000, while fancier bus shelters could cost up to $5000. However, the CTA may not be purchasing all of the bus shelters that are justified at its transfer facilities because their passengers are in the process of getting 2000 new bus shelters as a result of an agreement between the City of Chicago and a company called JCDecaux (www.jcdecaux.com, 2001). This company provides street furniture in exchange for advertising space.

Given the cost-effectiveness of bus shelters, it is surprising that the CTA has so few. There are around 12,000 bus stops in the system, but a mere 1000 bus shelters. A large reason that more shelters haven't been installed is that they tend to be difficult to clean and maintain. One advantage to contracting with a company like JCDecaux is that they provide maintenance for the shelters.

Table 4-16 Candidate Transfer Points for Weather Protection Improvements

Item	Value per trip	Cost	Payback Time	Minimum number of people needed to justify per day	Candidate Transfer points
Simple Bus Shelter	2.5 cents	$1000	1 year	140	All major transfer points without weather protection
Fancy Bus Shelter	3 cents	$5000	1 year	560	About 75 transfer points
Covered Walkway	10 cents	$100,000	2 years	1680	State/Lake Howard Red Line/Fullerton Red Line/69th Red Line/55th Red Line/87th O'Hare/Belmont Red Line/63th Red Line/Belmont Irving Park/Pulaski Red Line/47th 63rd/Ashland
Enclosed Walkway	20 cents	$2 million	3 years	11,100	State/Lake

Given the costs of en-route information and their benefits to passengers, many transfer facilities are candidates for improvements, as shown in Table 4-17. Transit agencies in Europe have realized the benefits of providing real-time arrival information to their passengers, and so this is potential area of investment in en-route information. Some stations in the CTA system are already getting real-time information, such as Midway, Cumberland, Davis, and O'Hare as a result of a project initiated by the Regional Transportation Authority (www.chicago-l.org).

Table 4-17 Candidate Transfer Points for En-route Information

Item	Value per trip	Cost	Payback Time	Minimum number of people needed to justify per day	Candidate Transfer points
Printed Timetable	3 cents	$210	1 year	21	All major transfer points
System Map	3 cents	$210	1 year	21	All major transfer points
Real-time Arrival Information	3 cents	$6000	1 year	560	Major Rail-rail and bus-rail transfer points
Facility Information	3 cents	$1000	1 year	90	All rail stations

Given the costs of escalators and their benefits to passengers, none of the transfer facilities are good candidates for new escalators, as shown in Table 4-18. The CTA is essentially mandated to provide easier movement between levels to comply with ADA requirements, and they have installed elevators at all of their renovated stations as well as escalators at many of them. However, the CTA is still in the process of adding escalators and elevators to rail stations, and so there are still many people who have to make a transfer by changing levels without assistance. There are some transfer points where more than one flight of stairs has to be negotiated to make a transfer, such as the path between the State and Dearborn subways (a flight to get down to the tunnel and a flight to get up to the other platform) and between the State Subway and the Loop. These are the worst transfer spots in the system, in terms of lack of assistance with vertical separation, as well as the most heavily used. However, the benefits of the escalators aren't enough to justify their costs.

Table 4-18 Candidate Transfer Points for Escalators

Item	Value per trip	Cost	Payback Time	Minimum number of people needed to justify per day	Candidate Transfer points
One escalator	2.5 cents	$1 million	3 years	55,600	None

Given the costs of better road crossings and their benefits to passengers, none of the transfer facilities are good candidates for an off-street bus terminal, as shown in Table 4-19. Some facilities have volumes greater than 5600 passengers per day, but only half of passengers are expected to make use of a given road crossing, and so better road crossings would not generate enough benefits to justify the costs.

Table 4-19 Candidate Transfer Points for Better Road Crossings

	Value per trip	Cost	Payback Time	Minimum number of people needed to justify per day	Candidate Transfer points
Off-street bus depot	2 cents	$1 million	3 years	55,600	None
Improved Crosswalks	2 cents	$100,000	3 years	5,560	None

Walking time appears to perform relatively well, and given its relatively low importance and the high cost of improvements, improvements are probably not worthwhile. The rail lines are fixed, and the bus lines already come as close to them as they can. One option is to make use of moving walkways for the longer walks, but given that escalators are not cost-effective, it is unlikely that moving walkways would be, either. The only location where walking distance seems to be a problem is in the downtown area. The subway lines are fixed, and so reducing the distance between them is not a feasible option considering the cost of additional tunneling. Bus routes could potentially be reconfigured such that they connect better to each other, the subways, and elevated lines. However, in the 70's, there was a dedicated bus boulevard along State Street. It was not successful, and it is unlikely that such an effort will be attempted again.

Concessions essentially cost the CTA nothing, so if there are any concessions that can be brought to a transfer facility, it is likely that the benefits will outweigh the costs. Concessions might also increase CTA's revenue.

There are many inexpensive opportunities for improving transfer waiting time, so potential improvements to this element should be explored. These opportunities include transfers between routes operating with the same headway (for at least part of the day), at transfer facilities that are the terminal for one or both of the routes, or where the walking distance for the transfer is relatively short. Table 4-20 lists the top transfer locations and some of their characteristics that may or may not make them good candidates for service improvements.

Table 4-20 Top Transfers and Opportunities for Transfer Waiting Time Improvement – CTA

Transfer Facility	Transfer type	A Line	B Line	Daily Transfer Volume	Matched Headways	Termicvnal	Consistent Walk Time
Downtown Subway Tunnels	Rail-rail	Red Line	Blue Line	29358	Y	N	N
Fullerton/ North Main	Rail-rail	Red Line	Brown Line	8850	N	N	Y
Howard	Rail-rail	Red Line	Purple Line	6986	N	Y	Y
Lake/State	Rail-rail	Red Line	Green Line	4956	N	N	N
Lake/Clark	Rail-rail	Blue Line	Green Line	4295	N	N	N
Lake/State	Rail-rail	Red Line	Purple Line	5475	N	N	N
Lake/State	Rail-rail	Red Line	Brown Line	5428	N	N	N
79th/ Dan Ryan	Bus-rail	Red Line	79	6059	Y	N	Y
Lake/Clark	Rail-rail	Blue Line	Brown Line	3398	N	N	N
87th/ Dan Ryan	Bus-rail	Red Line	87	3696	Y	N	Y
Howard	Rail-rail	Red Line	Yellow Line	3257	N	Y	Y
Garfield/ Dan Ryan	Bus-rail	Red Line	55	3329	Y	N	Y
Lake/Clark	Rail-rail	Blue Line	Orange Line	2690	N	N	N
63rd/ Dan Ryan	Bus-rail	Red Line	63	3025	Y	N	Y
69th/ Dan Ryan	Bus-rail	Red Line	67	2807	Y	N	Y
Lake/State	Rail-rail	Red Line	Orange Line	2832	N	N	N
Belmont/ O'Hare	Bus-rail	Blue Line	77	2562	N	N	Y
95th/ Dan Ryan	Bus-rail	Red Line	34	2485	N	Y	Y
Belmont/ North Main	Bus-rail	Red Line	77	1940	N	N	Y
69th/ Dan Ryan	Bus-rail	Red Line	71	1802	N	Y	Y
Pulaski/ Midway	Bus-rail	Orange Line	53A	1801	Y	N	Y

The span of service element performs very well, and improvements would be very costly, so it won't be considered for further improvement. Short spans of service has been a source of complaint in the past, in particular at a place like Midway, where there are people using the airport 24 hours a day, but the rail line does not operate 24 hours a day. However, the CTA has gradually been extending the hours of Orange Line operation, which has increased the availability of connections.

4.5 System Improvements

Potential transfer price improvements drawn from the system element assessment of Section 4.3.2 are shown in Table 4-21. Given the way that costs and benefits are calculated, all of these alternatives appear to be cost-effective, as the passenger benefits will meet or exceed the agency cost. In this example, a fare elasticity of –0.4 is used to calculate the additional passengers that would use transit as a result of the fare reduction. This figure comes from the Victoria Transport Policy Institute (www.vtpi.com), but its applicability to Chicago and reducing the price of a transfer has not been tested.

Free transfers are currently available only for rail-rail transfers and passengers using unlimited ride passes. Providing free transfers for all bus-bus and bus-rail transfers has the potential to cost the CTA revenue, but some of it might be recaptured in new trips taken by people who would not pay 30 cents to make a transfer, but who would transfer if it were free. The CTA will have a fare increase at some point, and this might be a good time to investigate the free transfers. With a fare increase, the losses due to providing more free transfers could be fully recovered. However, making transfers free only when the basic fare has risen may not lead to a significant number of new trips.

There is also an equity concern. Rail passengers generally get a higher level of service, and yet they get free transfers while bus riders do not. The rail riders get free transfers because connecting services may share the same track or exclusive public transportation space. There is also an argument that if some transfers are free, then other transfers should also be free. There is no reason why bus-rail transfers should be free when bus-bus transfers are not.

Table 4-21 Transfer Price Improvements

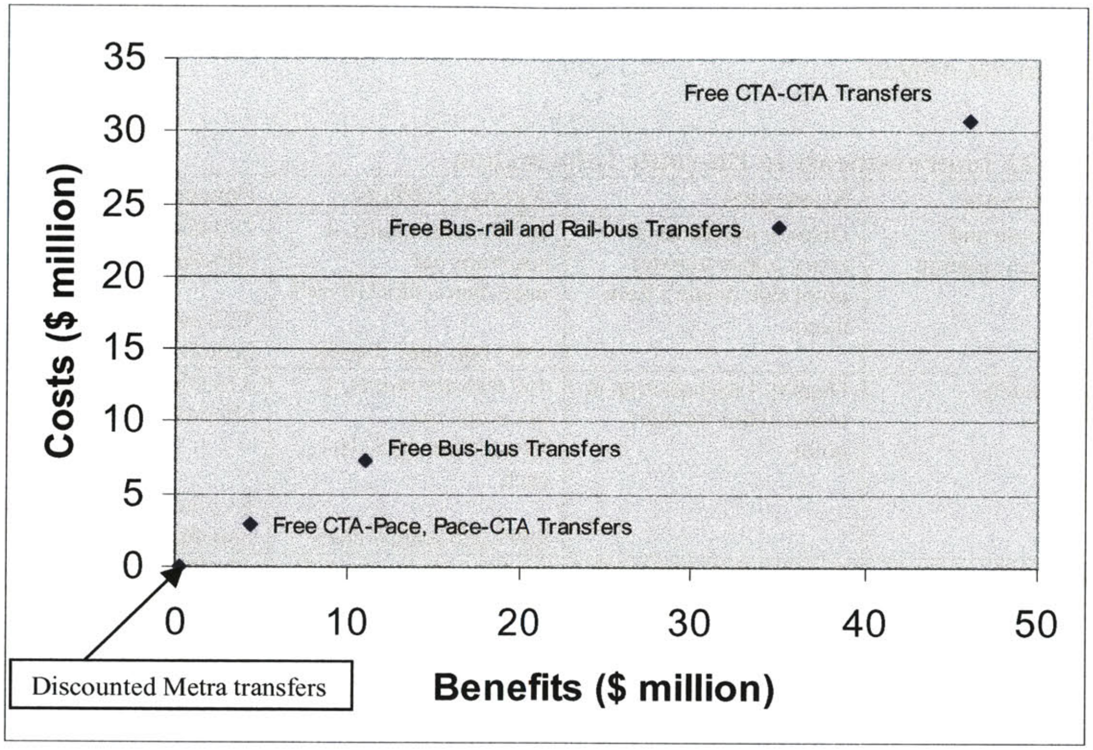
Improvements	Strategies	Agency Effects	Passenger Effects
Full Additional Fare to Discount	Provide a discounted CTA fare for all transfers between Metra and CTA	Loss of revenue; about $500 per day Additional daily passengers: 33 $62,050 annual loss	Decreased financial barrier to transfer for about 1000 daily passengers $182,500 annual benefit
Discount to Free	Provide free bus-bus transfers	Loss of revenue; about $30,000 per day Additional daily passengers: 6700 $7.3 million annual loss	Decreased financial barriers to transfer for about 100,000 daily passengers $10.9 million annual benefit
Discount to Free	Provide free bus-rail and rail-bus transfers	Loss of revenue; about $96,000 per day Additional daily passengers: 21,000 $23.4 million annual loss	Decreased financial barrier to transfer for about 320,000 daily passengers $35 million annual benefit
Discount to Free	Provide free CTA-CTA transfers	Loss of revenue; about $126,000 per day Additional daily passengers: 28,000 $30.7 million annual cost	Decreased financial barrier to transfer for about 420,000 daily passengers $46 million annual benefit
Discount to Free	Provide free Pace-CTA and CTA-Pace transfers	Loss of revenue; about $12,000 per day Additional daily passengers: 2700 $2.9 million annual cost	Decreased financial barrier to transfer for about 40,000 daily passengers $4.4 million annual benefit

The fare medium currently used by the CTA creates some issues for making bus-bus and rail-bus transfers free. While it may induce some additional boardings of CTA vehicles, if every transit card issued by the CTA allowed for a free transfer, then passengers would have no disincentive to give their cards to people ready to board the bus, thus providing people with an easy way to evade fare payment. Currently, to get a transfer card, a passenger has to pay an additional 30 cents, and so those people who do not pay for a transfer trip do not have the capability of a free transfer.

Providing free or discounted transfer prices to passengers coming from the other agencies is something that the CTA should consider in addition to providing free transfers between its own services. This might mean establishing a transfer discount between the CTA and Metra. This is already the case for the majority of Metra-CTA transfers during weekdays – Metra riders can board CTA buses for $1.00 instead of the regular $1.50 at the downtown commuter rail stations, which are served by bus routes 121, 122, 123, 124, and 126 and the Western and Clyborn Metra stations, which are served by bus route 33, the Magnificent Mile bus route. These services are all provided in the reverse direction in the afternoon peak, except for bus route 33, which only operates in the morning. Passengers transferring from the CTA to Metra in the off-peak do not have the same discounted or tailored services. There are several obstacles to providing discounts for transfers between the CTA and Metra. The first is that Metra and CTA have different fare structures: CTA has a flat fare and Metra has a distance-based fare. They also have different fare equipment, so discounts could not be provided automatically. However, if efforts are made to improve the connections between Metra and the CTA through the construction of one or more additional Metra stations in the Chicago area, then the number of transferring passengers might increase and it might become worthwhile to integrate the fares between the CTA and Metra to a greater extent. Pace passengers already have a discount when they transfer to the CTA, which is aided by a shared fare medium.

Figure 4-2 shows the estimated costs and benefits of various changes to the fare policy. The CTA has to work with the fact that it has a limited amount of money to work with and a fare-recovery ratio requirement, and so these changes may not be acceptable options. The results of calculating the benefits and costs of different changes to the transfer fare price don't lend themselves very easily to any order of priority. A more appropriate way to view the introduction of free transfers is perhaps in the context of a fare increase -- as a way to compensate people for more expensive fares and to protect against possible ridership erosion particularly on the lower quality bus service.

Figure 4-2 Annual Costs and Benefits for CTA System Improvements



4.6 Facility Improvements

Table 4-22 shows improvements to en-route information. En-route information is very good in some other transit agencies and countries, and it is very possible for the CTA to improve this element of its service substantially. There has been a pilot program to provide Frankle-Monigle signage at the CTA (www.chicago-l.org), with the hope that the CTA will soon have a consistent signage format. The CTA currently lacks even printed schedules at bus stops. The only transfer facilities at which all transferring passengers have printed schedules, assuming they are up-to-date, are Washington and Jackson streets downtown, where passengers can transfer between the Red and Blue lines. Passengers transferring between rail lines are not included with the passengers who would benefit from schedule installations, because they have access to the rail schedules for both portions of their journey. It is assumed that half of all passengers will not be affected by the presented information, but as many non-transferring passengers will make use of it as transferring passengers. Although a project to provide real-time arrival information at major transfer points would also be cost-effective, efforts to install system maps and schedules at transfer points would be equally or more appreciated by many passengers, especially those passengers who are unfamiliar with the system, and it would also be a less expensive project.

Table 4-22 Improvements to En-route Information

Improvements	Strategies	Agency Effects	Passenger Effects
Provide Route and Schedule Information	Display schedules at every major transfer point that doesn't have them	467 transfer points, 4 bus stops per intersection @$210 each $392,000 annual costs	280,000 passengers affected per day $2.5 million annual benefits
Provide System Information	Display a system map at every major transfer point	469 transfer points, 4 bus stops per intersection @ $210 each $393,000 annual costs	373,000 passengers affected per day $3.3 million annual benefits
Provide Facility Information	Improve signage at rail stations for transferring passengers	Improve signage at 111 stations $111,000 annual costs	121,000 passengers affected per day $1.1 million annual benefits
Provide Real-time Arrival Information	Display real-time arrival information at top transfer points	56 transfer points, 4 displays per transfer point @ $6000 each $1.3 million annual costs	440,000 passengers affected per day $4 million annual benefits

The four improvements to en-route information would provide cumulative improvements because they each provide something different. Route and schedule information provide passengers with information about where a given route goes and when it is expected to come. While many bus routes in the CTA system are fairly straightforward and stay on a single street, passengers may want to know where the route ends or where the route may deviate from its expected course. Even passengers who are familiar with a route may need to consult the schedule if they are traveling at a time of day when they don't normally travel or if they are traveling in the opposite direction from normal. System information provides passengers with information about how they might undergo a trip using multiple services. A partial map that only shows the rail lines, will not always show the most effective route between a given origin and destination. Facility information helps passengers navigate stations. Some stations have multiple exits, and transferring passengers should be given information about which exit they should take to get to their connecting service. While route, schedule, system, and facility information will only be useful to a fraction (half, as assumed in this analysis) of passengers, real-time information is useful to the majority of passengers because it provides assurance that a connecting vehicle is coming and information about when that connecting vehicle is expected to arrive. It can also be used to communicate important notices to passengers.

Weather protection options are evaluated in Table 4-23. Covered walkways are not very promising at the CTA, despite all of their benefits. A new station is being planned for State and Lake that will be similar to the station at Clark and Lake, so there will be little incentive to make an incremental investment such as a covered walkway at this station. Covered walkways are not practical at the Dan Ryan stations due to the height requirements that would be placed on them to accommodate tall trucks. For the bus shelters, many of the costs might be much larger than listed due to the need to reconfigure a sidewalk to accommodate the bus shelter. The sidewalks are too narrow for fancy bus shelters at Dan Ryan stations, and so they are not promising improvements at those stations where they could otherwise be cost-effective. That leaves basic bus shelters as being the most promising solution for improving weather protection throughout the system. They provide almost as much benefit as fancy bus shelters, but at a fraction of the cost. At the Dan Ryan stations, an awning could be placed across 3-4 meters of the sidewalk to provide passengers with protection as they wait for the buses. It would not be advisable to cover the shelter on all sides because people will need to use the sidewalk space. The fact that the transfer point is on a bridge makes for a shortage of space, and there are not many opportunities for improving the transfer environment except with a basic shelter. At other transfer points there may be more options, but due to the high demand, shelters are most needed at the Dan Ryan stations.

The City of Chicago is already in the process of acquiring around 2000 new bus shelters from JCDecaux, and one of the criteria for the placement of new bus shelters is a high percentage of transferring passengers (CTA, 2001). The CTA could request custom or deluxe bus shelters at some of its more high-profile transfer points from JCDecaux, build awnings outside its rail stations, and design stations with more enclosed spaces to provide better protection against the extreme cold and heat. Communities might also be willing to build their own bus shelters.

A potential problem for providing more street shelter is that some of the sidewalks may not have sufficient space. Also, there may be maintenance problems that could make these shelters more costly. Vandalism is also a concern. JCDecaux will provide maintenance for the shelters that it provides, but the CTA has to be conscientious about maintaining its own shelters, for without proper maintenance of the shelters and an upkeep of the schedules, the initial investments will be useless.

Table 4-23 Improvements to Weather Protection Between Services

Improvements	Strategies	Agency Effects	Passenger Effects
Open Area to Covered Waiting Area Only	Build basic shelters at 79th/Dan Ryan	2 shelters @ $1000 per shelter $2000 annual cost	3,100 transferring passengers affected per day $28,000 annual benefit
	Build basic shelters at 69th/Dan Ryan	2 shelters @ $1000 per shelter $2000 annual cost	2,800 transferring passengers affected per day $26,000 annual benefit
	Build basic shelters at all major transfer facilities that don't currently have one	2 shelters per facility @ $1000 per shelter, 400 facilities $800,000 annual cost	250,000 passengers affected per year $2.3 million annual benefit

The CTA has concessions at some of its transfer points, such as 95th on the Red Line and Western on the Brown Line. It would benefit from more at others. Providing more concessions would not necessarily cost the CTA any money, and it has a real estate department with the expertise to carry out the leasing. However, the CTA does have to provide incentives for businesses to locate in transit stations. The biggest incentive would be a large flow of passengers, especially transferring passengers who expect to wait at the transfer point for their connecting service and thus may have a few minutes to make a purchase. A strategy for the concessions element is suggested in Table 4-24.

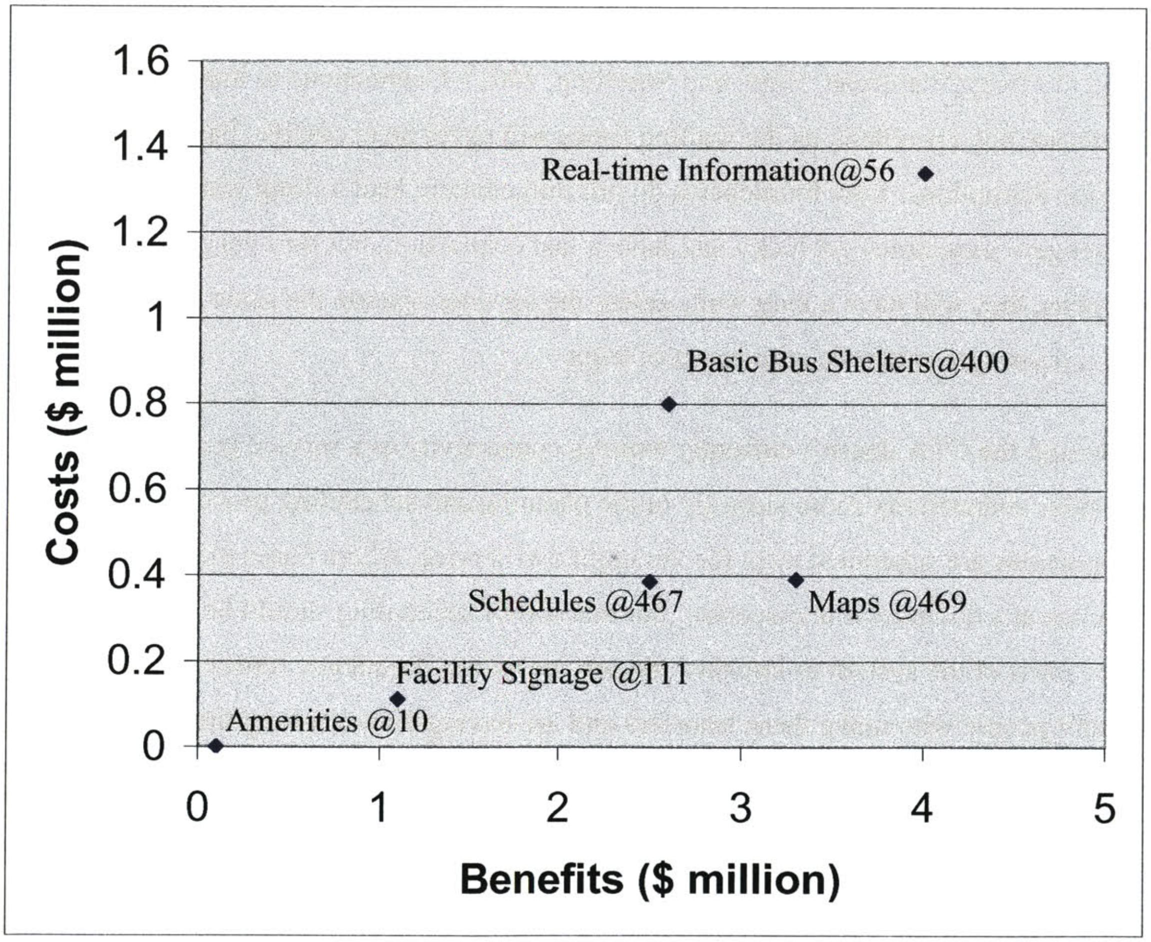
Table 4-24 Concessions

Improvement	Strategies	Agency Effects	Passenger Effects
No Concessions to Small Selection	Add coffee shop at 10 rail stations with lots of bus transfers	$0	48,022 passengers affected daily

Providing a small selection of concessions at more rail stations is likely to have the effect of making people more satisfied with transit, and this option should pay for itself. Providing a large selection of concessions at any CTA station is not likely to be practical, given the shortage of space.

Figure 4-3 shows the relative costs and benefits of these improvements.

Figure 4-3 Combined Facility Improvements - CTA



Assuming that the CTA will be most interested in improvements that have large benefits and low costs, maps and schedules should be the top priority. Then assuming that their next interest is those improvements with high benefits and large costs, they should invest in bus shelters and real-time information. Their final interest would then be improvements with low benefits and low costs, like amenities and facility signage.

Facility improvements have to comply with various standards, some of which may be CTA's own standards, and others of which may be the standards of other agencies that the CTA has to work in conjunction with.

4.7 Service Improvements

The CTA has a policy headway of 30 minutes, but headways are an hour at certain locations and times, and Pace and Metra may operate on even longer headways. Even if headways are 10 minutes, 33% of people consider a 10-minute wait at the transfer point to be too long (Wardman, Hine, and Stradling, 2001). Connections to high-frequency routes are not a problem, as the waiting times will never be excessive, barring major service disruptions. Low frequencies do not immediately lead to long wait times; passengers sometimes get lucky and have a fast connection, but for every time that happens, they will have a long wait, unless the services operate the same way every day and a passenger catches a regular set of trips.

Although the CTA doesn't currently express connectivity as a service goal, it should consider connectivity more strongly in the planning and scheduling process. Currently connections are scheduled only for the night owl service, where buses meet every 30 minutes at a downtown intersection, but this sort of scheduling should be extended to more parts of the system to improve the service on low-frequency routes. Doing so will benefit people who make these transfers and are having to wait a long time for their connecting vehicles.

Service improvements are different than facility and system-wide improvements in that it is often the case that resulting strategies will benefit some passengers but hurt others. The benefit of a strategy like increasing frequencies is that this improves the transfer situations for all transferring passengers and also improves the travel experience for all non-transferring passengers. Similarly, increasing the availability of connections by extending service hours benefits some people and harms no one. However, these actions usually come at a significant cost to the agency – an additional hour of bus service costs on average $82.78 (CTA, 2001). Some changes may require the approval of the board of directors and will need to be justified by overall demand and other service standards as presented in the service policies at the CTA, and not just connectivity demand. Even when frequencies and hours of service can't be increased, however, there are still actions that can be taken to improve the services for connecting passengers.

The greatest opportunities for reducing transfer waiting time are at terminal stations and where there are equal headways on two routes. Service management can also play a large role in reducing passenger waiting time. Some improvement strategies are shown in Table 4-25.

17% of passengers transfer at the starting point of a route, where there are many opportunities for schedule improvements. At the starting point, schedulers have flexibility with the layover time and departure times of trips, there are more likely to be supervisors present, and schedule adherence is likely to be high. Many people also transfer during times when the routes they are using have approximately the same headway. If the headways could be adjusted or if arrival and departure times could be adjusted to reduce transfer waiting time, then many passengers would benefit. Many passengers are also transferring at locations where a supervisor is present, even if it is not a route starting point. The presence of a supervisor provides an opportunity for service management to take place. Bus drivers have to concentrate on driving safely and keeping to their schedule, and so they cannot be relied on always to consider the needs of transferring passengers. However, a supervisor with information about the location of transferring passengers has the ability to make decisions that benefit passengers.

Table 4-25 Transfer Waiting Time

Improvements	Strategies	Agency Effects	Passenger Effects
Headways Matched and Arrival and Departure Time Coordinated	Timed Transfer System Look for matched headways in schedule, look at transfer volumes by direction, and schedule for dominant direction of transferring	Production time	Shorter waiting times for transferring passengers
Arrivals and Departures Coordinated	Remove Just Misses From Schedule	Production time	Shorter waiting times for transferring passengers
Service Management	Provide supervisors with tools and guidelines for minimizing transfer waiting time Bus Holding Lights	Longer running times, more equipment for supervisors, more training Installation and maintenance of bus holding lights	Shorter waiting times for transferring passengers

While waiting time can be measured directly in minutes, the acceptability of waiting time is subjective. However, except for cases when a passenger can just walk onto a connecting vehicle, passengers generally believe that their transfer waiting time could be shorter. There are some benefits to providing good connections when they happen to come along, such as with a bus holding light, but the better option would be to guarantee consistently good connections, and this begins with good scheduling.

If one of the routes terminates at the transfer point, this provides more flexibility in the scheduling because there are no through passengers whose trips will be lengthened by extended slack times or holding for the sake of making a connection. Furthermore, the layover time can be adjusted for the sake of reducing the transfer time. Even without schedule coordination, there is a higher chance of a vehicle waiting at the transfer point, so passengers can board their connecting vehicle immediately, because the vehicles will be recovering and drivers may be taking a break there. The schedules at terminals are also easier to coordinate because instead of there being 8 potential directions of transfer, there are either 2 or 4 directions of transfer, depending on whether both or only one of the routes terminates at a given point.

If there are times in the week when the headways are the same or can be made the same, then this makes scheduling connections easy, because one good connection can be planned, and the rest will be identical, assuming that the flow of passengers remains similar throughout the time period. Also, it benefits passengers to know that every trip they arrive on will be met with a good connection, as then they will not have to look to their schedules to determine the best connection.

Consistent walking times allow schedulers to coordinate service. If the distance between services is long, it is likely that there will be a large variance in the time it takes passengers to make the connection. The longer the walk, the greater the variation in connection walking time between the fastest and the slowest walker. The greater the variance in the walking time, the smaller benefits there are to scheduling connections, and when the optimization is done, the results might show that some vehicles have to leave before all of the transferring passengers have arrived. It is important to know what the connection walking time is, as this will play a part in how much time is given for a particular transfer in the schedules. With cross-platform transfers, the connection walking time can be assumed to be close to nothing. However, a minute or two should assumed for a typical bus-to-rail connection in the CTA.

The reliability of a route plays a large role in whether or not scheduling connections will actually result in better connections. The likelihood of schedule adherence increases if the schedules accurately reflect the running times on the route and if there is supervision at the transfer points to ensure that vehicles don't leave early. Due to reliability issues, scheduling connections between routes that intersect midway through the route, where they are likely to stray from the schedule, may not result in shorter waiting times. Furthermore, due to the difficulty in adhering to schedules, coordinating schedules will only be fruitful on routes with longer headways. If neither route terminates at the transfer point, then it will probably not be useful to coordinate schedules any time there are headways under 20 minutes.

The greatest opportunities for reducing transfer waiting time for transferring passengers come in the off-peak. Operators can use the most reliable vehicles at these times and there is less traffic. Most importantly, however, the headways are larger at these times, and so the benefits from scheduling coordination are higher. Table 4-26 provides a suggested guide for schedule coordination.

Table 4-26 Suggested Headway Threshold for Schedule Improvements Under Various Transfer Point Conditions

Matched Headways	Terminal	Short Walking Distance	Headway Minimum for Schedule Coordination
Y	Y	Y	5 minutes
Y	Y	N	10 minutes
Y	N	Y	15 minutes
Y	N	N	20 minutes
N	Y	Y	10 minutes
N	Y	N	20 minutes
N	N	Y	20 minutes
N	N	N	30 minutes

Going through the schedules of each route pair and looking for periods of time when coordination is appropriate is time-consuming and this thesis is not the place for the effort. However, the obvious places to start in the CTA are at the terminals, like Midway, Howard, and 95th/Dan Ryan, especially in the off-peak, when the headways are likely to be larger. The walking time at these stations is short, as they are at most CTA stations, and so schedule coordination is likely to generate benefits whenever the connecting routes have headways of 10 minutes or more if the headways are unmatched, and 5 minutes or more if the headways are matched. When headways are matched, the scheduling process is easier because the arrivals and departures of the connecting vehicles interact with each other the same way over and over again. However, with unmatched headways, the interaction between the connecting vehicles changes with every trip. This makes scheduling connections between routes time consuming for schedulers and makes the facilitation of transfers difficult for the service managers. As a result, unmatched headways lead to higher headways thresholds for schedule coordination. Many transfers occur at transfer facilities that are route terminals, have short walking distances, or host connecting routes that operate at the same headway, and so the benefits of schedule coordination would be large, especially during periods of the day when the headways are larger.

Supervision is as important to service connectivity as scheduling. Supervision at a transfer facility has the potential to improve connections, whether they are planned or not. Supervisors can help passengers avoid just misses and monitor the success of planned connections.

Bus holding lights are an alternative to supporting the intentions of the schedules. They are installed to minimize transfer waiting time at transfer points by avoiding the long waits for buses. A recent bus holding light survey (CTA, 1999) shows that at the time of the survey, 101 stations did not have bus holding lights, 8 had bus holding lights that were not working, 11 were working, but non-optimally, and the renovations being done to 22 Green Line stations had not been completed, but bus holding lights were planned for those stations. Bus holding lights are not common along the two heaviest lines (Red and Blue Line), but they are more so on the Brown Line, the Orange line, and at Purple Line stations in Evanston.

The evaluation criteria for service changes at the CTA are based on net cost per new passenger, available budget, and existing and projected ridership. The service design guidelines do, however, allow for experimental services, and so some of these strategies could be tested as experimental services before becoming permanent (CTA, 2001). The process generally assumes a need to comply with the service standards and implies that improvements can be brought about by modifying the jobs that CTA employees currently do. However, another approach would be to treat connectivity improvements as a new initiative, and suggests improvements independent of the service standards.

4.7 Cross Area Prioritization

For cross-area prioritization, the following items have to be considered:

- What improvements can be made immediately?
- Are there opportunities that have to be taken advantage of now before they are lost?
- Are there any improvements that can be made at no cost to the agency?
- What is the top responsibility of the agency?
- What improvements will bring the most benefits to passengers?
- What are the annual costs and benefits?

Scheduling is done by the CTA and changes can be made and implemented very quickly. If the schedule changes don't significantly change the service that is provided, then they don't need the approval of the board of directors. Time points can also be changed fairly quickly. However, time would be needed to gather running time data to make sure that the times listed at the time points are reasonable.

The capital improvements program being undertaken under the management of URS is a prime opportunity to improve the experience of transferring passengers. It is providing opportunities for facility improvements, especially those such as bus shelters or second entrances to rail stations, which are potentially very applicable to heavy bus-rail transfer points such as those along the Red Line.

No improvement is without some cost, but of the elements considered, only transfer waiting time improvements can often be made at very little cost to the agency. There will still be the time that it takes the schedulers to revise the schedules, but this is minimal compared to the time savings of passengers, given the large number of passengers, the number of minutes of waiting time that could be avoided per passenger, and the fact that the schedules are used every day.

Providing good service should be an agency's top priority, since it is fully responsible for the services that are provided every day. While the CTA is also responsible for the transfer facilities, this responsibility is shared with other Chicago agencies.

System improvements, given that facility improvements can't be spread everywhere, and service improvements will be rather diffuse, would probably provide passengers with the most benefits. However, they would also cost the agency a lot of money. The cost of certain system improvements would exceed the cost of many of the individual facility improvements – in a single day. However, if as a result of schedule improvements a minute was removed from every passenger's wait time at the transfer point, the benefits would be comparable to the benefits of providing free transfers.

Service improvements should be the main focus of the CTA. They should be continuously addressed and considered for improvement. System elements can be ignored for periods of time, facility elements can be ignored somewhat, but services have to be addressed on a continual basis. However, the CTA is in a special situation since it has funding to renew many of its stations and facilities. It should use this opportunity to build facilities that are more conducive to transferring. Therefore, service improvements should be prioritized, then facility improvements, then system improvements. However, it is likely that improvements in all areas can be achieved in parallel. It is also probable that the overall effect of improving service connectivity will be maximized if improvements are made in multiple areas, given the synergies of many of the elements. For example, lowering the transfer fare would induce ridership, and the CTA would have to respond with higher frequencies, and this would reduce the transfer waiting time for transferring passengers.

Table 4-27 shows the suggested service connectivity improvement plan for the CTA that is a result of this process. It attempts to put the improvements in a logical order, staying true to what should be priorities at the CTA.

The first priority should be improvements to the schedules. Schedules should be coordinated at terminal points first, as this is where the most benefits are likely to be obtained, given the wider range of headways that schedule coordination can accommodate and that there are so many options for making transfers at terminals in the CTA. Furthermore, many of the connections between the CTA and the other transit services, Pace and Metra, occur where at least one of the routes is terminating. It is very important that the CTA have good connections to and from these other service providers because the suburban market is large and growing. Depending on the situation, some of the schedule changes will lead to matched headways and coordinated service, and others will lead to services that are coordinated such that just misses are avoided. This will depend on the compatibility of the headways. The long term plan for the schedules could be to standardize the longer headways around a small set of values, for example, 15, 20, or 30 minutes.

Once the schedules have been written to reduce the waiting time of transferring passengers at teriminals, then the focus should be on routes with headways of 20 minutes or more. Many routes have headways of 20 minutes or greater in the late evening, before the night owl service has begun but before demand has drastically dropped off. Where the schedules haven't yet been "locked" by the schedule changes at the terminals, the schedules of low-frequency routes should be coordinated such that the transfer waiting time is minimized. With lower frequencies, there is less production time needed to adjust the schedules, as there are fewer trips to coordinate. Furthermore, the elimination of very long transfer waiting times from the schedules will bring large benefits to transferring passengers. If possible, the headways of the low-frequency routes should be matched so the connection times are consistent.

Once the schedules have been modified to reduce transfer waiting time, service management should be used to support the intent of the schedules. Ideally the vehicles would be able to adhere to the schedule, but there is always some variability. Currently, the major goals of service management are to ensure that there are no major gaps in service and that all passengers are carried to their destination. Waiting time in general should become a higher priority, and this includes the waiting time of transferring passengers. Service managers would benefit from information about the current location of buses, as it would allow them to make better decisions about whether or not it is worthwhile to have one vehicle wait for transferring passengers from another vehicle. This information could come from GPS tracking of vehicles or radio contact with the drivers or the operations control center. Service managers cannot be present at every transfer facility or at all times of day, and so there should also be a way to manage service either from the control center, or locally, by the operators.

Once the improvements have been made for the services that the CTA provides, both in terms of the schedules and the service management, then the improvements can be publicized with new schedules and maps. The analysis of different facility improvements suggested that installing schedules and system maps at major transfer facilities is an improvement that would generate large benefits at a relatively low cost. The schedules could highlight the connections that have been planned and the synchronization of schedules, and the maps would show the available connections. Schedule modifications may not have been made at every transfer point, but the transfer conditions will be improved with the presence of a schedule and map.

In many cases, it will be economical to install the schedules and maps with a bus shelter. A bus shelter with schedules and a system map should become the standard features of a bus transfer facility. Along with the presence of a supervisor, transferring passengers will get the message that their major travel needs – comfort and short waiting times – are being recognized by the CTA.

Once transfer facilities start being considered "places" in the sense there is street furniture, additional riders, and supervisor presence, then the CTA can offer more attractive locations for concessionaires to sell items. The greatest potential is at rail stations where there is real estate that the CTA can offer.

Table 4-27 Suggested Service Connectivity Improvement Plan for CTA

1) Improve Schedules
    a. Terminals
    b. Routes with Headways Over 20 minutes
2) Gear Service Management Towards Service Connectivity
3) Install Maps and Schedules at Major Transfer Facilities
4) Install Shelters at Major Transfer Facilities
5) Invite Concessionaires to Improved Transfer Facilities

This is the suggested plan for the short and medium term. In the long term, the CTA should consider real-time information at major transfer points. Also, there will be more opportunities for service connectivity improvements as improvements are made throughout the system. If the service can become more dependable, with better service management, a better communication system, and better equipment, then there will be more opportunities for schedule coordination. As stations are renovated, there will be opportunities for adding features that are conducive to providing good transfers, such as covered walkways and escalators. As BRT improvements are made, running time are likely to become shorter, and this will allow higher frequencies, which is conducive to good connectivity. Furthermore, if the system can attract more passengers, then there may be justification for longer service hours, which is also conducive to service connectivity.

4.8 Monitoring

Monitoring is an important part of this process because it will allow an agency to observe the connectivity improvements in the system and to determine if they are affecting the system in positive ways by increasing ridership, improving customer satisfaction, and improving efficiency. In general, transfer volumes, customer satisfaction, and services all need to be monitored, but the monitoring needs to be geared towards the kinds of improvements being made.

For example, if price is changed, then ridership has to be monitored for the new transfers that are free or discounted. It will be important for the CTA to know how passengers respond to lower costs to predict the effects of future fare changes.

Similarly, if facility improvements are made, transfer volumes should be monitored at the affected transfer points to see which improvements led to higher levels of customer satisfaction or ridership, so that the agency will be able to decide whether to extend the improvements to other transfer points or to attempt other improvements.

Transfer rates and customer satisfaction levels on services and transfer points that are affected by service improvements should be monitored. It would be useful to get measures of the actual transfer waiting times and the effect of the transfer scheduling and holding on total running time. Making use of AVL information would be an efficient way of monitoring the services to make sure that the connections are occurring as scheduled.

Chapter 5. Summary and Conclusions

This chapter will summarize the results of this research. It will describe the framework that was established, the process that was built around this framework, and the results of applying this process to the Chicago Transit Authority.

5.1 Summary

In order to better understand how connectivity might be improved in a transit system, a framework was developed for categorizing connectivity issues. Through a review of prior efforts to understand the transfer, those elements that were most important to connectivity were identified. In order to present these elements in such a way that suggested a direction for their improvement, a tier was developed for each element. A tier shows the best, worst, and mid-quality levels for an element. Elements were also categorized as system, facility, or service elements in order to rank them with similar elements and prioritize them against elements that would be competing with them for funding and attention. Finally, a process was developed which assessed connectivity within a given boundary, tailored the process according to the assessment, prioritized improvements in each area and across areas, and made suggestions for monitoring connectivity so that future iterations of the process would have a better basis for decisions.

There are thirteen elements that are particularly important to transit service connectivity. Five of them are system elements. System elements affect transferring passengers throughout the system, and due to their universality, a change in a system element can have a significant impact on the system. The five system elements are transfer price, pre-trip information, fare media, in-vehicle information, and fare control.

Six of the elements are facility elements. Good facilities provide many benefits to passengers, but they are often costly. Transfer facilities are usually not uniform throughout a system, so different improvements will be appropriate for different facilities. The six facility elements are weather protection, en-route information, changing levels, road crossings, walking distance, and concessions.

Two of the elements are service elements. The services are more complex, and their effect on transferring passengers is great. The two service elements are transfer waiting time and span of service.

Once the important elements were selected, the features of these elements that made them good or bad for connectivity were determined, fulfilling the first objective, creating a definition for good connectivity. The elements were also ranked within their area according to their importance to passengers, and this further contributes to the understanding of what makes good connectivity. From the perspective of the transferring passenger, the transfer should be inexpensive, short, and comfortable. The best levels for the elements are shown in Table 5-1, and the tiers are described in detail in Chapter 2.

Table 5-1 Elements and Their Best Levels

Element	**Best Level**
SYSTEM	
Transfer Price	Free
Pre-trip Information	System Information with Trip Planner
Fare Media	Same
In-vehicle Information	Transfer Announcements, Real-time and Static Information on Connecting Routes
Fare Control	No Validation Needed and Can Leave Public Transportation Space
FACILITY	
Weather Protection	Fully Protected Connection
En-route Information	System, Facility, Schedule, and Real-time Information
Changing Levels	No Vertical Separation
Road Crossings	No Road Crossings Required
Walking Distance	No Walking Required
Concessions	Large Selection
SERVICE	
Transfer Waiting Time	High Frequency on Connecting Route
Span of Service	Matched

Service elements generally have the most potential for cost-effective improvement. If there are matched headways, buffer times, short connection walking distances, supervision, or driver-to-driver communication, then the opportunities for short transfer waiting times are great. Shorter transfer waiting times can be achieved through scheduling and/or service management. Most transit agencies have a good deal of control over the services they provide, and they should do what they can to make them as passenger-friendly as possible. Agencies will be limited in the number of service hours they can provide due to budget constraints, but often the situation for transferring passengers can be improved by changes in the schedule and through better service management.

While agencies have to focus on the services they provide on a daily basis, they should also regularly review their facilities. Facilities don't have to be operated or managed in the same way that services do, but they still require regular maintenance and renovations. Facility improvements are investments that benefit passengers over a long period of time and can make transferring more comfortable, shorter, and less stressful.

System improvements can make instantaneous changes in a system, but opportunities for them do not arise very often. Fares do not change very often, and once a website or phone service has been established, they cannot be changed frequently or quickly. System improvements might be considered when opportunities for change present themselves or the system needs a major change for it to remain competitive with other modes.

The second objective of this research was to develop a process for assessing and improving connectivity. In this process, connectivity is assessed according to what conditions passengers are transferring under. As a result of the assessment, certain elements are considered for improvement. Choosing improvements begins with the connectivity framework and establishing thresholds for various improvements. Transfer facilities or route-pairs that meet the standards for a given improvement are then identified. Then packages of improvements are determined, such as installing maps at all major transfer facilities, as there will be economies of scale for bringing improvements to multiple transfer points at once, presumably, and because many transfer points will need certain improvements. The costs of the different improvement packages are evaluated, and those improvements that can bring the most benefits at the least cost are prioritized within each area. Then the improvements are compared across areas and prioritized again. The process comes to a close with a monitoring step that aims to improve future iterations of the process and observe the progress of the connectivity improvements.

5.2 CTA Recommendations

The third objective of this research was to apply the process to the Chicago Transit Authority. The assessment showed that there are several connectivity elements that could be improved. First, at the system level, most passengers pay a discounted fare for their transfer rather than have a free transfer. Pre-trip information and fare media perform quite well, though. Most CTA vehicles do not provide a high level of in-vehicle information, and the fare control system is less convenient that it might be, but passengers generally don't care very much about in-vehicle information or the fare control system compared to price.

At the facilities level, weather protection and en-route information are rather poor at the CTA. Passengers transferring to the rail system are provided with basic shelter, but passengers transferring to the bus system generally have nothing. Most passengers have some sort of assistance when they are changing levels, but a large portion of the transferring population does not, as many stations do not have functioning escalators. The walking distances are generally short. Most transferring passengers have no concessions.

In large part due to the fact that they are not a part of the existing service standards, the schedules generally are not coordinated with the intention of reducing transfer waiting time. Neither are spans of service matched for the purpose of maximizing the transfer potential.

Of all the system elements, changing the transfer price has the greatest potential to improve customer satisfaction and increase ridership. Even though the loss in revenue would be large if the transfer fares were eliminated, more riders or a base fare increase would balance the losses. If the base fare were to be raised to $1.80, and the transfer fare eliminated, the CTA's revenue would actually increase by approximately $27 million per year, assuming typical elasticities.

The facility elements with the highest potential for improvement are weather protection, en-route information, and concessions. 47% of passengers have no weather protection, and those that do may not have their walkway covered. Most passengers do not have schedules available at the place they are transferring, and this may leave some passengers unsure about how long they will be waiting and whether or not there is a vehicle coming at all. Also, most passengers do not have access to concessions when they are transferring. While this is not as important to passengers as being protected from the cold or the heat or having information, it is not very expensive for the CTA to have more vendors in and around transfer stations, and so this is a potential area of improvement. Based on the estimated costs and benefits, the order of the improvements should be maps and schedules, basic bus shelters, then real-time information. For facility elements, the standards and best level criteria developed in this thesis could be used as guidelines for future design and reconstruction.

For service elements, there is potential for reducing the transfer waiting times at the CTA. While some strategies for reducing transfer waiting time, such as increasing the frequency on a route, are expensive, others are not. Modifying arrival and departure times from a transfer point has the potential to reduce the transfer waiting times of passengers by a significant amount. If modifying the schedules can reduce the transfer waiting time of every transfer by one minute, the benefits to passengers would outweigh the costs to the agency of building ten fancy bus shelters – in one day. This shows how large the potential benefits could be, and suggests that this is where the CTA should be focusing its efforts if it wants to improve its service in the most cost-effective way. There is room in the service standards for more attention to be paid to transfers. After all, half of CTA passengers make transfers, and the schedules should reflect this. For example, the CTA could standardize headways and require that all headways be 10, 20, or 30 minutes in the off-peak, for example, as this would make it easier to coordinate schedules. It could also introduce transfer waiting time criteria in the service standards. For example, it could require that the schedules should not make passengers wait more than half of a headway for a connecting service.

In Chapter 4, a plan was presented for improving transit service connectivity at the CTA. The first step would be to improve the schedules, starting with terminal transfers and then addressing transfers between low frequency routes. Schedulers would assume that the number of vehicles assigned to a route wouldn't change and would look for schedule coordination opportunities, starting with the most popular route-pairs and moving onto the less popular ones. The next step would be to create a service management plan that supported the new schedules. Service managers would have to be trained in how to facilitate transfers. The locations of some supervisors would have to change, and some of the responsibility for ensuring that connections are made might lie instead in the operations control center or with the operators themselves. It will depend largely on who will have access to information about the location of vehicles and who will be in the best position to make a good decision.

Once the schedules and service management plan have been established, the transfer facilities can be improved with schedules and maps publicizing the service improvements. Bus shelters should also be added, both to hold the schedules and maps, but also to protect passengers from the elements. The benefits of maps, schedules, and bus shelters is quite large, and considering that the City of Chicago is expecting 2000 new bus shelters in the near future, many of which could be positioned at transfer facilities, the improvements are relatively inexpensive.

Finally, with the transfer facilities better defined by the presences of shelters and schedules, and possibly supervisors, and hopefully more passengers, there would be a greater incentive for people to open stores or concessions at or near transfer facilities. This would benefit passengers, giving them the opportunity to make a purchase while they wait for a connecting vehicle, as well as providing the transfer facility with additional security. The CTA doesn't own property at its bus-bus transfer facilities, but it does control real estate at its bus-rail transfer facilities, and so the real estate department should actively seek out tenants for the spaces in its rail stations. This would improve the transferring conditions for passengers and may even bring the CTA additional revenue.

In the long run, the CTA should try to acquire technology to help its service managers and supervisors reduce transfer waiting time. It should also make use of its GPS system and provide passengers with real-time arrival information. Future stations should be designed for transferring passengers, and stations in the medians of highways should be avoided because it is difficult to bring improvements to these stations. The service design guidelines should demand more from the schedules so that the needs of transferring passengers are better served.

5.3 Future Work

This research attempted to cover many areas, and so it is not surprising that not all of the areas could be fully explored and that there is clearly a need for more research on how transit agencies should improve transit service connectivity. This research lies in the areas of service management, station design, market research, and data analysis.

Service Management

Service Management Strategies at Transfer Points

This research would follow up on efforts to better coordinate the schedules of connecting routes. Connections with matched headways, one headway that is a multiple of the other, or schedules that have been rewritten to reduce the chance of just misses will need different types of service management. The type of actions that need to be taken will also vary by time of day, load, amount of deviation from the schedule, and the technology that is available to the operators and the service managers. By facilitating connections that have been incorporated into the schedules, the service managers will be taking on responsibilities beyond those that they already have. Whether the decisions are pre-determined or dynamic will depend on the information available to the service managers. The major question that a service manager has to answer is how long a vehicle should be held to facilitate transfers to and from another vehicle. They have to balance the needs of transferring passengers with the need to minimize the travel time of through passengers and to make sure that gaps don't develop along the route they are managing. They also have to balance the need to keep service evenly spaced and to follow the schedule. This research would be most beneficial if the results of service management actions were observed and compared to the service that passengers received when service management was done as it is typically done.

Schedules for Connections

To allow for shorter transfer times, the schedules will have to be remade, and perhaps even made differently. By giving more slack time at points where there are many transfers, the likelihood of passengers having short transfer waiting times can be increased. However, sometimes the transfer points with the heaviest transfer volumes occur midway through a bus's route, where there is no slack time in the schedule. The majority of the slack time in most schedules is built in at the terminals. This suggests that routes may benefit from having their terminals be at the major transfer points. The CTA is experimenting with this for some transfer routes that intersect the rail lines midway through their route. These efforts should be monitored to see if they are successful and to help determine if the changes should be carried out at more times of the day or on more routes.

Effects of Introducing Standard Headways at the CTA

Rewriting lower frequency schedules with a discrete set of headways, such as 10, 20, and 30-minutes, would have the effect of making schedule coordination much easier. It would be interesting to know how expensive it would be to make such changes.

Optimal Placement of Service Managers for Facilitating Transfers

Some transfer types will require different types of service management. Some will benefit from the real-time decision-making capabilities of an on-site supervisor. Which transfer points are the best candidates for these supervisors should be decided and balanced against where the service managers are needed to control a route, regardless of the transferring passengers.

Market Research

Passenger Response to Change in Transfer Price

Studies have been done to show how transit passengers respond to fare changes, but there has not been a study specific to changes in transfer fare. It would be useful to have a better understanding of what the ridership effects of a change in the transfer price would be.

Design of a Survey Agencies Can Use To Support or Establish Element Rankings and Tiers

The CTA already conducts a survey of its passengers every two years, and it would be useful to have passengers questioned specifically about the elements in the framework. This could help attach values to specific improvements and confirm the ordering of the elements or perhaps suggest a reordering.

Data Services

Real Performance Measures for Service Elements

Harnessing AVL data to measure actual transfer waiting times would be a useful way of determining the benefits of various schedule improvements. Without this information, transfer waiting time must be estimated either from the schedules or from passenger surveys, and these may not reflect the real situation.

Monitoring Transfer Volumes

Providing regular reports on transferring throughout the system would help to ensure that the needs of transferring passengers are considered and that improvements are focused on transfer facilities where the most people will be affected positively. It will also help with the monitoring process.

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