Multi-Centered Time Transfer System for Capital Metro, Austin, Texas

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This paper describes how a radial bus route system was modified into a multi-centered timed-transfer bus network. The intent was to modify the transit network to fit the modern city, which has many centers in addition to the Central Business District. The system is particularly applicable for cities that have a low density of development with typical midday bus headways of 30 minutes. Some implementation problems occurred, particularly because no off-street facilities were obtained. The locations that were established are either on street or on a shopping center. It is concluded that existing networks can be adapted into a Timed Transfer System, and that for systems with long headways network optimization is more critical than route optimization.

The Capital Metropolitan Transportation Authority (Capital Metro) was voted into existence on January 19, 1986, when the citizens of Austin, Texas and several adjacent jurisdictions voted themselves a one-cent sales tax for transit service. Officially Capital Metro took over responsibility for providing transit services in the capital region on July 1, 1985.

Before the vote in January 1985, an interim board had supervised a study to give Capital Metro a Service Plan (*1*). The interim board also visited a number of cities in August 1984 to see for themselves how other cities provide transit service. One of the cities visited was Edmonton, where the interim board viewed the operation of the Timed Transfer System, as well as the Light Rail Transit line.

SERVICE PLAN

The Service Plan for Capital Metro (*1*) tried to correct the ills of an underfunded system. The Austin Transit System of approximately 85 buses served a population of about 500,000. Service usually meant a headway of 40 to 60 minutes midday and 20 to 60 minutes in the peak. The Austin Transit System interlined a number of routes, forming a kind of figure eight. Unfortunately these long routes were subject to traffic delays, adherence to schedules was characterized by a certain randomness. Needless to say, patronage was low.

The vote to approve a one-cent sales tax showed that the population of Austin wanted something better. The Service Plan recommended that Capital Metro provide clock headways with a midday headway of 30 minutes and 15 minutes in the peak if justified. Also, it recommended increasing the size of the bus fleet in service during the peak hour to 314 fixed route buses, 21 Dillo buses (a downtown bus that looks like a streetcar trolley) and 14 or more Special Transit Service buses for the mobility impaired by mid-1988. The Service Plan recommended numerous new routes, including several cross-town routes and Transfer Centers.

In May 1985 the Capital Metro Board authorized a study to see whether the Service Plan could form the basis of a Timed Transfer System for the Austin area (*2*). It was concluded that with modifications, the Service Plan could serve as a basis and a Timed Transfer Concept (Figure 1) was accordingly developed. The study was followed by an Implementation Study (*3*) for the Capital Metro Service Area. This paper deals with the development of the Timed Transfer Concept plan, as well as the difficulties encountered with implementation.

MODERN CITY

It is probable that a substantial difference exists between the City as it actually is and as it is perceived. Many planners and transit operators view the city as having a Central Business District (CBD) surrounded by reasonably dense development. This area is usually provided with a fixed-route radial type of transit system. Surrounding this "perceived" city is suburbia, which is difficult to serve and which is often ignored by transit operators.

The actual city is more dynamic than generally assumed. It may still have a CBD, either declining or in the process of renewal following a decline. The pattern has often been that central city residents migrated to the suburbs. However, some renewal is occurring closer to the city center. As shopping centers of various sizes develop in the region, they are assuming the characteristics of mini-business districts. Lately, office centers have also been locating throughout the region.

The City of Austin is a perfect example of this dispersed development: it has experienced very rapid growth in the past two decades and shows CBD renewal as well as the development of regional centers.

For a transit system to serve only the CBD means limiting its potential market. If the city has become multi-centered, the transit system must serve these multi-destinations as well. The Capital Metro transportation system of Austin will provide a rare opportunity to observe the following:

1. How the transit network was adapted to serve a multi-centered city, with a Timed Transfer System, and
2. Whether transit patronage increased.

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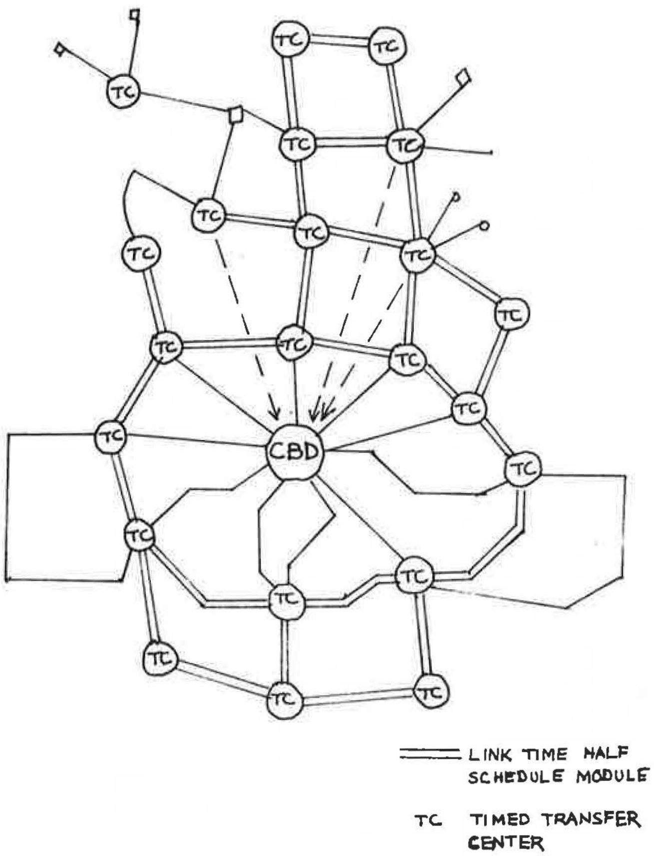

FIGURE 1 Timed transfer concept.

This paper will confine its discussion as to how the transit network is being adapted into a Timed Transfer System. The adaptation will require two or three years, because land has to be acquired for some of the proposed Transit Centers. The effect on patronage cannot be measured until two years after full implementation.

TIMED TRANSFER CONCEPT

In a Multi-Centered Timed Transfer Network, transit tries to provide opportunities for travel from any given point to any other given point. The aim is for all transit routes (Rail, LRT, Bus, Paratransit) to meet simultaneously at the same location at regular intervals (preferably the same minutes past the hour). To accomplish this, routes and schedules have to be developed together. In many cities in the western United States and Canada, as well as the suburbs of older cities, the density of development is low. The result is that the headway that can be justified at midday is usually 30 minutes. In peak hours the service is more related to demand volumes and service is therefore more frequent. A Timed Transfer System would not be the system to choose if the density of development is such that frequent service (or headways of 10 minute or less) can be provided all day.

If the headway is 30 minutes, buses would meet along a route every 15 minutes. Allowing for a layover/recovery time of 3 minutes, a meet could occur every 12 minutes of travel time. At that location, crosstown routes and/or feeder routes could also meet. In fact, with a Timed Transfer Network, a kind of super-grid develops with transfer locations about 12 minutes travel time apart. By locating the (Timed) Transfer locations some distance away from the CBD, the crosstown distances between centers can also be 12 minutes of travel time and form a circle or square, the circumference of which is (h times 12) minutes for each side. In any particular system this circle need not be closed. Consideration should also be given as to whether express buses are justified from the first and/or second rings of Transit Centers.

DEFINITIONS

The definitions used in the transit industry vary greatly, so the same definitions as used by Vuchic in his books and manuscripts (*4, 5*) will be used here.

h = headway
h_p = pulse headway, also called schedule module
h_i = headway of individual route
j = integer
L = route length
N = number of buses or vehicles, $N = T/h$
T = cycle time, equal to 2 sum of $(T_o + t_t)$
T_o = travel time = (operating travel time)
t_t = terminal time (layover/recovery time)
V_c = cycle speed (V_c for cycle is $120 \cdot L/T$)
V = operating speed ($V_o = 60 \cdot L/T$)

For transfer meets to occur, $h_i = j \cdot h_p$ or any individual headway has to be equal to or be a multiple of the pulse headway or schedule module.

For clock-headways, 60 minutes $= j \cdot h_j = j \cdot p$. The schedule will repeat at the same minutes past the hour.

For travel time between centers, $j\,(T_o + t_t)/2 = j \cdot h_p/2$. The travel time must be equal to or be a multiple of half the schedule module, which is equal to the pulse headway or sum of operating time plus terminal time.

For travel time for a feeder route, $= h_p \cdot j - t_t$

DEVELOPING THE TIMED TRANSFER CONCEPT

A Timed Transfer Concept is developed by starting at one specific location—a shopping center, for example. From this location there would be one or more radial routes to the central business district (CBD). The possibility of there being more than one route arises from the fact that adjacent radial routes may be changed to go to the same Timed Transfer Center. The second set of routes developed would be crosstown routes. Using the road system available, several 12-minute travel time distances are plotted, to determine suitable locations for other transfer centers. The third set of routes would be feeder routes serving residential, industrial or office areas. The possibility of establishing express routes from the transit center to the CBD or another major destination, such as a university or government center, should also be explored. This express route could be a peak hour-only service or an all-day service, depending on demand.

In Austin the starting point was Highland Mall (H) (see Figure 2). From this mall it was possible to reach Windsor Park (or Capital Plaza) (D), Hancock Center (E) and North-

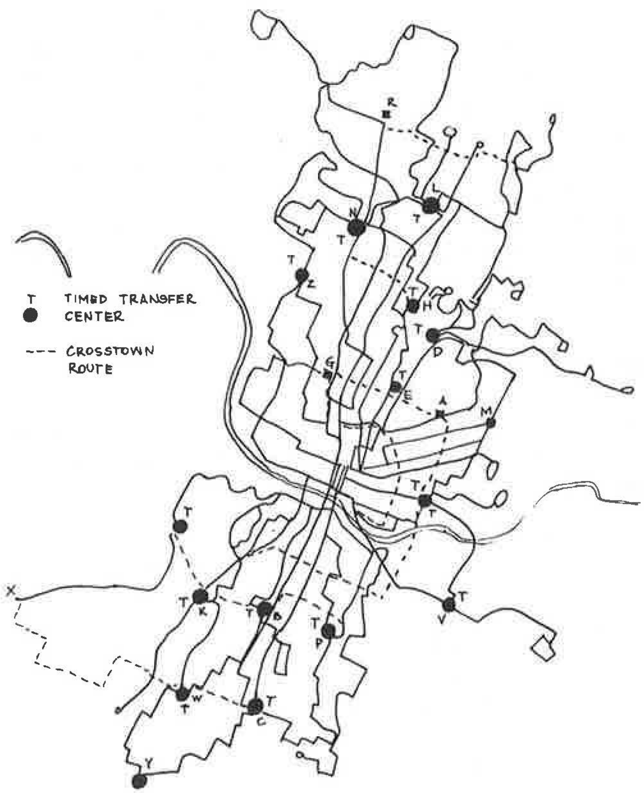

FIGURE 2 Proposed multi-centered time transfer system.

cross Mall (N) (via Justin Avenue) in 12 to 17 minutes. Northcross Cross Mall and Windsor Park were then used again as starting points to locate the next set of transfer centers. From Windsor Park these were MLK/Springdale (M) and the municipal Airport (A); from Airport and Springdale/MLK the next center is East 7th and Pleasant Valley (T), the next one is Vargas and Riverside (V), from there IRS/I.H.35 (P) and so on along the Ben White Crosstown route to Radam (B), Westgate (K) and Barton Square Mall (F).

It is preferable that transfer locations in a Timed Transfer Network be off-street, so that passengers can transfer between buses safely as well as quickly. On-street transfer locations should be viewed as temporary. Transfer locations are often located at existing or proposed activity centers such as shopping malls, colleges or universities, hospitals, or stadiums. However, a park-and-ride lot near the intersection of a freeway or arterial road may also be a good location.

With a Timed Transfer System, it is also possible to develop a kind of super-grid beyond the first set of Transit Centers. The sides of the links in this super-grid have a length of $(h_p - t_t)/2$, or for a 30-minute module, about 12 minutes' travel time. The links in the super-grid can form a square or a rhombus.

The travel times to the CBD are not necessarily critical. The main control is that the round trip time of any route is either equal to h_p or a multiple of h_p. For a 30-minute module that means 30, 60, 90 or n times 30 minutes. Sometimes two routes of 45 minutes can be combined and give a total of 90 minutes total round trip time. All these travel times are taken midday which is the design period.

In the CBD the transit routes can be concentrated on one transit street or transit mall, or can be dispersed over a number of streets. It all depends on the land use and the shape or layout of the City Center. Smaller cities may also have a Timed Transfer Center downtown. In the case of larger cities that may not be desirable because of traffic congestion. An example of having a downtown transfer center is Saskatoon, Saskatchewan, Canada; here one downtown block has been converted into a transit mall, where all routes meet at the same time.

It is more usual for larger cities to link routes on either side of the CBD and create a diametric route, depending on travel time and passenger demand. The regular transit routes may be complemented with downtown distributor routes which operate frequently: in Austin the Dillos fulfill this function.

From the foregoing discussion, it can be seen that travel time and terminal time are the critical components. The design should be based on the basic midday service, because there is usually a more frequent service available during the peak hours. For that reason special attention must be paid to scheduling, in particular since routes and schedules are developed together. For a Concept Plan average speeds can be used; however, implementation requires simulated test runs in actual traffic conditions.

In a Timed Transfer System there is also some flexibility when overloads occur. For example, if a feeder bus overloads a main line bus, the feeder bus should be continued to the CBD or any other major trip attractor (CBD, Government Center, University) in addition to the main line bus. The possibility of running the feeder bus continuation express or limited stop should also be investigated. Continuing a number of feeder routes would lead to the platooning of buses, an alternative which may be preferable to that of providing more frequent service. First transfers are maintained to crosstown routes, but the demand may vary between summer and winter (university in session), allowing more or less through running. In other words supply can more easily be matched to demand, without having to reissue timetables, with the connection still in place.

In Edmonton, Alberta, feeder buses have been extended in the peak hours from Transit Centers as express runs, and in some cases there are six feeder routes that have to be continued, forming platoons of six buses at a time. It is of course possible to replace these six buses with one L.R.T. train at a later time.

Feeder routes can serve more than one Timed Transfer Center. For example, a direct route between two Transit Centers requires 12 minutes of operating time and 3 minutes' terminal time. A feeder route linking the same two terminals could take 41 minutes operating time with 4 minutes' terminal time.

One of the big advantages of a Timed Transfer System is that further route development can take place incrementally from any Timed Transfer Center. The only requirement is that the feeder route has a round trip length equal to (schedule module or pulse headway minus terminal time). For a 30-minute schedule module this round trip travel time would be about 26 minutes.

In addition, feeder routes can also be become demand-responsive during low patronage periods and could be combined with Special Transit Services operations, which are services for the mobility-impaired.

SCHEDULING APPROACH OF TIMED TRANSFER SYSTEM

In a timed transfer system routes and schedules are developed together, and transit centers must be located equidistantly from each other in terms of travel time; therefore linear optimization is not as easy as in other types of transit networks, where routes are developed individually. Timed Transfer means that the problem of optimization is not linear but two-dimensional. Timed Transfer is designed to confer travel opportunity, and therefore holds the potential of more patronage. Waiting time is evaluated by the passenger as four times that of riding time, an evaluation that does not show in linear scheduling optimization. The philosophy here is: "It is better to operate with a little less bus and schedule optimization and have passengers in the buses, than to have schedule optimization and empty buses."

By placing the layover/recovery time (terminal time t_t) at the transit centers, the randomness along the route can be reduced, which greatly improves schedule reliability.

For Timed Transfer to work there is a need to obtain reliable running times for the various times of the day. The midday period will be used for design. Layover time should occur only at the Transit Center and nowhere in between. Buses should never run ahead of schedule, so that operating time should be established in such a way that it would be impossible to run ahead of schedule. In other words for on-time performance it is better to set the operating time sharp and increase the terminal time. In practice, it may mean that the bus will arrive a few minutes late into the terminal. However, because of the increased terminal time, connections can still be made.

There are a number of different transit markets that should be kept in mind, such as the following:

1. To relieve peak hour traffic.
2. To relieve parking demand, particularly at major activity centers. (Both 1 and 2 are the better use of scarce space.)
3. Service to those who do not want to drive.
4. Service to the mobility-impaired (this service may be on regular transit or Special Service Transit).

For these markets there are different time periods that require different intensity of service. These periods are differentiated by the following:

Period 1. Offices and other places of work opening and closing for their employees (the a.m. and p.m. peak hours on weekdays, Monday through Friday).

Period 2. Time that offices and stores are open [midday].

Period 3. Time that offices are closed and stores are open. (This is the case in the evenings Monday through Friday, from 11 a.m. to 6 p.m. on Saturdays, and increasingly in the afternoons on Sundays and holidays.)

Period 4. Time that offices and stores are closed. (Early Saturday, Sunday morning, Sunday evening and late evening Monday through Saturday.)

The scheduling periods shown in Table 1 should therefore be considered. These times may differ in each community, in that stores may or may not be open on Sundays and holidays. Also store opening times on Saturdays vary; in some communities stores are closed on Saturday evening. The latest service should be able to cater to the last movie-theater performances. The type of equipment used should be related to the demand.

TRAVEL TIME CHANGES

On current bus routes, the operating time can be determined by a "speed and delay" study on board the bus. In new areas a simulated transit run should be made. In the case of proposed subdivisions, average speeds in similar areas should be used. In developing a "concept plan" average speeds can be used; however, when the functional plan is developed actual running times must be used. In the peak hours travel time may increase due to traffic congestion. Again, speed and delay studies should be made. On the residential feeder routes more time may be required in the morning peak hour since there will be more boardings and fare transactions. This delay can be reduced by the use of passes or multiple ride tickets. Usually the midday running times remain feasible during the peak hours on feeder routes.

However, bus routes along radial and arterial roads will suffer from traffic delay. The running time chosen here should permit the vehicle to be on time.

If the frequency of service is doubled in the peak hours, the headway is halved. It then becomes possible to increase operating time. For example, the sides of the super-grid (operating time plus terminal time) in a congested region may be increased from 15 minutes to 22.5 minutes, since meets with a headway of 15 minutes occur every 7.5 minutes.

There are two primary concerns with a Timed Transfer System: what happens when travel time increases and what if travel time decreases. Each of these problems can occur permanently, temporarily or occasionally.

TABLE 1 SCHEDULING PERIODS

Day of Week	Time of Day					
	6–9 a.m.	9 a.m.–Noon	Noon–3 p.m.	3–6 p.m.	6–9 p.m.	9 p.m.–Mdnt.
Weekdays	a.m. Peak Period 1	Midday Period 2	Midday Period 2	p.m. Peak Period 1	Evening Period 3	Night Period 4
Saturdays	Early Sv. Period 4	Midday Period 3	Midday Period 3	Midday Period 3	Night Period 4	Night Period 4
Sundays	Limited service	Early Sv. Period 4	Midday Period 3	Midday Period 3	Night Period 4	Limited service
Holidays	Limited service	Early Sv. Period 4	Midday Period 3	Midday Period 3	Night Period 4	Limited service

Travel Time Increases

The first step is to analyze, by implementing a speed-and-delay study aboard the bus, the real cause of the increase in travel time. Sometimes the cause may be transit operations, such as poor schedule adherence by the driver, or the driver's stopping the bus for a cigarette or other type of break, or poor schedules. If the cause is traffic signals, then the answer should be found in traffic management. However, other solutions are also possible, such as reducing the number of bus stops along the route from every block to every other block.

Other approaches are as follows:

1. Establish far-side bus stops.
2. Study specific bottlenecks, whether lanes be added or whether transit can be given special priority. One of the easiest methods is to institute a "right turn lane only," except for buses. This solution goes well with establishment of a far-side bus stop bay.
3. Reduce signal cycle times. In many cases there is a mistaken belief that longer cycle times are more efficient and that more phases improve efficiency. Phases and cycle times should be reduced whenever possible.
4. Investigate the type of fare systems that will speed up boarding, such as passes, multiple ride tickets, and similar means. Other passenger-handling techniques, such as boarding through more than one door, should also be investigated.
5. Reduce terminal time.
6. Increase route length and add a bus, or decrease route length.
7. Increase speed.

An occasional increase in operating time requires incident management. If the delay is less than 5 minutes, the connecting routes should hold. If it is more than 5 minutes, it will depend on the headway of the connecting route. If h_i is 15 minutes or less, after 6 minutes the bus could leave; otherwise it may hold, particularly in the evening peak hour and a chance that the next bus will also be late.

Travel Time Decreases

Travel time usually decreases when few stops have to be made, as in late evening, Saturday mornings, Sundays and holidays. The answer here usually is to combine feeder routes or to combine a feeder route with a radial route. Feeder routes can also be replaced with a demand service for an area. If travel time decreases, the route can also be lengthened.

IMPLEMENTATION PROBLEMS

Introducing major route and schedule changes in a transit system can be traumatic. Capital Metro tried to implement two Timed Transfer Centers in July 1986, Windsor Park and South Congress. Neither succeeded because the land for an offstreet site was not available.

In Windsor Park initial public meetings did not show any opposition. However, when a temporary on-street location was chosen, the opposition was vocal. This center was therefore postponed, and in later planning relocated to a nearby shopping center.

The South Congress site was not obtained, so the center was temporarily located about 4 minutes' travel time further east, next to a shopping center. This temporary location is Capital Metro's first official timed transfer center. Five routes pulse into the South Transfer Center every 30 minutes. However, the temporary location causes some backtracking and duplication of certain routes.

Major changes introduced in July 1986 also introduced some additional transfer locations, mainly at shopping malls. At the same time, clock headways were introduced on all routes. An additional 100 buses were added to the bus fleet to accomplish these changes and other service improvements.

Major complaints arose where long routes were cut into segments and transfers were not timed properly. In defense of the scheduling and operations sections, it must be noted that their task was not an easy one, as it involved rewriting all schedules, doubling the service, introducing new routes and developing all schedules, using a newly introduced computer package. The most serious deficiencies were rectified soon after implementation of the July 27, 1986 changes.

NEXT PHASES

The next two phases were to be implemented in 1987. The first problem was to acquire offstreet sites at South Congress, Capital Plaza Shopping Center, and near Mearns Meadow. The second aspect was to use existing transfer locations as part of the overall Timed Transfer plan.

The second aspect was implemented first, as the lead time was less and could be started more easily. Four locations on the north side of Austin became Timed Transfer Centers, two of which are on-street (Northcross Mall and Mearns Meadow) and two are on shopping centers (Highland Mall and Hancock Center). It is possible that one of the on-street sites will be transferred to a shopping center (Northcross Mall). As a result of the four northside centers, one on-street southside transfer location will also be established (Vargas/Riverside).

The second stage of implementation has to wait until the two off-street sites are completed. One will be on a shopping center (Capital Plaza) and is the one that replaces the Windsor Park site that caused local neighborhood opposition. The second one is South Congress (being moved from its temporary location to the original intended site), which will make the implementation of four more on-street Timed Transfer Centers possible on the south side. The Capital Metro Board has failed, however, to approve either the acquisition or long-term leasing arrangements for off-site Transit Centers.

Southside Implementation

The southside implementation is a good example of the necessity for Timed Transfer and why it results in network optimization rather than route optimization.

Ben White Crosstown Example

The No. 28 Ben White Crosstown route goes from the IRS office complex next to Interstate Highway 35 along Ben White to a regional shopping center called Barton Square Mall. In the process it crosses six radial routes.

In July 1986 the No. 28 Ben White Crosstown route operated using the minimum number of buses to go from one end of the route to the other without attempting to "time connect" with any of the six radial routes. Figures 3 and 4 give the previous and current situations, as well as the proposed route change. Table 2 shows both current and new delays experienced by passengers who attempt to transfer. Needless to say, under the current situation the route carries few passengers.

The southside changes propose to change the ends of the route into two Timed Transfer Centers (P and F) and to deviate the No. 28 route into two more Timed Transfer Centers (B and K). The first is the South Austin Community Hospital (B), one block south of Ben White. A timed meet can be designed initially on-street on Radam Lane. The second deviation is at Westgate (K) Shopping Mall, again one block south. Because a layover time of 3 minutes is introduced at both timed transfer locations, and because the route deviates from a straight line, the total travel time will increase by 12 to 15 minutes end to end, requiring an additional bus to maintain a 30-minute headway. At the same time, some radial

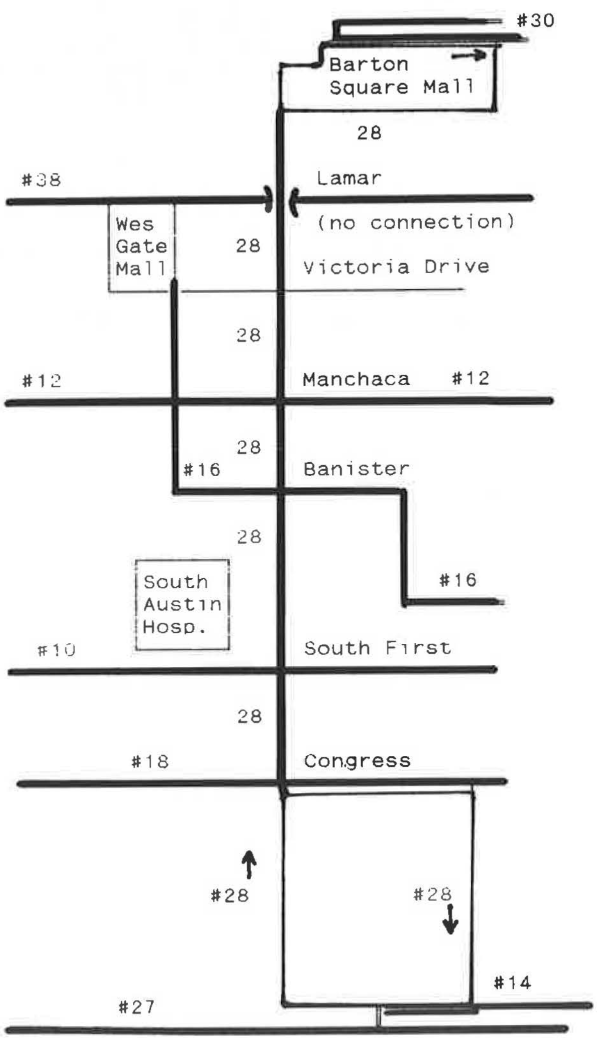

FIGURE 3 Ben White Crosstown example: before timed transfer bus network.

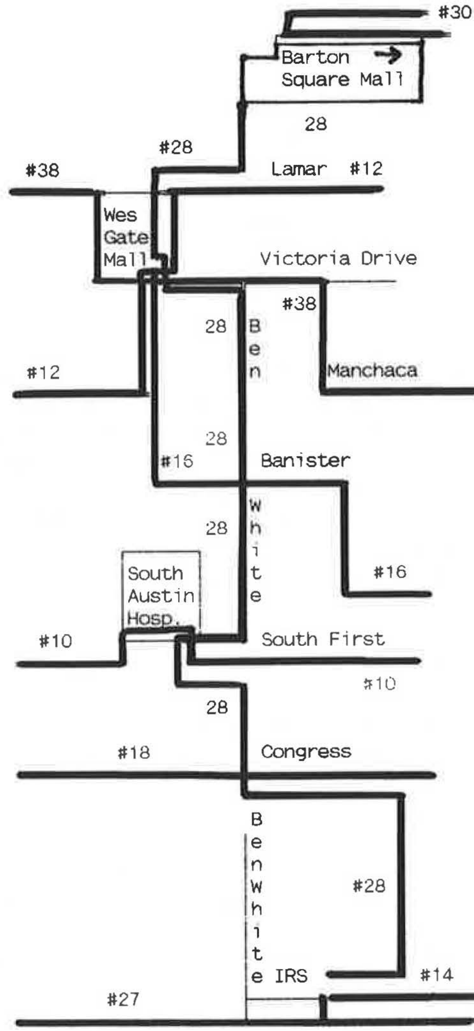

FIGURE 4 Ben White Crosstown example: timed transfer network.

routes would be diverted into the newly created Transit Centers.

In the "before" situation the short transfer times were usually matched with the long transfer times in the opposite direction. Clearly, from a passenger perspective, the proposed alternative is better; particularly if waiting time is evaluated as about four times riding time by the passenger.

Bus Requirements

The Service Plan (*1*) predicted a need of 314 peak hour vehicles by 1988 from the 67 that were operated in 1984. After the July 1986 changes, 194 buses were in service. The Timed Transfer Plan will not differ in vehicle requirements: together with other service improvements, the recommended plan will require 287 peak-hour vehicles. The Capital Metro Service Area is quite a dynamic region and additional service will be required in several areas, so the Service Plan estimate is still valid.

The extra costs associated with a Timed Transfer System are the off-street transfer facilities or Transit Centers. The

TABLE 2 CURRENT AND PROPOSED DELAYS IN TRANSFERRING

	Transfer Delays (min.)	
Location	Current	Proposed
Barton Square Mall	1, 8, 17, 22	4, 5, 19, 20[a]
Westgate	no service	3 (all routes)
Manchaca	2, 4, 5, 9, 19, 25, 26, 28	Meet at Westgate
South First	3, 3, 4, 10, 26, 27, 27	3 (all routes at South Austin Hospital)
I.R.S.	7, 8, 11, 13, 22, 24	3 (all routes)

[a]Subject to review.

plan at present is to use on-street space first, as well as already built shopping centers wherever possible. At shopping center locations, some pavement improvements may be required or leasing arrangements may have to be made. Two or three off-street facilities per year were planned for the next three years. The costs of these off-street facilities can vary greatly, depending on land costs, the amount of architecture, and amenities included. It is premature to give exact costs at this time.

CONCLUSIONS

1. Because schedules and routes must be developed simultaneously, it is essential to have current and reliable data regarding travel time.
2. If an off-street facility is planned, it is essential to obtain the land early in the process.
3. It is quite possible to adapt an existing system to a Timed Transfer System, and yet not disturb the existing route structure too much.
4. Linear optimization of scheduling has to yield to the Timed Transfer controls, if a proper transit network is to be established. This is particularly true of systems that have long headways.

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