PB/FA

PARSONS BRINCKERHOFF/FLOOD ASSOCIATES

a joint venture

File: Task 4.2
Amendment 8
3206.6.4.1

August 31, 1984

Mr. John Meyer
Executive Director
Jacksonville Transportation Authority
Post Office Drawer "O"
Jacksonville, Florida 32203

RE: Working Paper On Operational Plan Considerations

Dear Mr. Meyer:

With this letter we are forwarding one copy of the Working Paper on Operational Plan Considerations which has been prepared under our Contract Amendment No. 8 Subtask 4.2. This Working Paper is based on the Proposed Study Plan To Comply With Subtask 4.2, Amendment 8, dated July 16, 1984.

As the result of this study (see pages 3, 4, & 5 of the Paper) we recommend that the JTA seriously consider minor modification of the Starter Line to open the possibility of two alternatives for System expansion:

1. (No Change) Expand essentially as already described in the two EIS documents (as a fallback position), or
2. (Preferably) Adopt a very benef[illegible] modification as is described in this Working Paper as Alternatives E[illegible] (See pages 10, 11, 12, and 14).

We also urge that the proposed Starter Line modification be decided upon as quickly as possible to enable the options 1 and 2 above to be considered in the Vehicle/Subsystems procurement process now under way.

As part of its process of evaluation of the Working Paper, we request that the JTA independently evaluate the possible need for additional environmental impact studies or assessments that might be required for implementation.

We are prepared to meet immediately for review of this paper.

Sincerely,

PARSONS BRINCKERHOFF/FLOOD ASSOCIATES

R. A. Shellmer
Project Manager

RAS:ss

cc: Steven L. Arrington

JACKSONVILLE TRANSPORTATION AUTHORITY
AUTOMATED SKYWAY EXPRESS PROJECT

WORKING PAPER ON OPERATIONAL PLAN CONSIDERATIONS

Prepared Under
Amendment 8, Subtask 4.2

PARSONS BRINCKERHOFF/FLOOD ASSOCIATES
a joint venture

August 29, 1984

JACKSONVILLE TRANSPORTATION AUTHORITY
AUTOMATED SKYWAY EXPRESS PROJECT

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1. (No Change) Expand essentially as already described in the two EIS documents (as a fallback position), or

2. (Preferably) Adopt a very beneficial modification as is described in this Working Paper as Alternatives E plus D (See pages 10, 11, 12, and 14).

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WORKING PAPER ON
OPERATIONAL PLAN CONSIDERATIONS

SUMMARY

The adopted ASE system plan, Alternative A herein (Figure 1), has been compared with five possible modifications to the system, Alternatives B through F. The modifications address the desirability of: (a) increasing the amount of capacity in reserve for possible growth of passenger volumes, and (b) permitting operation of direct service between St. Johns Place and Terminal Station, to serve the hotel-convention center market.

Analysis supports rejection of the following alternatives, for the reasons stated:

B - A "traffic circle" junction (Figure 2) to permit service between St. Johns Place and Terminal Station; it reduces system capacity, increases most passenger travel times, raises operating and capital costs, and imposes severe right-of-way requirements.

C - A full grade-separated wye junction (Figure 3) to permit service between St. Johns Place and Terminal Station; it slightly increases system capacity and marginally improves average passenger travel times, but increases operating and capital costs out of proportion to these benefits.

D - Routing of the Southwest Line via the West Line instead of via the South Line (Figure 4); it makes better use of system capacity and improves most service frequencies and the average passenger travel time, but lengthens travel times between Riverside and Downtown, and

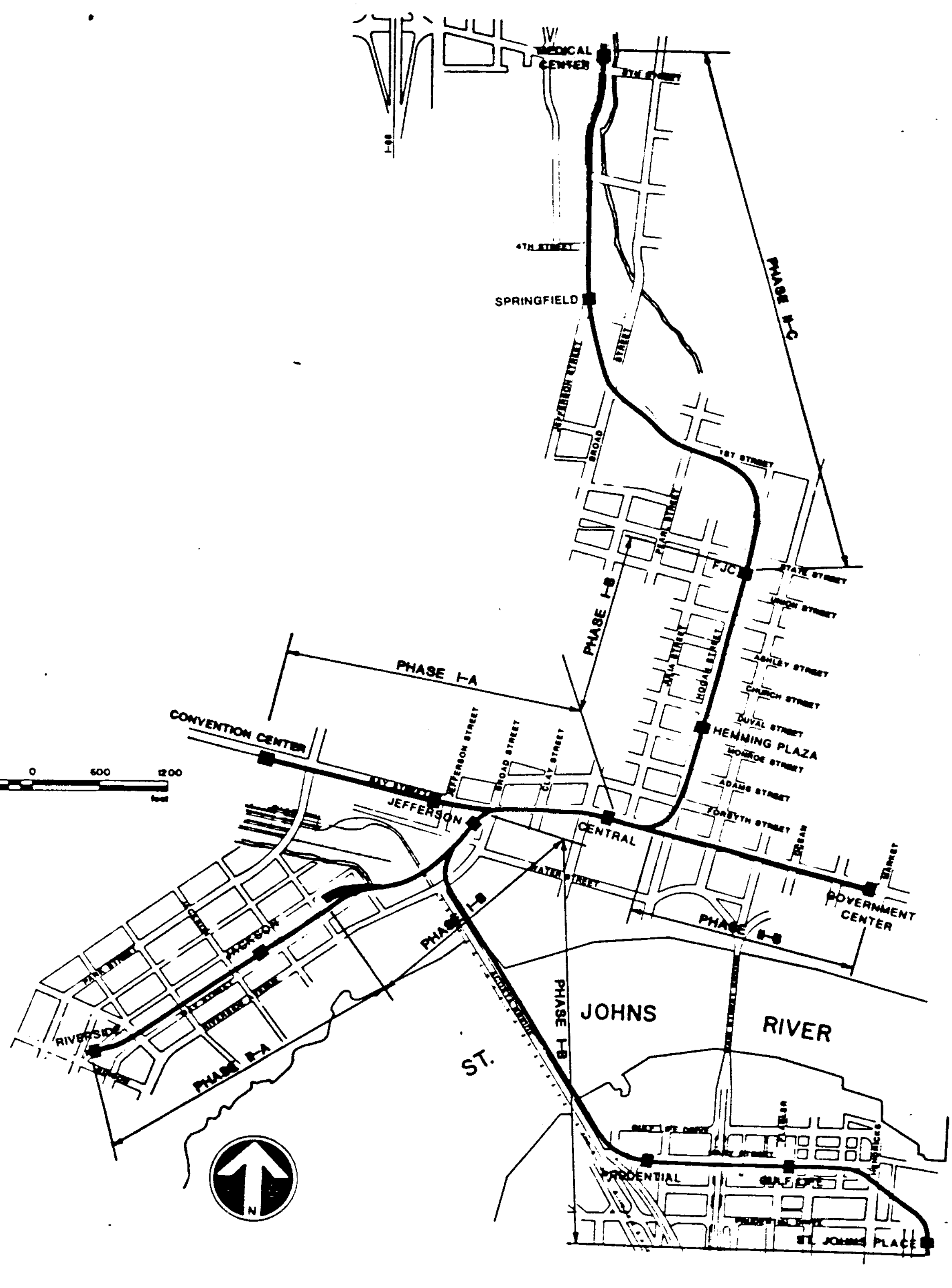


FIGURE 1 ALTERNATIVE A ASE FULL SYSTEM

JACKSONVILLE AUTOMATED SKYWAY EXPRESS

JACKSONVILLE TRANSPORTATION AUTHORITY

JANUARY, 1983

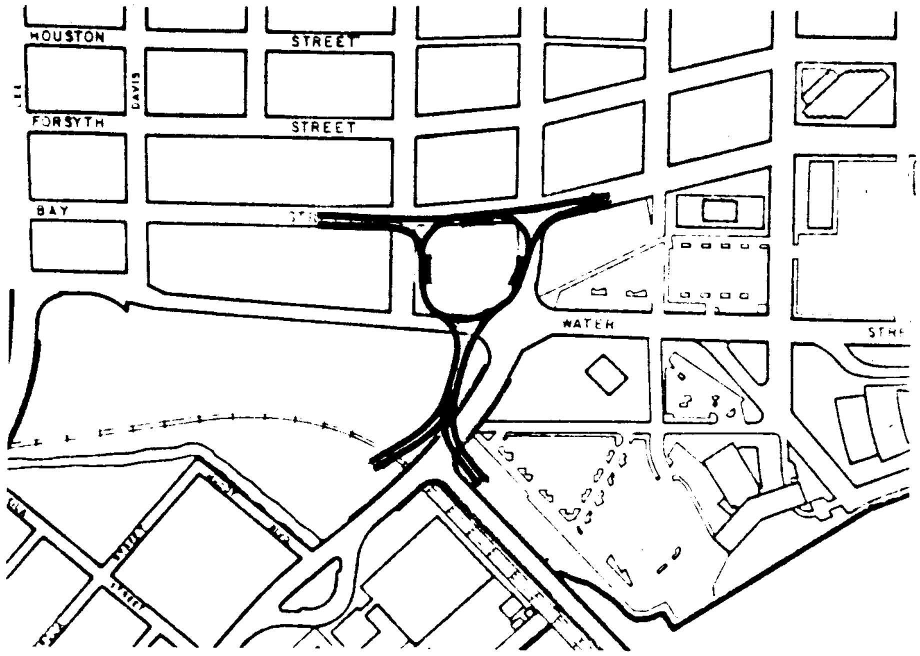


FIGURE 2   ALTERNATIVE B   "TRAFFIC CIRCLE" JUNCTION
Each line represents a single guideway

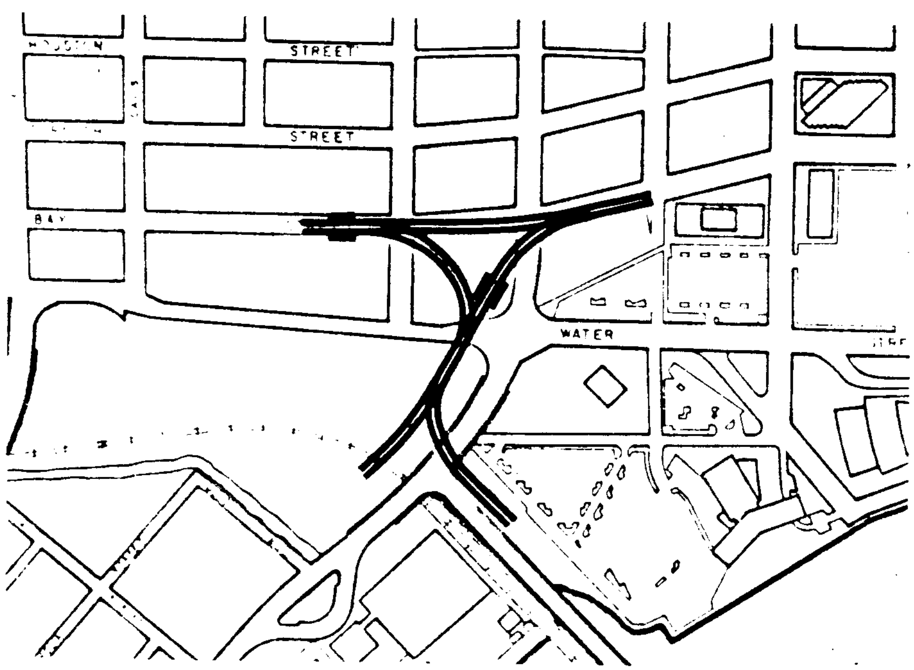


FIGURE 3   ALTERNATIVE C   FULL GRADE-SEPARATED WYE JUNCTION
Each line represents a single guideway

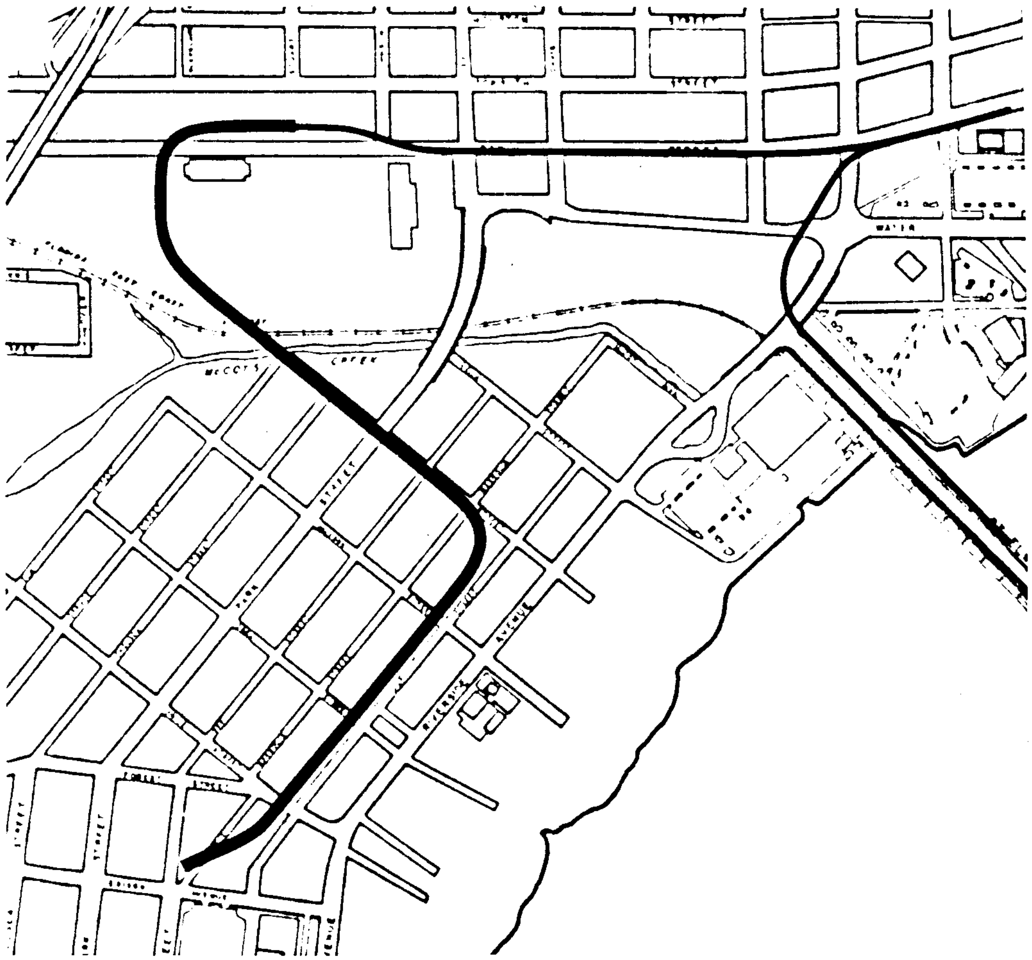


FIGURE 4 ALTERNATIVE D SOUTHWEST LINE VIA WEST LINE
Southwest Line represented by heavy line;
stations not shown

increases operating and capital costs out of proportion to its benefits. This alternative would be of greater potential benefit in conjunction with Alternative E or F; it can be reconsidered and implemented at a later date if found necessary.

Alternatives E and F (Figures 5 and 6) are found to be feasible, economically justifiable, and without severe right-of-way or environmental impact problems. These two alternatives are:

E - Double-decking of the Bay Street Line between Hogan and Broad Streets. This alternative doubles the system capacity through its maximum passenger volume area. It entails minor changes in the structure of the Starter Line, but these changes do not invalidate the FEIS or SFEIS.

F - Relocation of the North-South Line to a new alignment via Hogan Street south to Water Street instead of Bay Street so that the North-South Line crosses the East-West Line rather than paralleling or merging with it in Bay Street. This alternative also doubles the system capacity; in addition, it eliminates one station and provides one new station. It requires relocation of the Central Station approximately 300 feet eastward to a point near the intersection of Bay and Hogan Streets, possibly requiring an additional SEIS prior to proceeding with the Starter Line.

Alternatives E and F are similar in effect, except that:

(a) E costs less.

(b) F will marginally improve ASE coverage of the Downtown area.

(c) E entails no new environmental studies for the Starter Line.

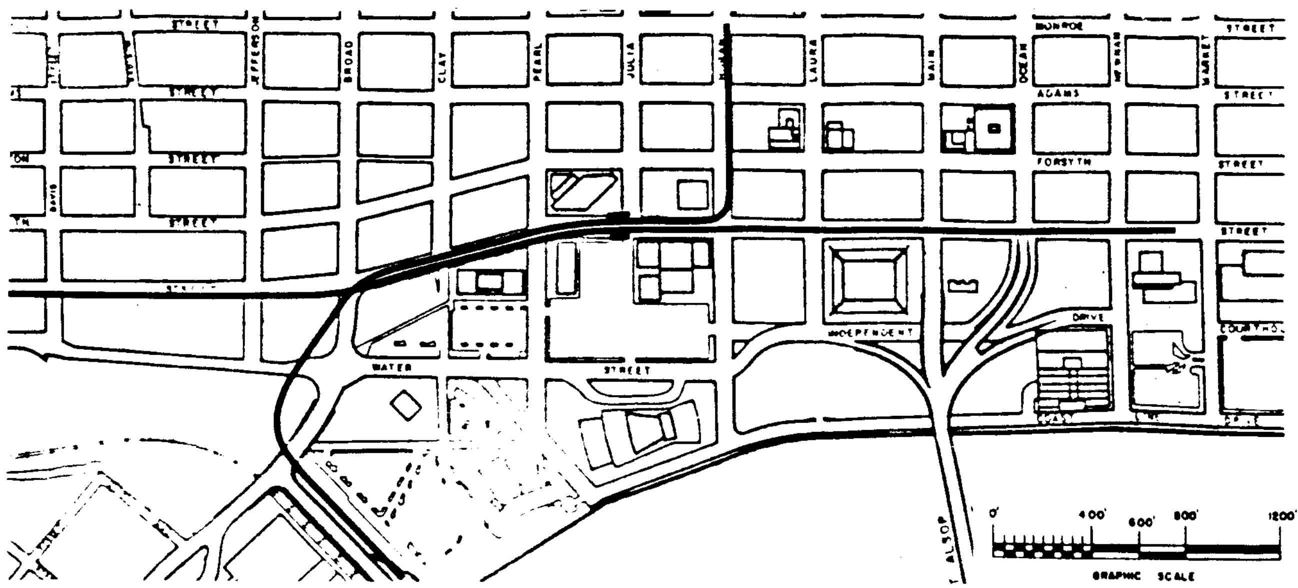


FIGURE 5 ALTERNATIVE E FOUR-GUIDEWAY CENTRAL SECTION ON BAY STREET
Each line represents a dual guideway
only Central Station is shown

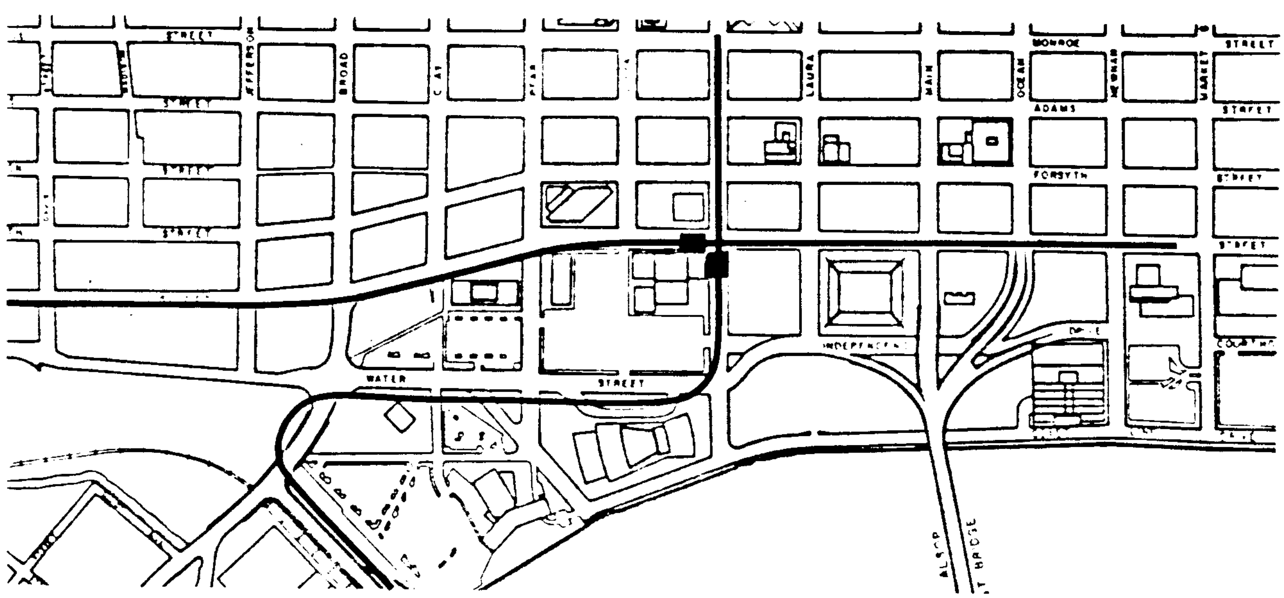


FIGURE 6 ALTERNATIVE F NORTH-SOUTH and EAST-WEST LINES CROSSING AT HOGAN AND BAY STREETS
Each line represents a dual guideway
only Central Station is shown

On the basis of these findings, Alternative E is preferred.

Alternative E or F, combined with Alternative D, would enable very large user benefits to be obtained at moderate operating costs and with no more vehicles than are required for the base system, Alternative A. These are the most cost-effective of the possibilities investigated and give the best opportunity either to obtain a large reserve capacity or else procure a lower-capacity vehicle system, compared with high-capacity systems that will be required for Alternative A.

Alternative G, not previously discussed, is a variation of the East Line to Government Center, avoiding environmentally-sensitive parts of Bay Street and allowing provision of a station to serve the Festival Shopping development. This alternative need not be evaluated at this time because it can be implemented independently of all other alternatives and it does not affect the System operational plan. Its merit should be determined and a decision made prior to final design of ASE System Phase I-B. The approximate alignment of this alternative, beginning at Central Station, is east on Bay Street, south on Hogan Street, east near Coast Line Drive, under the Main Street Bridge, then north to the south side of City Hall with future extension to the east.

RECOMMENDATION

It is recommended that the adopted Starter Line (Phase I-A) design plan be amended to provide the option of building the central portion of the Phase I with four (two over two) instead of two guideways. The actual decision to build two or four guideways can be made after the Starter Line design has been finalized, but before designing Phase I-B, provided

modifications are made now in the adopted Starter Line. Those modifications are:

* Eliminate the "hump" in the eastbound guideway which is intended to allow the future westbound to southbound guideway to cross under the eastbound guideway.

* Eliminate the third guideway stub (intended to connect to the northbound guideway from the South/Southwest Line).

* Provide for a possible switch and westbound to southbound turnout (intended to carry the westbound to southbound track over the eastbound Starter Line guideway, if four guideways are not built.

* Provide foundations, piers, and other design features necessary to support the future, additional upper-level guideway structure and facilitate its construction without disruption to Starter Line service.

These changes would affect about 1,000 feet of the Starter Line including the Central Station. None of the changes appear to have significant environmental consequences; in general, they should improve the appearance and reduce the mass and right-of-way requirements of the Starter Line. Therefore, it should not be necessary to make any changes or supplements to the existing EIS documents. The net cost of the recommended changes to the Starter Line is less than $0.3 million; one percent of Starter Line capital cost.

It is further recommended that if the final decision in favor of four guideways is made, the Southwest Line should be routed to the end of the West Line at Terminal Station rather than to a junction with the South Line as currently adopted.

Prior to construction of Stage I-B, it may be necessary to prepare a Supplemental EIS covering the double-decking of Central Station and a portion of the Bay Street alignment and the alignment between Terminal Station on the West Line and Jackson Street Station on the Southwest Line. The Bay Street alignment, in its adopted form, must include substantial lengths of third guideway and of raised guideway in order to provide grade-separated junctions at Bay and Hogan Streets (not yet shown in preliminary engineering drawings, but required) and at Bay and Broad Streets. The four-guideway structure would be of more uniform appearance and therefore may have little additional impact. If Stage I-B is built without the additional dual guideway, but after building the Starter Line with the modifications described above, it would cost no more than will the adopted plan. If it is built with the additional dual guideway, it will cost approximately $2.8 million more than the adopted plan (1984 prices). This figure, which includes the $0.3 million that would be spent during construction of the Starter Line, is about two percent of the Full System capital cost.

One reason for making provision for four guideways is to assure that the center of the ASE System has provision for ample capacity for future passenger volumes, including effects of possible future development and of ASE System extensions. The adopted System's central dual guideway has been shown to have adequate capacity for year 1995 "Full System" passenger volumes, but lacks flexibility with regard to now-unforeseen growth or system extent and imposes service frequency limitations that are less than optimum. The Starter Line, which may have a train every two and one-half minutes during peaks when it begins service, could see a reduction of service to one train every six to seven minutes by 1995.

DISCUSSION

The Study Plan for the Amendment No. 8 work under this Subtask 4.2 makes the following main points:

1. The ASE Full System (Figure 1 Phases I and II) can function as intended to the year 1995.

2. Looking further into the future and considering possibilities of system expansion beyond the Full System, it is possible that passenger demand will exceed the capacity of the system at its center.

3. Construction of larger stations to permit use of longer, higher-capacity trains is not a desirable means of increasing system capacity.

4. As the system grows from the Starter Line to the Full System, scheduling constraints will result in reduction of service frequencies on the Starter Line (to and from the Terminal Station), to as few as one train out of every five trains passing through Central Station.

5. Modification of the system plan to increase its capacity at the center might be feasible and cost-effective and should be investigated.

6. There is also a need to investigate making provisions for direct service between the Convention Center and the hotels south of the river.

The Study Plan enumerated the principal modifications to be considered. These modifications also address another issue; that of finalizing the

configuration of the future junction of lines at Bay and Hogan Streets. Study of these possible modifications included the following analyses:

* Capacity provided at critical locations.

* Level of service provided to passengers.

* Actual alignments possible.

* Right-of-way and other physical or environmental considerations.

* Capital cost of otherwise feasible alternatives.

As a result of these analyses and their interpretation, the following conclusions are drawn.

Service Between the Convention Center and Hotels South of the River

Two alternatives were examined as means of enabling direct service between the Convention Center and hotels south of the St. Johns River. One (Alternative B), a junction in the form of a traffic circle, was found to have the following disadvantages, compared with the adopted plan (Alternative A):

* Reduced passenger capacity on the most heavily-used parts of the system.

* During peak periods, many of the passengers desiring direct service would either have long waits or would take the first available train and transfer at Central Station.

* Slower service through the junction area, increasing travel times for a major portion of riders.

* Reduced frequency of service on routes serving a major portion of riders.

* Extensive right-of-way requirements including use of land currently planned for intensive development.

* Substantial additional capital cost (not estimated due to extent of other negative impacts of the alternative).

The other alternative investigated for this direct service, Alternative C, is a full wye grade-separated configuration that would enable trains to operate directly between any two of the three legs joined by the junction. This alternative was found to have the following advantages or disadvantages, compared with the adopted plan:

* Slightly increased usable capacity relative to passenger volumes.

* During peak periods, many of the passengers desiring direct service would either have long waits or would take the first available train and transfer at Central Station.

* Slightly improved passenger travel times.

* Increased operating costs, roughly equal to the value of passenger travel time savings.

* Significant visual impacts due to changes and additions to ASE structures in the junction area.

* Additional capital cost.

The conclusion drawn from these results for the grade-separated wye configuration is that no capital cost expenditure for this alternative can be justified because: (a) the user benefits obtained are only about equal to additional operating costs incurred, and (b) the gain in system capacity is too small to use as a justification for the capital cost. (If the capacity of the adopted plan becomes inadequate, the wye plan also would have to be considered inadequate.)

Neither of the two alternatives, B or C, would entirely prevent the need for or likelihood of transferring at Central Station in order to make the trip for which direct service is sought. Therefore, other alternatives that would reduce the trip time, although still requiring a transfer, should be considered.

Alternatives D, E, and F all offer reduced travel time for trips between St. Johns Place and Terminal Stations due to their provision of more frequent service on one or both of the two lines used for this trip.

The travel times of all alternatives for this trip are compared below.

The comparison shows that Alternative C (the grade-separated wye configuration) is better than most alternatives, but by less than a minute, and equal to the combination of F with D. The combination of E with D offers the best travel time of all for the Terminal-St. Johns trip, 9.4 minutes.

PASSENGER TRAVEL TIMES BETWEEN TERMINAL STATION
AND ST. JOHNS PLACE STATION
(Typical Peak Period, One-Way Travel Times, In Minutes)

Alternative	Wait/Transfer	Ride	Total	Time Advantage
A	5.8	7.5	13.3	-- (base)
B	3.8	7.0	10.8	2.5
C	3.1	6.8	9.9	3.4
D	3.1	7.5	10.6	2.7
E	3.0	7.5	10.5	2.8
F	3.5	7.5	11.0	2.3
E + D	1.9	7.5	9.4	3.9
F + D	2.4	7.5	9.9	3.4

Alternative D

The rationale for Alternative D, which routes the Southwest Line via the West Line instead of via the South Line, is to reduce the number of lines (allowing better service frequencies) and to give more nearly even loading of the lines. Benefits include:

* Fewer passenger transfers.

* More frequent service to passengers using the South, West, and Southwest Lines.

Disadvantages include the following:

* Increased travel time between the Riverside area and Downtown.

* Increased operating cost.

* A substantial increase in capital cost due to the addition of more than one-half mile of dual guideway.

* Probable adverse environmental impacts due to right-of-way requirements and the proximity of the alignment to the Post Office Building near Union Terminal.

This alternative produces a small net user benefit, comparing the value of travel time savings to increased operating costs. It improves system operations and should result in fewer problems as the system approaches its passenger capacity, and it prevents the serious reduction of service frequency on the West Line when system expansion takes place.

Alternative E

This alternative is like the adopted plan, Alternative A, except that provision will be made when building the Starter Line to allow a second dual guideway to be built above the segment in Bay Street from Hogan Street to Broad Street. In this way, the Starter Line and the future East Line would have exclusive use of the lower guideway pair, while the North, South, and Southwest Lines would make use of the upper pair.

This configuration, Alternative E, results in the following advantages:

* Starter Line service frequency is not affected by addition of the North, South, and Southwest Lines.

* A major increase in system capacity is obtained.

* Passengers benefit substantially from improved service frequencies.

* Operations are simplified, with resulting improved reliability and regularity of service.

Disadvantages of Alternative E, compared with Alternative A, are as follows:

* Increased operating cost (if more frequent service is provided).

* A larger structure along a 1,000-foot portion of Bay Street.

* Increased capital cost including a small increase in Starter Line cost and a modest increase ($2.8 million) in Stage I-B cost.

Alternative E generates user time savings valued at substantially more than its increased operating costs. The resulting net user benefit is close to the added capital cost to build the alternative, without considering the potential value of its added reserve capacity. Environmental impacts are present but do not appear excessive. No additional right-of-way is required.

This alternative permits minor simplification of the Starter Line in that it becomes unnecessary to build a "hump" into the eastbound guideway, included in the adopted plan to allow the westbound-to-southbound connecting guideway to cross underneath the eastbound guideway.

This is an acceptable alternative and is preferable to Alternative A.

Alternative F

In this alternative, the north-south guideways cross above the east-west guideways at Bay and Hogan Streets. The North-South Line is routed south on Bay Street to Water Street and then west along Water Street to the intersection of Riverside, Water, and Broad Streets, where it turns and divides to connect to the Acosta Bridge and the Southwest Line. This alternative eliminates the Jefferson-A (Broad Street) Station but permits a new station, probably of greater service value, near the intersection of Pearl and Water Streets. To provide for passengers to transfer between the East-West and North-South Lines, Central Station would be shifted eastward and built with pedestrian interconnections to a new North-South Line station in Hogan Street, just south of Bay Street.

The advantages of Alternative F are exactly the same as those cited for Alternative E, but with the addition of improved coverage due to the new station in Water Street.

The disadvantages of Alternative F are:

* Increased operating cost.

* Increased use of Downtown streets for ASE lines.

* Increased capital cost (more than Alternative E).

* Probable need for further environmental impact analyses before proceeding with the Starter Line, because of the relocation of Central Station.

User time savings of Alternative F are almost as great as those of

Alternative E, and operating costs are essentially the same. Its capital cost is somewhat greater than that of E, but within a range justifiable on the basis of net user benefits and the gain in reserve capacity. Environmental impacts and right-of-way requirements are not excessive, but the environmental impacts of the Starter Line could be affected due to the relocation of the Central Station. Additional environmental analyses might therefore be required before proceeding with the Starter Line and this could delay its implementation.

In sum, the drawbacks of Alternative F are sufficient to make it inferior to Alternative E.

Alternative E with Alternative D

Because Alternative D results in more nearly equal passenger volumes on the two guideway pairs provided by Alternative E, both guideway pairs can be served by a vehicle system having only half the capacity needed for Alternative A. Further, because neither guideway pair has branches in this E+D configuration, optimal service frequency can be provided at every station in the system. As a result, E+D provides very large user benefits and lower operating costs than E (slightly lower than D), giving net economic benefits well in excess of the added capital cost.

Alternative F with Alternative D

These alternatives in combination are much like E+D. Alternative F's slightly longer transfer time at Central Station and its higher capital cost give less favorable but still attractive economic analysis results.

PASSENGER VOLUMES

Ridership forecasts were made, during preliminary engineering, for the the "Full System" (adopted as the end result of the Feasibility Study), the River Crossing Alternative, the Riverside Alternative, and for the Starter Line. No forecast has been made for the current Phase I or Full Systems (which include the Starter Line) and no forecasts are for years beyond 1995 (except the somewhat outdated JUATS 2005 forecasts which assume a much larger system of 19.3 route miles and 28 stations).

For operations plan purposes, and for system configuration studies that precede update of the operations plan, a ridership basis was needed. This has been prepared as a first step in carrying out the present operations plan update.

Two separate passenger trip estimates were used as sources for this purpose. These, both 1995 PM peak station "ons" and "offs" by direction, were for the Full System and the Starter Line. The Full System station ons and offs (and transfers) were hand-distributed within a table to create an origin-destination matrix containing the beginning number of ons and offs. The Starter Line on and off volumes were increased slightly (about 10 percent at Central Station) to reflect the interconnection with the remainder of the Full System, and about one-third of these revised ons and offs at Central Station were hand-redistributed to other Full System stations.

The resulting matrix was then summarized to determine directional maximum line flow volumes and line-to-line movement volumes. The matrix is given in Table 1. Figure 7 indicates directional peak hour passenger flows.

TABLE 1
ASE FULL SYSTEM
1995 PEAK HOUR PASSENGER TRIPS
(Approximation by PB/FA Based on 1981 and 1982 Estimates for Full System and Starter Line)

TO STATION / FROM	Med. Ctr.	Spring-field	FJC	Hemming Plaza	Central	Jeffer-son-A	Pruden-tial	Gulf Life	St. Johns Place	Jackson	River-side	Gov't. Ctr.	Jeffer-son-B	Term-inal	Totals
Medical Ctr.	-	10	180	1,000	453	362	75	65	17	25	18	90	5	10	2,310
Springfield	12	-	13	60	12	25	2	2	1	14	18	-	-	-	159
FJC	81	2	-	244	78	50	15	12	5	5	15	20	5	20	552
Hemming Pl.	163	2	120	-	102	85	20	17	6	22	30	25	12	20	624
Central	77	3	92	72	-	134	58	44	28	73	232	12	10	175	1,010
Jefferson-A	55	1	50	77	395	-	181	195	320	45	143	25	5	20	1,512
Prudential	40	-	45	25	341	74	-	44	50	6	20	40	10	40	735
Gulf Life	35	-	35	20	280	41	31	-	49	4	15	35	13	40	598
St. Johns Pl	90	-	115	68	770	442	193	97	-	30	111	133	50	100	2,199
Jackson	5	-	10	180	210	79	29	30	50	-	27	30	10	15	675
Riverside	14	-	84	400	533	168	62	70	100	77	-	67	10	10	1,595
Gov't Center	22	-	23	15	59	60	100	97	17	5	18	-	8	30	454
Jefferson-B	-	-	11	25	163	5	10	10	13	5	5	16	-	47	310
Terminal	5	-	30	156	855	20	65	72	30	27	45	82	202	-	1,589
Totals	599	18	808	2,342	4,251	1,545	841	755	686	338	697	575	340	527	14,322

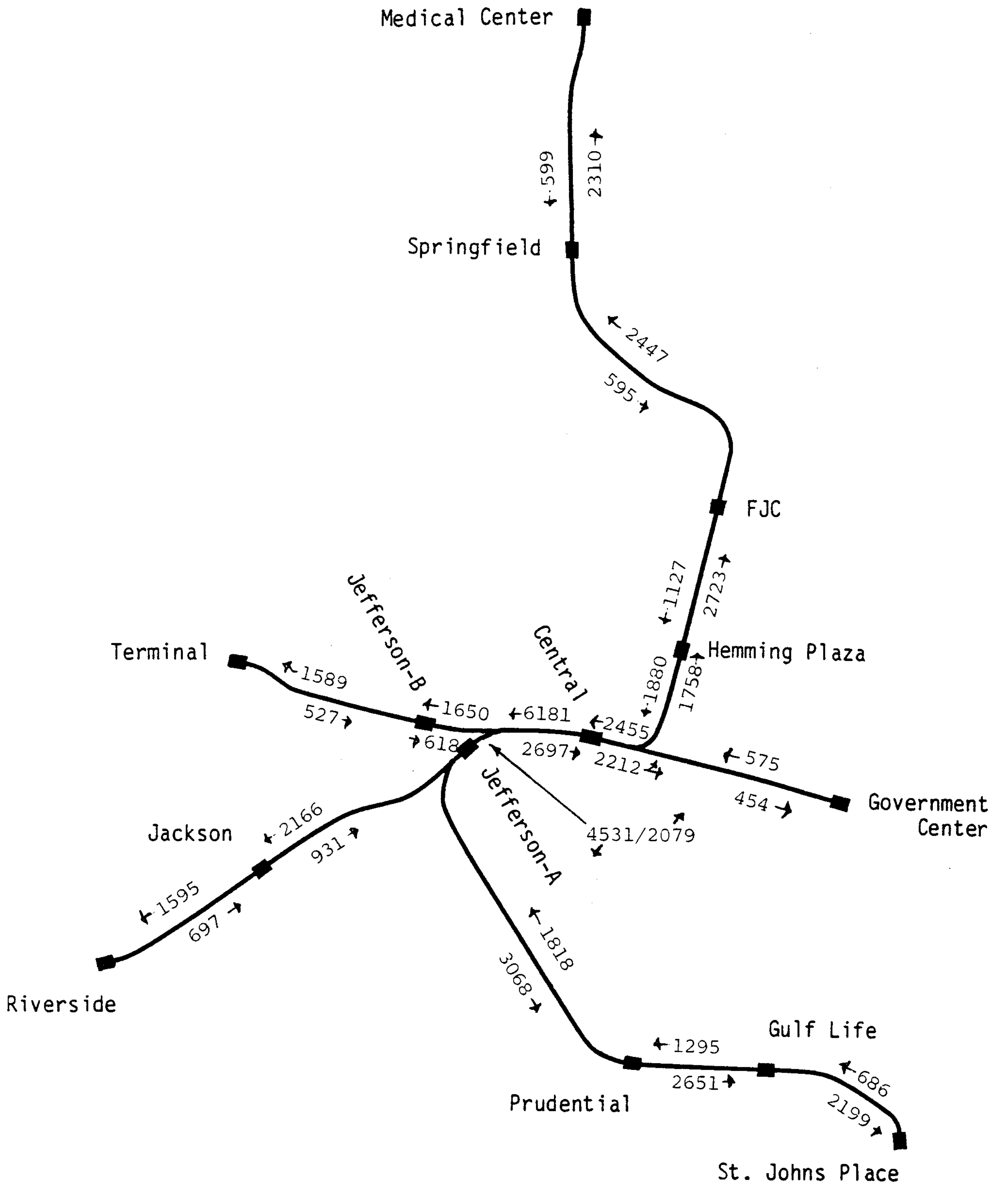


FIGURE 7

ASE FULL SYSTEM
1995 PM PEAK HOUR
PASSENGER FLOW VOLUMES
BY DIRECTION

AMOUNTS OF SERVICE

The adopted Full System plan, referred to here as Alternative A, five other alternatives, B through F, and two combinations of alternatives, E+D andd F+D, have been examined from an operational point of view to determine practical service patterns and resulting capacities for each individual route that must be operated. For this purpose, a basic service frequency module of 80 seconds was found to be best. More frequent service is not likely to be reliable, being too much subject to delay because of variation in station dwell times or other operating anomalies. An 80-second headway (45 trains per hour in each direction) permits appropriate combinations of service routes, each having required passenger capacity for the passenger movements served.

To understand these statements better, refer back to Figure 1, the passenger flow diagram. In the diagram, the afternoon peak hour maximum load point occurs just west of Central Station, where a total of 6,181 passengers will be on trains heading west, southwest, or south. If a single train can carry 180 passengers (based on the preliminary engineering Baseline Vehicle and two-car trains), then 35 trains could carry this entire volume, seemingly leaving ten trains excess capacity if trains operate every 80 seconds.

This will not solve the scheduling problem, however. Further examination of Figure 1 shows that the 6,181 passengers comprise three routes -- one to the West Line, one to the Southwest Line, and one to the South Line. Further, the diagram reveals that the maximum load on the latter two lines occurs, in each case, south of Jefferson-A Station. The Southwest Line must carry 2,166 passengers and the South Line, 3,068 passengers. The West Line maximum load, 1,650 passengers, does occur in the same link of the system where the overall system maximum load occurs. Converting the three lines separately to trains for each line, we find the following:

West:	1,650 ÷ 180 =	9.2 trains	(one each 6.5 minutes)
Southwest:	2,166 ÷ 180 =	12.0 trains	(one each 5.0 minutes)
South:	3,068 ÷ 180 =	17.0 trains	(one each 3.5 minutes)
Total:		38.2 trains	(one each 1.6 minutes)

Although these results still indicate that excess capacity exists, further examination shows that service cannot be allocated among the three lines in the indicated proportions, and maintaining reasonably uniform service frequencies for each line, without using still more trains. The closest approximation using 1.6-minute headways would result in:

West:	6.5 minutes ÷ 1.6 minutes = 4, or 1 out of 4 trains:	25%
Southwest:	5.0 minutes ÷ 1.6 minutes = 3, or 1 out of 3 trains:	33%
South:	3.5 minutes ÷ 1.6 minutes = 2, or 1 out of 2 trains:	50%
Sum		108%

Since 108% is unattainable, a larger number of trains per hour has to be used.

This can perhaps be more easily understood by recognizing that if one train out of four goes to the West Line, and two out of four to the South Line, no more than one out of four (not one out of three) can go to the Southwest Line. It is necessary to assume more frequent service in order to find an acceptable pattern that meets or exceeds the required capacity of each route.

For the adopted Full System (Alternative A), a satisfactory solution is found to be 45 trains per hour, with one of every five assigned to the West Line, two to the Southwest Line, and two to the South Line. This gives 6-2/3-minute service headways on the West Line, and a pattern that repeats at that interval.

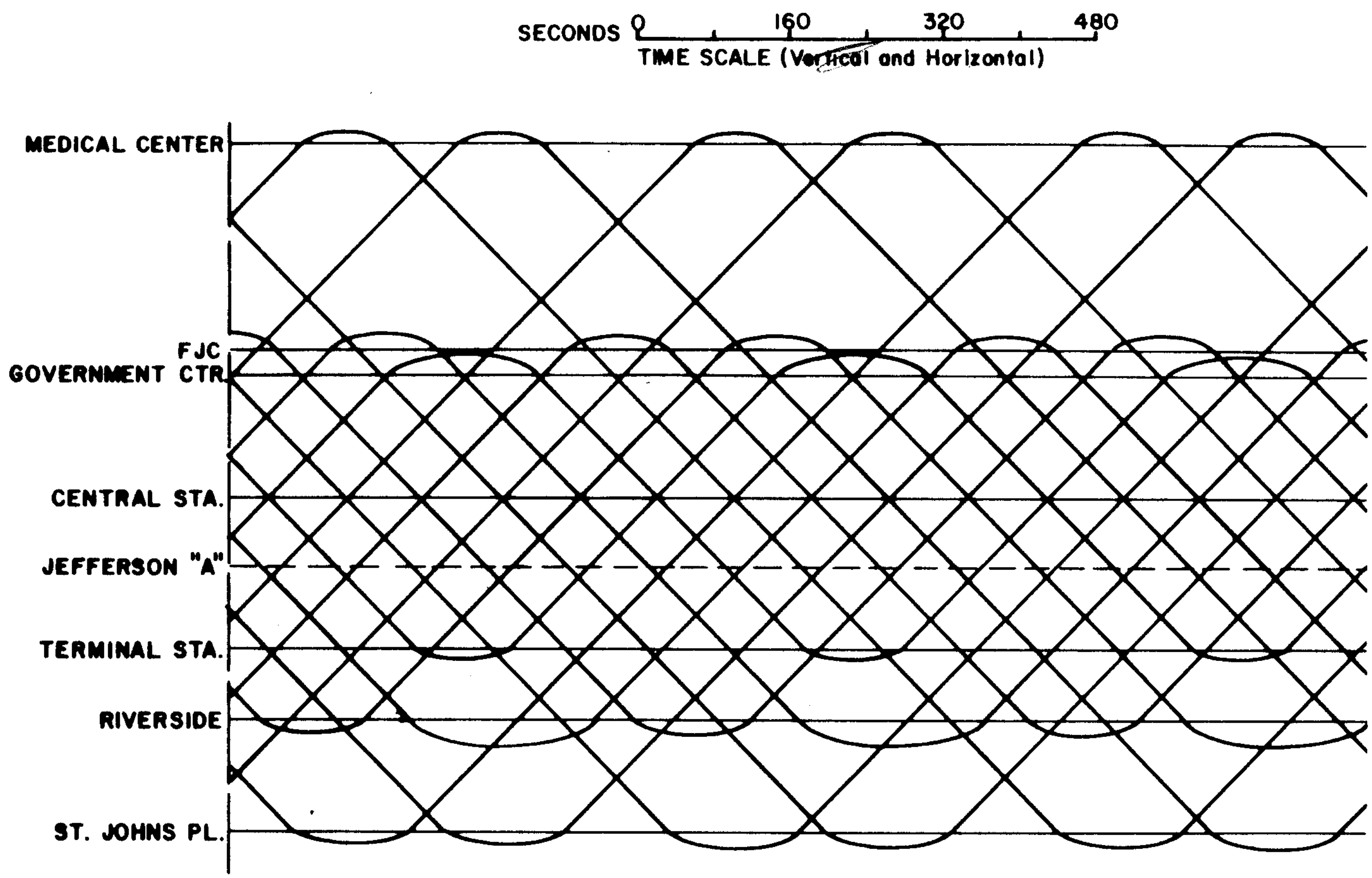
This exercise reveals the natural operating pattern for the routes and loadings projected for this system. It shows, further, that the system is approximately at its capacity, using 80 seconds as the normal minimum headway. Successful operation at shorter headways would enable the system to carry more passengers, but non-uniform growth on the three lines could invalidate the 1-2-2 pattern and frustrate efforts to satisfy passenger demand.

Having established the basic 80-second headway pattern, this was used as a basis for analysis of all the alternatives. The service patterns were developed as train graphs, shown in Figures 8 through 13. Figure 12 applies to both Alternative E and Alternative F, which are operationally very similar. Figure 13 applies to Alternatives E+D and F+D.

The train graphs reveal the constraints that ultimately will apply to scheduling for each configuration. Schedule objectives include:

* Allocation of service to routes according to their passenger volume.
* Avoidance of excessive headways on any route.
* Achievement of uniform spacing of trains within each route.
* Minimization of time for transferring between trains.
* Avoidance of train conflicts at turnbacks.
* Maximization of system capacity, recognizing capacity requirements of each route.

Comments on the performance of the various alternatives with respect to the above objectives follow.



NOTE: ALL SERVICE USES TWO-CAR TRAINS

FIGURE 8 TRAIN GRAPH OF PEAK PERIOD SERVICE ON ASE FULL SYSTEM ALTERNATIVE A -- ADOPTED SYSTEM

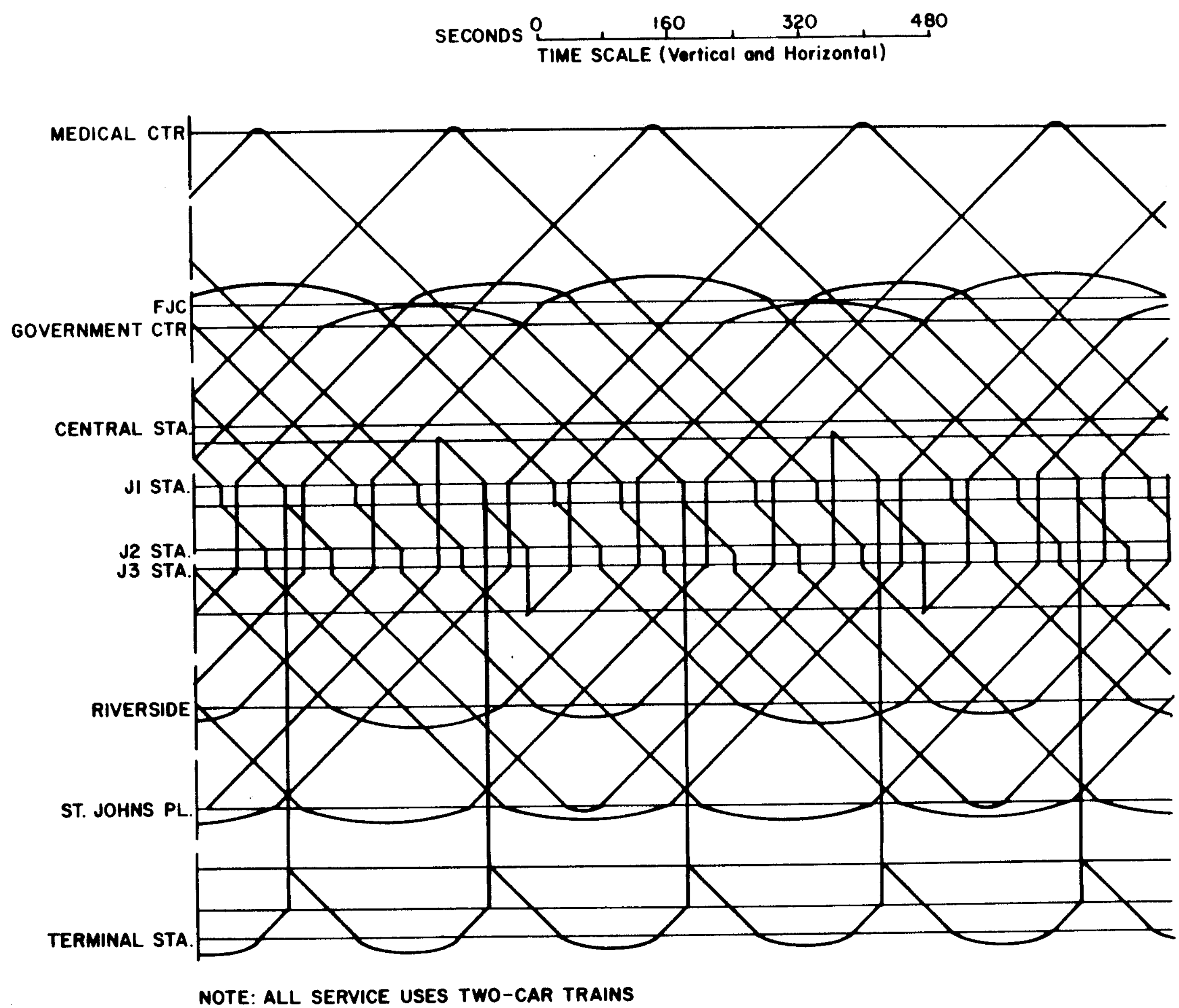


FIGURE 9 TRAIN GRAPH OF PEAK PERIOD SERVICE ON ASE FULL SYSTEM

ALTERNATIVE B -- "TRAFFIC CIRCLE"

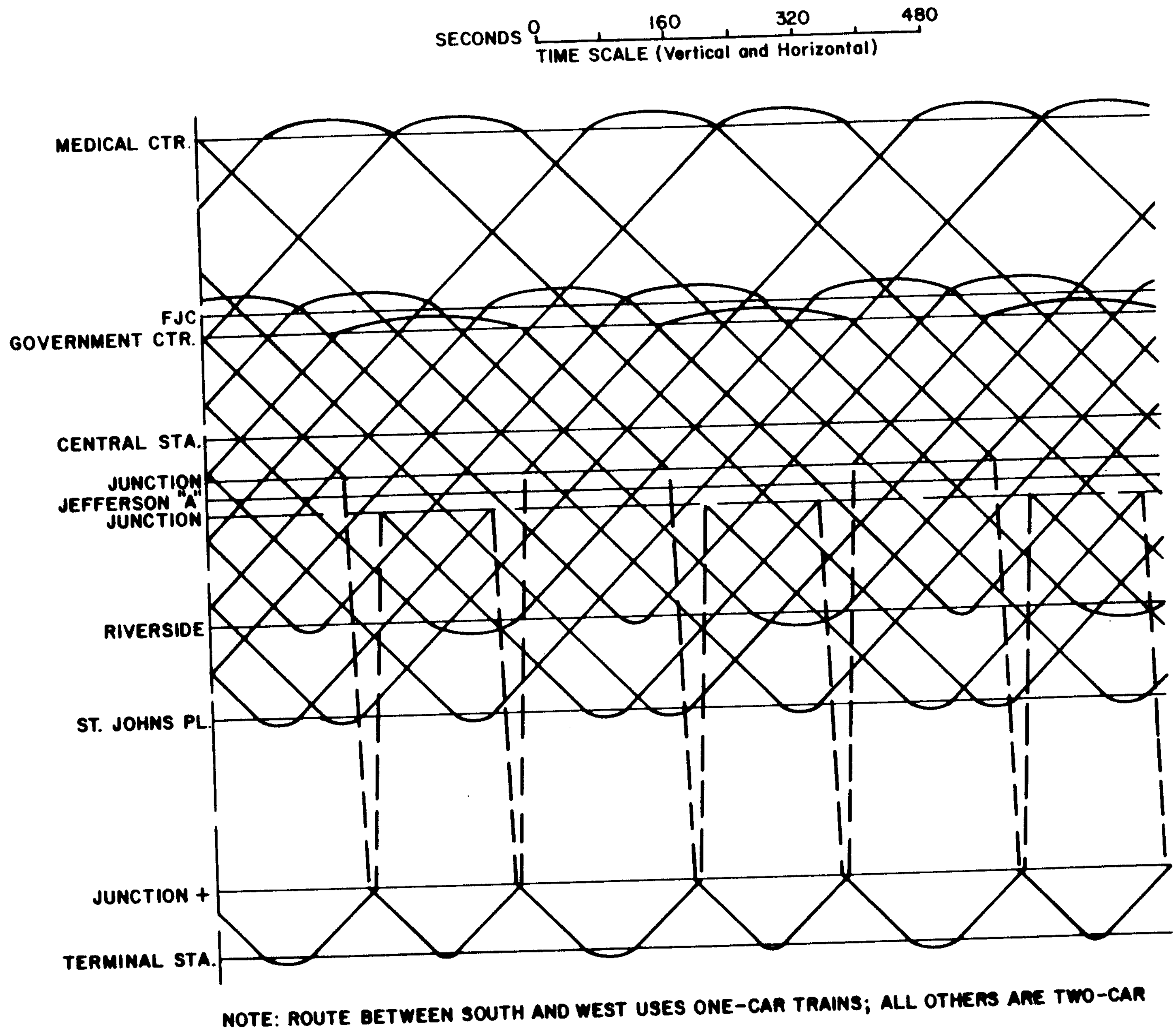
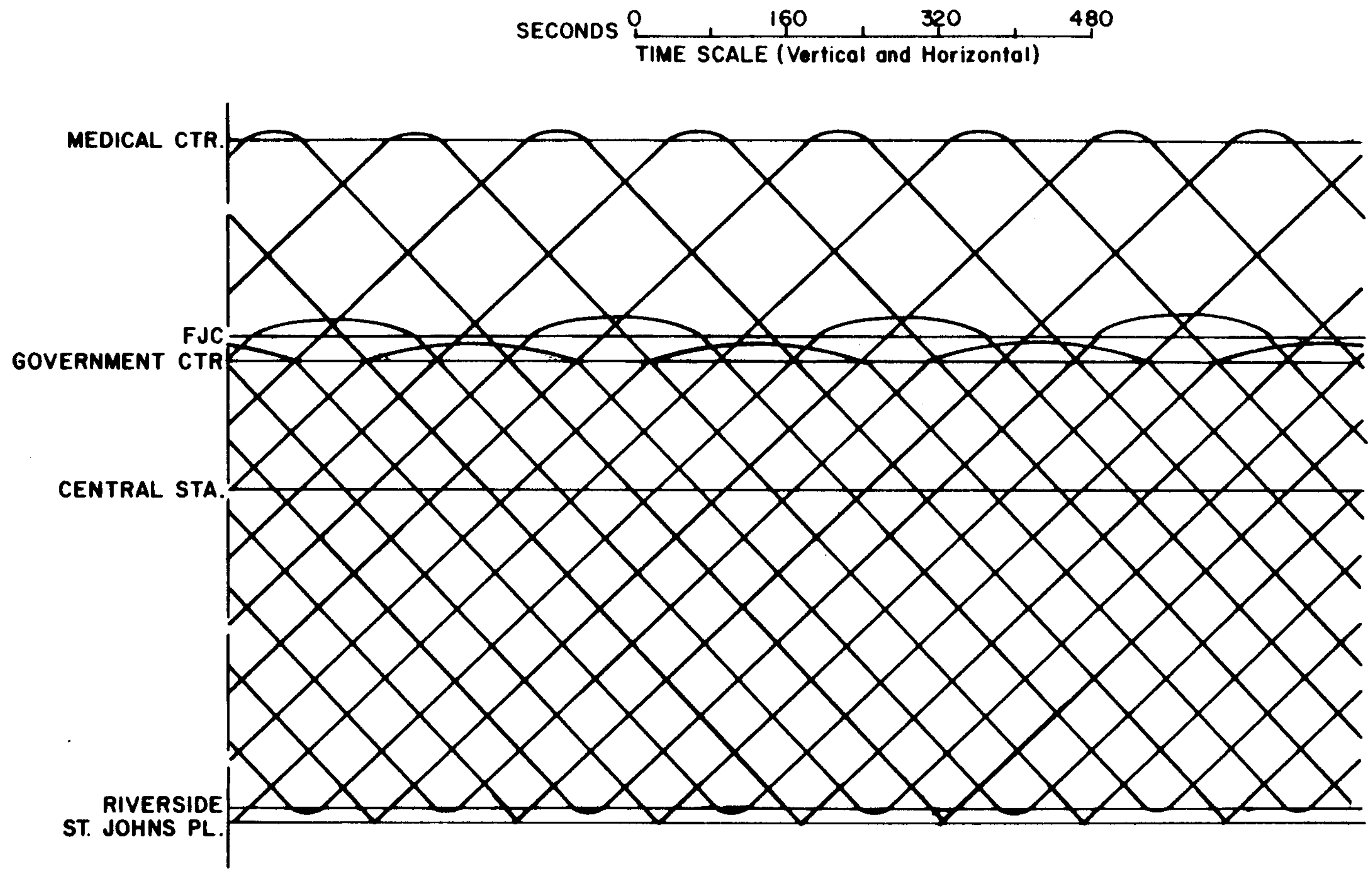


FIGURE 10 TRAIN GRAPH OF PEAK PERIOD SERVICE ON ASE FULL SYSTEM

ALTERNATIVE C -- FULL-INTERCHANGE WYE JUNCTION



NOTE: ALL SERVICE USES TWO-CAR TRAINS

FIGURE 11 TRAIN GRAPH OF PEAK PERIOD SERVICE ON ASE FULL SYSTEM ALTERNATIVE D -- SOUTHWEST LINE VIA WEST LINE

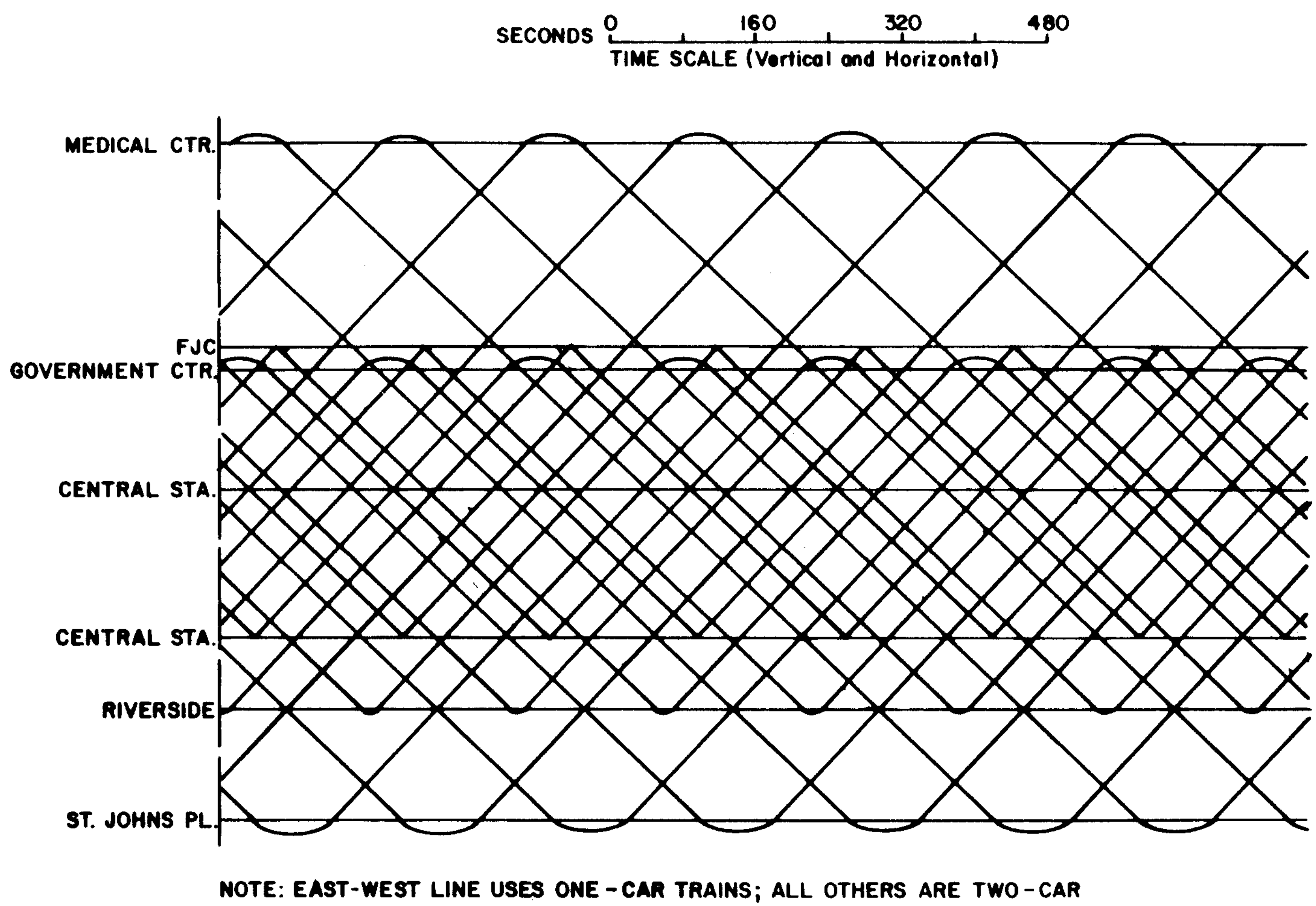


FIGURE 12 TRAIN GRAPH OF PEAK PERIOD SERVICE ON ASE FULL SYSTEM

ALTERNATIVES E OR F -- DOUBLE-DECKED LINE ON BAY STREET OR NORTH-SOUTH AND EAST-WEST LINES CROSSING AT BAY AND HOGAN STREETS

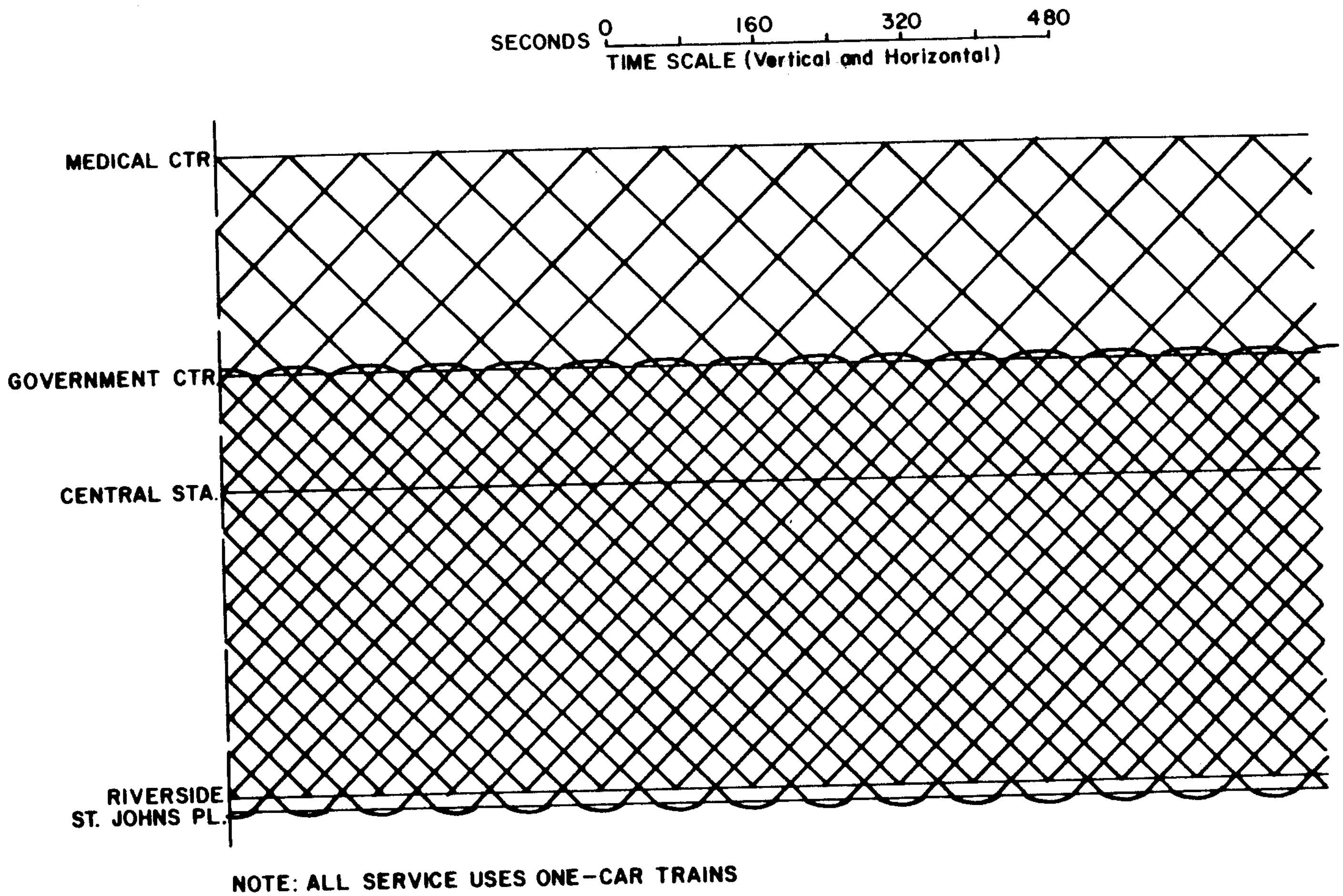


FIGURE 13 TRAIN GRAPH OF PEAK PERIOD SERVICE ON ASE FULL SYSTEM ALTERNATIVE E WITH D OR F WITH D -- FOUR-GUIDEWAY CENTRAL SECTION; SOUTHWEST LINE VIA WEST LINE

1. Allocation of service to routes. All alternatives enable allocation of service in reasonable proportion to passenger volumes.

2. Excessive headways. The longest headway occurs on the East Line, in Alternative B, in which service to/from Government Center can be provided only once every eight minutes. Alternative A serves both West and East Lines at 6.7-minute intervals. These intervals, or headways, might be considered marginal if not excessive, for Downtown ASE service.

3. Uniform spacing of trains. Alternatives A, B, and C have some irregularity of service intervals; Alternatives D, E, and F achieve uniform headways. Irregular spacing causes the trains for which passengers must wait longer to tend to be overloaded, compounding problems of effectively using system capacity.

4. Transfer times. Both transfer and waiting times have been analyzed as part of an overall passenger travel time analysis, discussed later in this paper.

5. Number of cars required (using the preliminary engineering Baseline Vehicle). For the schedules shown in the train graphs, Alternative A has 30 cars in operation, B, C, and D each have 32, and E or F have 34. These last two alternatives have been scheduled with moderate excess capacity in order to provide an integrated pattern giving excellent East-West Line headways. Alternative E (or F) with D requires only 30 cars to operate at 80-second headways throughout the system and meet nominal 1995 Full System capacity requirements.

6. Conflicts at turnbacks. Alternatives A through D incur conflicts due to having instances in which one train is being turned back at a station while another must pass through or leave that station in

the inbound direction. Such occurrences impose additional train movements to resolve the conflict, and may justify or require special design provisions other than those now shown on preliminary engineering drawings.

7. System capacity. Alternative A has adequate capacity for the projected 1995 peak hour loading. Alternative B has less capacity than A and is unsatisfactory in this respect. Alternatives C and D have slightly more reserve capacity than A. Alternatives E and F have about 30 percent reserve capacity on one guideway pair, and nearly 400 percent reserve on the other guideway pair. Alternative E or F, in conjunction with D, would result in a more nearly balanced use of the two guideway pairs, giving the potential of over 100 percent reserve capacity for each. Capacity is further addressed in the section immediately following.

PASSENGER DEMAND AND CAPACITY

Table 2 compares estimated 1995 peak period passenger flows with the amounts of service in the train graph schedules. Alternatives A through D are scheduled for the maximum possible amount of service through the central part of the system, unless headways are shortened to less than 80 seconds. The Alternative E or F train graph uses all available capacity on the guideway pair serving the North, South, and Southwest Lines, again on the basis of 80-second headways, but only one-fourth the capacity of the other guideway pair.

The Alternative E (or F) with D train graph uses 80-second headways throughout but capacity analysis assumes only one 90-passenger Baseline Vehicle per train; the Baseline Vehicle system can have two-car trains, which would double the E+D capacity shown in Table 2.

TABLE 2
DEMAND/CAPACITY ANALYSIS OF 1995 SCHEDULES
(Peak-Direction, Peak-Hour Passengers; Train Graph Schedules)

	Alternative	North of FJC Sta.	Between West Line and Central Station	Max. Load Point, South-west Line	Max. Load Point, South Line
A:	Demand	2,447	1,650	2,166	3,068
	Schedule Capacity	3,240	1,620	3,240	3,240
	Demand/Capacity	0.76	1.02	0.67	0.95
B:	Demand	2,447	1,343[1]	2,166	2,722[1]
	Schedule Capacity	2,700	1,350	2,700	2,700
	Demand/Capacity	0.91	0.99	0.80	1.01
C:	Demand	2,447	1,425[1]	2,166	2,815[1]
	Schedule Capacity	3,240	1,620	3,240	3,240
	Demand/Capacity	0.76	0.88	0.67	0.87
D:	Demand	2,447	------ 4,082[2]	------	3,327
	Schedule Capacity	4,050	------ 4,050[2]	------	4,050
	Demand/Capacity	0.60	------ 1.01	------	0.82
E,F:	Demand	2,447	1,650	2,166	3,068
	Schedule Capacity	4,050	2,025	4,050	4,050
	Demand/Capacity	0.60	0.81	0.53	0.76
E+D,	Demand	2,447	------ 4,082[2]	------	3,327
F+D:	Schedule Capacity	4,050	------ 4,050	------	4,050
	Demand/Capacity	0.60	------ 1.01	------	0.82

NOTES:

1. Actual demand is likely to exceed this amount, which assumes that all passengers who could use direct service between South and West Lines do so. Any who transfer instead of waiting for direct service will increase the volumes to which this footnote is applied.

2. West and Southwest Lines are combined in Alternative D.

GENERAL NOTE:

The peak 15-minute passenger demand may exceed the average hourly demand rate by 20 to 40 percent. Ideally, therefore, the demand/capacity ratios should be 0.83 or less.

PASSENGER TRAVEL TIMES AND TRANSFERRING

Based on the train graphs, passenger travel times were analyzed for the alternatives. This work made use of the peak hour passenger trip table described earlier. This trip table is adequate for travel time analysis of the alternatives in that relatively large patronage changes on individual line-to-line movements have relatively small impacts on aggregate passenger travel time, and would generally tend only to increase or decrease differences among the three alternatives, not change their ranking. For this analysis, the trip table was compressed from its station-to-station form, containing 182 cells, to a 56-movement list, by combining groups of adjacent stations and omitting empty (zero-volume) cells.

Travel times were derived from the calculations on which train graph running times were based, using average times between groups of stations consistent with the compressed passenger trip table.

Waiting and transfer times were taken from the train graphs, using half the headway for average waiting time, and actual time between arriving and departing trains for transfer time.

The passenger travel time analysis has the results given in Table 3.

The table shows that Alternative A is better than Alternative B and slightly inferior to Alternative C in average passenger level of service, in terms of both absolute (unweighted) and behavioral (weighted) travel times. Although more people must transfer between trains in Alternative A than in the other two alternatives, transfer and waiting times are minimal.

TABLE 3

PASSENGER TRAVEL TIME ANALYSIS

TRAVEL TIME OF 14,322 PM PEAK HOUR PASSENGER TRIPS ON ASE

(Includes Waiting, Riding, Transferring)

	Unweighted Time in Minutes			Weighted Time in Minutes		
Altv.	Total	Mean	A-Altv.	Total	Mean	A-Altv.
A	82,512.2	5.76	--	131,635.4	9.19	--
B	90,058.3	6.29	(7,546.1)	145,739.4	10.18	(14,104.0)
C	80,322.0	5.61	2,190.2	126,817.4	8.85	4,818.0
D	84,605.0	5.91	(2,092.8)	125,697.7	8.78	5,937.7
E	71,459.0	4.99	11,053.2	103,871.2	7.25	27,764.2
F	72,381.5	5.05	10,130.7	106,177.4	7.41	25,458.0
E+D	71,504.7	4.99	11,007.5	92,946.9	6.49	38,688.5
F+D	73,280.7	5.12	9,231.5	97,386.9	6.80	34,248.5

NOTE: The term "weighted time" refers to the application of a penalty factor to time spent waiting for a train or for transferring between trains. The factor, 2.5, is derived from behavioral studies which show that transportation users have greater resistance to spending time waiting or walking than to spending time riding in a vehicle.

Neither Alternative B nor Alternative C would eliminate transferring between the South and West Lines, because the frequency of the direct service operable between those lines is insufficient to induce passengers to wait for the next direct-service train if their train was just missed. The resulting mixed pattern, in which some passengers use a direct routing and others make a transfer, is confusing to those unfamiliar with the system. The Alternative A concept is simple to explain both verbally and graphically, and is common in mass transit systems worldwide.

OPERATING COSTS

Using the most recent PB/FA operating cost estimates as a basis, a model was developed for estimation of operating costs of the alternatives. The model, representing annual operating costs at 1984 price levels, is:

$$(55.979 \times VHT) + (0.016 \times P)$$

where VHT equals annual vehicle hours traveled and P equals annual passengers carried.

Table 4 provides the derivation of peak hour and annual vehicle hours traveled. Using appropriate factors from earlier patronage studies, the estimated 14,322 peak hour passenger trips were expanded to a total of 33.29 million annual passenger trips, assumed to be the same for all alternatives.

Application of the operating cost model to the vehicle hour and passenger figures results in the following estimated annual operating costs:

Alternative A	- $3,563,000
Alternative B	- 3,578,600
Alternative C	- 3,789,300
Alternative D	- 4,139,700
Alternative E,F	- 4,320,200
Alternative E+D, F+D	- 4,108,300

ECONOMIC EVALUATION

Using Alternative A as the base, the other five alternatives were evaluated with respect to user travel time benefits, operating costs, and capital costs. This evaluation is given in Table 5.

TABLE 4
PROJECTED AMOUNTS OF SERVICE OPERATED
FOR ALTERNATIVES A THROUGH F

Altv.	Route*	Round Trip Time in Minutes	Pk. Hr. Round Trips (Veh.)	Pk. Hr. Vehicle Minutes	Pk. Hr. Vehicle Hours	Annual Vehicle Hours**
A	1	23.9	36.0	860.4		
	2	13.1	36.0	471.6		
	3	9.9	18.0	178.2		
	Total	-	-	1,510.2	25.17	54,132
B	1	24.7	30.0	741.0		
	2	13.9	30.0	417.0		
	3	10.7	15.0	160.5		
	4	13.3	15.0	199.5		
	Total	-	-	1,518.0	25.30	54,412
C	1	23.9	36.0	860.4		
	2	13.1	36.0	471.6		
	3	9.9	18.0	178.2		
	4	12.5	9.0	112.5		
	Total	-	-	1,622.7	27.05	58,176
D	1	23.9	45.0	1,075.5		
	2	16.4	22.5	369.0		
	5	15.7	22.5	353.3		
	Total	-	-	1,797.8	29.96	64,434
E	1	23.9	45.0	1,075.5		
	2	13.1	45.0	589.5		
	3	9.9	22.5	222.8		
	Total	-	-	1,887.8	31.46	67,660
F -- SAME AS E						
E+D	1	23.9	45.0	1,075.5		
	5	15.7	45.0	706.5		
	Total	-	-	1,782.0	29.70	63,875
F+D -- SAME AS E+D						

* See Train Graphs, Figures 8 through 12
Route 1 - Medical Center - St. Johns Place
Route 2 - FJC - Riverside
Route 3 - Government Center - Terminal
Route 4 - Terminal - St. Johns Place
Route 5 - Government Center - Riverside
**Peak Hour x 2,150.67 (factor derived from Starter Line operating data)

TABLE 5
ECONOMIC EVALUATION OF ALTERNATIVES

	ALTERNATIVE						
	B	C	D	E	F	E+D	F+D
	Amounts are Net, Compared to Alternative A						
Peak Hour Weighted Time Savings (Min.)	- 14,104	4,818	5,938	27,764	25,458	38,689	34,249
Annual Time Savings (Hr.)	-211,560	72,270	89,070	416,460	381,870	580,335	513,735
Value of Time Saved ($)	-846,200	289,100	356,300	1,665,800	1,527,500	2,321,300	2,054,900
Net Annual Operating Cost ($)	15,600	226,300	576,700	757,200	757,200	545,300	545,300
Net Annual Economic Benefit ($)	-861,800	62,800	-220,400	908,600	770,300	1,776,000	1,509,600
Present Value of Net Benefit ($ Millions, Discounted over 20 Years @ 10%)	- 7.337	0.534	- 1.876	7.735	6.558	15.120	12.852
Cost of Additional Vehicles ($ Mills.)	2.283	2.283	2.283	4.566	4.566	--	--
Cost of Additional Const. ($ Mills.)	N/A	N/A	2.680	2.802	5.537	5.482	8.217
Total Additional Cap. Cost ($ Mills.)	N/A	N/A	4.963	7.368	10.103	5.482	8.217
Ratio, Present Value/Capital Cost	N/A	N/A	N/A	1.05	0.65	2.76	1.56

NOTE: The values of time saved are based on estimated 1995 ridership for the Full System which, of course, overstates benefits obtainable during earlier years or for smaller system configurations. However, no credit is taken for the fact that alternatives that provide a higher level of service would attract more ridership or command higher fares. The value of reserve capacity is not quantified in this analysis, but if included would increase the value of E+D and F+D more than any other, and would also increase the value of E and F.

Conclusions drawn from the analysis, in the context of other aspects of this paper, are as follows:

* Alternative B is found to have negative user travel time benefits and to cost more to operate than Alternative A. Considering also the fact that it has inferior capacity, severe right-of-way impacts, and obviously substantial (although not estimated) capital costs, Alternative B should not be further considered.

* Alternative C, relative to Alternative A, generates small but positive user travel time benefits, slightly in excess of its added operating costs. In view of its moderate capacity advantage over Alternative A, this alternative could be considered seriously except for its right-of-way and environmental impacts, which argue against making the necessary added capital investment.

* Alternative D provides a higher level of service to its users than A, but user benefits are less than its added operating costs. It does not significantly improve system capacity and therefore has no justification for its capital cost penalty. In conjunction with Alternative E or F, it would make more nearly-balanced use of the two pairs of guideways and therefore might be justified.

* Alternative E has a major user benefit advantage over Alternative A, giving a net annual economic benefit of almost a million dollars. The present value of that benefit flow is nearly equal to the cost of additional vehicles, construction, and related engineering required by the alternative. At the same time, it provides sufficient reserve capacity to enable further system expansion or accommodate unexpected amounts of Downtown growth.

* Alternative F is similar to Alternative E, but due to its higher capital cost, and possibility of delaying implementation of the Starter Line, it is less easily justifiable.

* Alternative E with Alternative D permits operation of maximum service frequency throughout the system and therefore gives optimal user time savings. This system configuration permits such service to be operated efficiently, giving annual operating costs slightly below those shown for Alternative D. The resulting present value of net benefits is almost twice that of E alone, and the total capital cost increases only marginally because the operating pattern does not require any more vehicles than are needed for the base alternative, A. The combination of E with D has an indicated benefit/cost ratio of 2.8 (assuming vehicles to exploit reserve guideway capacity are not purchased).

* Alternative F with Alternative D follows the same pattern, but with slightly less advantageous results; its benefit/cost ratio is 1.5.

APPENDIX

ALIGNMENTS AND CAPITAL COSTS

ALTERNATIVE CAPITAL COST ESTIMATES

MACS Code	Description	Alternative Cost in 1984 Dollars x 1,000* D	E	F
20.02.04	Fare Collection			216.30
20.02.05	Vehicle Control	205.92	404.73	500.40
20.02.06	Surveillance & Security		52.50	52.50
20.02.08	Comm. Equipment	21.44	13.15	55.73
20.06.10	Right-of-Way	980.85	75.60	- 6.85
20.10.00	Demolition	52.68		
20.11.10	Stations, Exc. G'way		771.75	750.13
20.11.20	Elevated W'ways			151.20
20.11.90	Landscaping	17.01		11.55
20.13.30.01	Elevated G'ways	- 1.23	658.71	1,401.85
20.13.30.02	Piers & Footings	- 3.18	50.15	462.87
20.13.30.03	Guidance Eqpt.	331.09	80.18	279.89
20.13.30.04	Power Dist. Eqpt.	428.98	125.50	390.22
20.13.40.01	At-Grade G'ways	- 28.95		123.40
20.13.40.02	Street Pvg., Curb & S.W.			- 35.63
20.13.40.03	Traffic Signals and Signs			53.59
20.15.10	Utility Relocs.	- 9.32		4.51
31.00.00	Relocations	140.00		
Sub-total		2,135.29	2,232.27	4,411.66
PLUS: 25.5% (Engineering, Administration, and Contingencies)		544.50	569.23	1,124.97
TOTAL		2,679.79	2,801.50	5,536.63

* Net, Compared to Alternative A