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ENGINEERING COST ANALYSIS OF THE URBAN TRACKED AIR CUSHION VEHICLE SYSTEM

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Preliminary Memorandum

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16. Abstract

The Urban Tracked Air Cushion Vehicle (UTACV) is presently being developed as a means of improving urban transportation. Because implementation of the UTACV into revenue service will require the commitment of large amounts of capital resources, an investigation should be made to determine the capital cost and other financial requirements involved. Accordingly, this report covers the development of a cost analysis conducted for the UTACV. The report covers the development of a computer program used for determining the costs incurred in the application of the UTACV for various hypothetical situations and for performing sensitivity analyses for the cost parameters. Specifically, based on various levels of passenger demand, the computer program determines the system operating characteristics (number of vehicles, headway, trip time,etc.), total project cost, operating costs, revenues, and requirements for debt financing. The report will also describe a modification of the original computer program to include a comparative cost analysis between the UTACV and Rapid Rail, Express Bus and Line Haul PRT systems. The systems were compared over a wide range of passenger demands and operating conditions.

17. Key Words Computer Program, UTACV Operating Characteristics, Capital Costs, Operating Costs, Financing Requirements, Parametric Cost Analysis, Comparative Cost Analysis between UTACV, Rapid Rail, Bus & PRT

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1.0 INTRODUCTION

The Urban Tracked Air Cushion Vehicle (UTACV) presently under development possesses significant technological potential for solving transportation problems within the urban environment. Extensive evaluation of the system is required in a multidisciplinary manner to determine those specific applications most suitable for the UTACV and of maximum benefit to the urban community. Since the implementation of most new technology systems designed for the improvement of urban transportation necessitates large capital resource commitments, the economic impact of the UTACV requires particular attention. A complete economic evaluation of the UTACV will eventually contain pertinent site dependent information such as projected ridership estimates, analyses of methods for non-revenue financing, investigations of possible long term impacts on the enonomic development of the community, and net present value comparisons of alternative system proposals. Prior to these detailed studies, however, important information can be obtained on the economic characteristics of the system by performing an engineering cost analysis. Accordingly, this report describes an initial cost study conducted for the UTACV during its development stage.

The basic objectives of the cost study were the following:

1. To identify and quantify all of the cost elements which will contribute to the total capital and operating costs of a revenue system.

2. To investigate various methods of financing the total annualized cost of the system so that its economic impact in terms of fare levels and non-revenue financing, can be assessed.

3. To investigate the sensitivity of the total annualized cost to its various cost elements indicating where reductions in costs will be most effective.

4. To provide a means of comparing the UTACV, on a cost basis, with other modes of transportation for the same site independent applications.

This report is divided into two main sections reflecting the general development of the study. Section 2.0 contains a comparitive cost analysis performed for the UTACV against other systems as they were separately applied to solve the same idealized transportation problem.

Section 3.0 of the report contains a sensitivity analysis of UTACV cost parameters and more detailed description of the development of the data and techniques used to perform the Section 2.0 analysis.

Several comments must be made regarding the interpretation of results contained in this report. The cost comparison study in Section 2.0 assumed an idealized site independent situation, which allowed the various systems to be compared on the basis of providing equivalent service while operating under the same conditions. As will be discussed in Section 2.0, however, with no consideration given to site dependent modifying factors, erroneous conclusions may be inferred if results from the comparison study are utilized to predict actual situations.

Various assumptions were made regarding the method of system financing which differ between Sections 2.0 and 3.0. In Section 3.0 a conservative method of financing was assumed while in Section 2.0 a more realistic financing method was used. The conservative financing assumptions in Section 3.0 were required to determine the relative parametric sensitivity of all cost related factors; however, the resulting fare levels should not be interpreted as representative of the costs to be expected in actual revenue service. In general, one should be in full cognizance of the assumptions which were applied to any particular phase of this study before any definitive conclusions are made regarding actual site dependent applications.

2.0 COMPARATIVE ANALYSIS OF UTACV SYSTEM COSTS WITH THOSE OF OTHER LINE HAUL SYSTEMS

2.1 BACKGROUND

By analyzing a system's total annualized cost, it is possible to obtain an indication of the cost incurred in providing a service to the community. The total annualized cost of a system includes all operating, maintenance and debt financing costs. The ability of a system to defray these costs with the revenues collected through fares then becomes a measure of the financial viability of the system and a useful indicator for comparison with other systems providing the same service. This section of the report describes the results obtained from performing a comparative cost analysis based on the criteria above between the UTACV, Rapid Rail (R.R.), Express Bus (Bus) and Personalized Rapid Transit (PRT) systems. The methodology and basic cost data used in determining the total annualized costs for a variety of systems and operating conditions will be described. The comparative cost analysis, as detailed in this report, will be structured around the basic conclusion of the study which indicated that the ability of a system to defray its total annualized cost from revenues is a function of the following three primary parameters:

1. The method of system financing;
2. The system length;
3. The volume of system patronage.

Each parameter will be discussed separately in terms of its influence on the finanical viability of the UTACV system individually and in comparison to the other systems investigated.

2.2 BASELINE SYSTEM CHARACTERISTICS FOR COMPARATIVE COST ANALYSIS

2.2.1 Operating Characteristics

To facilitate the cost comparison of UTACV, express bus, rapid-rail and PRT systems, a baseline transportation problem was formulated for which each system was individually applied as a solution. The baseline assumed was an airport access situation where passengers had to be transported from a remote urban air terminal to an outlying airport. The route in each case was to be an exclusive guideway, one-third elevated and two-thirds at grade. For each system, three guideway lengths (10, 20, and 35 miles) were analyzed for a range of patronage from 2.3 to 10.6 million passenger trips per year.

Table 2-1 shows the typical operating characteristics for the different modes of transportation investigated resulting from their application to the several baseline situations. For this analysis the level of patronage was set at 5.6 million passenger trips a year for the three different baseline lengths. One of the primary user benefits of the UTACV is its decreased trip time over that required of the other systems. The UTACV's advantage in trip time becomes increasingly greater as the trip length is increased up to about 50 miles at which point the difference in average speeds for the various systems remain relatively constant. Thus, for relatively short trips in the range of ten miles or less, slower vehicles may be adequate; but for longer trips, faster systems become increasingly attractive. The number of vehicles required for each system is also a direct function of the trip time and represents another favorable characteristic of faster systems particularly for longer trips.

2.2.2 Capital Costs

It was important in the cost study to equally compare the total resources required for implementing the compared systems into revenue service. To accomplish this, it had to be determined at the outset to what the extent guideway costs were to be included in the total project cost. Any assumptions made regarding guideway costs were critical, as these costs represent a major portion of a system's total project cost. UTACV and PRT systems always require guideways, thus the full costs must be considered. An existing road or rail line however could be utilized in a specific application of the bus or rapid rail system, eliminating the need for a new guideway. The possibility of utilizing such existing facilities is remote, however, as the route would be pre-empted from use except by the express bus or rapid rail system. For this reason coupled with the desire to compare the total capital resources required on and equal basis, a new exclusive guideway structure was assumed to be required for all the systems, and its cost was considered in the total project cost.

The determination of appropriate unit guideway costs for each of the systems investigated required several basic assumptions. Because of the preliminary nature of this investigation, a literature search was conducted as the primary means of obtaining cost data on the compared systems. The results of the literature search concluded that there was a wide range of over-lapping cost information available on the various systems. In addition, it was difficult to determine, in many cases, exactly what cost components were included in these estimates. To resolve this situation and assure that all of the systems were evaluated on an equal basis, the guideway costs were divided into their major cost elements. A basic guideway structure of common configuration and cost, regardless of the vehicle technology, was assumed. Additional cost elements were then added to the basic guideway cost resulting from increased requirements dictated by the specific vehicle technologies. As an example, the basic structure for all of the systems was assumed

TABLE 2-1. BASELINE SYSTEM CHARACTERISTICS*

	PARAMETER	UTACV	RAPID RAIL	EXP. BUS	PRT
	Vehicle Cruise Speed, Mph	150	75	50	45
	Vehicle Capacity, Passengers	80	75	50	10
10 Miles	Trip Time, Minutes	7	11	14	16
	Number of Vehicles & Spares	6	10	17	94
20 Miles	Trip Time, Minutes	11	19	26	29
	Number of Vehicles & Spares	9	16	32	174
35 Miles	Trip Time, Minutes	17	31	44	49
	Number of Vehicles & Spares	14	27	52	288

*5.6 Million passenger trips per year
2 min. swell at station

to be similar to the proposed express bus guideway connecting Kansas City with its new International Airport. The cost of this basic guideway was then increased for the UTACV over that of the bus system due to the additional requirements of a reaction rail, electrical substations, guideway electrification and a more complex control system. Note that, because the investigation was basically site independent, right of way costs were not included and only a nominal site preparation cost was assumed.

The station base costs were assumed to be equal for all of the systems because identical passenger service at the terminals was to be provided regardless of the vehicle technology. The base cost for the maintenance facility was also assumed to be equal for the different systems with the exception of an additional vehicle -volume dependent cost factor which tends to favor those systems with fewer vehicles. The base unit capital costs used for the various systems in the comparative cost analysis are shown in Table 2-2.

2.3 DISCUSSION OF MAJOR PARAMETERS

2.3.1 Method of System Financing

The method of system financing defines the manner in which a particular transportation systems allocates its revenues to cover the total annualized costs of providing a service to its patrons. There are essentially two major categories of expenses comprising the total annualized costs: (1) the operating and maintenance costs (O & M), and (2) the debt retirement costs. The O & M costs are the total costs requiring payment, on a short term basis, to continue operations. O & M costs include energy, labor, maintenance, interest on debts, administration, overhead and depreciation. Debt retirement costs are those costs set aside to pay off the principal on long term loans used in the purchase of capital equipment for the initial system. Depending upon how much of the original transportation system is financed through loans, the debt retirement costs can represent a major portion of total annualized costs.

Table 2-3 lists typical O & M costs in cents per seat mile for the various line haul systems investigated. The costs indicated for rapid rail and express bus are averages taken from the expense accounts of actual transportation companies. The figures for UTACV and PRT were estimated, as there are yet no systems of this type in revenue operation. As can be seen, the O & M costs, in cents per mile, were predicted to be less for the UTACV than for the other systems, particularly the express bus. This estimate resulted because the UTACV will be highly automated and low in labor intensity. The UTACV will also exhibit an additional advantage in overall system O & M costs since it requires fewer vehicles due to its higher average speed.

TABLE 2-2. UNIT CAPITAL COSTS USED FOR COMPARATIVE PURPOSES

COST PARAMETER	UTACV	RAPID RAIL	EXPRESS BUS	PRT
1. GUIDEWAY (1/3 ELEVATED 2/3 ON-GRADE), ALL COSTS $MILLION/MILE				
A. Base Cost	1.86	1.86	1.86	1.86
B. Electrification	0.344	0.344	0	0.344
C. Control & Instrumentation	0.411	0.411	0.035	0.411
D. Safety Guards	0.042	0.042	0.042	0.042
E. Substructure	0.172	0.172	0.172	0.172
F. Site Preparation	0.155	0.155	0.155	0.155
G. Reaction Rail	0.165	0	0	0
H. Electrical Substation	0.02	0.02	0	0.02
I. Engineering (% of total cost)	4.5%	4.5%	4.5%	4.5%
Total Cost, $Million/Mile	3.2	3.0	2.3	3.0
2. VEHICLES, $MILLION				
A. First Vehicle	2.6	0.75	0.09	0.03
B. Over Ten	1.85	0.50	0.06	0.02
3. TERMINALS, AIR, $MILLION				
A. Base Cost	7.5	7.5	7.5	7.5
B. Vol. Dep. Cost, f (PHR), f =	0.006	0.006	0.006	0.006
4. TERMINALS, COMMUTER, $MILLION				
A. Base Cost	0.86	0.86	0.86	0.86
B. Vol. Dep. cost, f (PHR), f =	0.004	0.004	0.004	0.004
5. PARKING LOTS, $MILLION	0.275	0.275	0.275	0.275
6. MAINTENANCE FACILITIES, $MILLION				
A. Base Cost	5.0	5.0	5.0	5.0
B. Vol. Dep, Cost, f (No. Veh.), f =	0.025	0.025	0.025	0.025

To compare the debt retirement costs associated with the various systems investigated, the total capital cost for each system was determined for the baseline applications previously described. Table 2-4 shows the total capital resources resulting from their application to the 10 mile baseline situation with a passenger volume of 5.6 million per year. The results show that the capital costs are somewhat greater for the UTACV than for the other systems. As is evident from the data outlined in Table 2-2, the UTACV system is more costly primarily because of the extra guideway requirements and the vehicle cost. The annualized debt retirement cost associated with each of the systems is directly proportional to its capital cost. The debt retirement cost for the UTACV system is, therefore, correspondingly higher than that of the other systems.

In discussing how the financing method affects the total annualized costs, two important points should be made regarding O & M and debt requirement costs as they are related to specific vehicle technologies. Advanced technology systems such as the UTACV have lower O & M costs than bus systems, for example, which are more labor intense. This advantage is particularly significant because O & M costs are difficult to reduce and in reality tend to increase with time, as labor and material costs rise.

Advanced technology systems, on the other hand, tend to be handicapped by comparitively high debt retirement costs. Debt retirement costs, however, can be subject to reduction in terms of the fare level required to cover these costs through the application of non-revenue sources of financing. It is important to recognize that non-revenue capital financing does not actually reduce the capital resources required for a system, but it does reduce the burden of financing the capital cost by the patrons and shifts it to the community at large. The higher fare levels required for more capital intensive systems can, therefore, be diminished if all or a portion of the capital costs of that system are financed through a capital grant or other non-revenue funding sources (general obligation bonds).

Based on the above discussion, several observations can be made to relate how the method of system financing affects the level of revenues required to cover the total annualized costs. The most conservative method of financing, resulting in the highest fare levels, assumes that revenues must be sufficient to defray all O & M costs and all debt retirement costs associated with financing the entire initial capital cost of the system. The other extreme assumes that the entire capital cost of the system is covered by non-revenue financing, reducing the revenues required to an amount equal to the O & M costs. Between these extremes, the most realistic situation occurs when it is assumed that O & M costs are covered in full by revenues and that a partial grant is used to reduce the debt retirement costs.

TABLE 2-3. BASE UNIT OPERATING AND MAINTENANCE COSTS FOR VARIOUS TYPES OF TRANSPORTATION

PARAMETER	URACV	RAPID RAIL	EXPRESS BUS	PRT
ENERGY, ¢/SEAT MILE	.20	.11	.08	.20
OPERATIONS & LABOR ¢/SEAT MILE	.61	.70	1.16	.80
VEHICLE MAINTENANCE, ¢/SEAT MI	.28	.31	.44	.55
ELECTRICAL MAINTENANCE, ¢/SEAT MILE	.11	.13	0	.12
OVERHEAD, ¢/SEAT MILE	.23	.27	.60	.29
GUIDEWAY MAINTENANCE, $/LN. MI./YR.	2000	2000	4000	2000

TABLE 2-4. CAPITAL COSTS FOR BASELINE SYSTEMS*

	UTACV	RAPID RAIL	EXPRESS BUS	PRT
GUIDEWAY	33	31	24	31
VEHICLES	15	5	1	2
TERMINALS	18	18	18	18
MAINT. FACILITIES	5	5	5	7
TOTAL COST	71	59	48	58
TOTAL COST/MILE	7.1	5.9	4.8	5.8

*10 - Mile System Length
5.6 Million Passenger Trips Per Year
All Costs in $ Million

The Urban Mass Transportation Act of 1964 recognized the need to assist in the area of non-revenue financing and was created so that transportation systems could be established without the local community or patrons being required to carry the total financial burden of the project. The Act authorizes capital assistance up to two-thirds of the cost of that part of a project which cannot be reasonably financed from revenues (net project cost). The remaining one-third of the net project cost must be provided by the local community from cash surpluses, replacement or depreciation funds, or reserves available in sash or new capital.

The impact of the method of system financing on the total annualized costs is described in Table 2-5. The table illustrates the total annualized cost which results from assuming the two extreme methods of system financing for each of the compared systems as they are applied to the 10 mile baseline situation.

TABLE 2-5. TOTAL ANNUALIZED COST VS. FINANCE METHOD*

	UTACV	RAPID RAIL	EXPRESS BUS	PRT
Full Debt Retirement				
O & M Costs	1.28	1.36	2.07	1.73
Debt Ret. Costs	8.15	6.50	5.13	6.27
Total Annualized Cost	9.43	7.86	7.20	8.01
No Debt Retirement				
O & M Costs	1.28	1.36	2.07	1.73
Debt Ret. Costs	0	0	0	0
Total Annualized Cost	1.28	1.36	2.07	1.73

*ASSUMPTIONS:

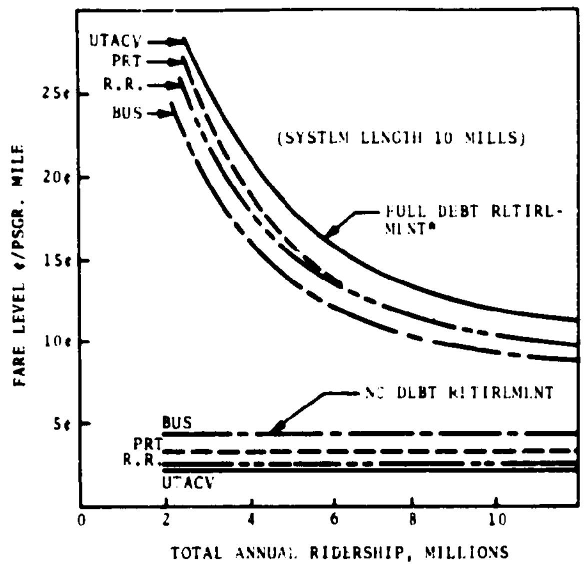
10-mile system length
5.6 million passenger trips per year
10% interest rate
30 years debt term on fixed facilities
12 years debt term on vehicles
All costs in $ Million

The revenues generated by any transportation system are a direct function of the fare level charged and total number of patrons using the system. These revenues must in turn be equal to the total annualized cost of operation described above as a function of the method of financing. This complex relationship is illustrated in Figure 2-1 which illustrates the break-even fare level versus the system patronage for the two extreme methods of system financing as each system investigated is applied to the 10 mile baseline situation. As would be expected, the UTACV system requires the highest fare level when full debt financing is assumed because of its greater capital cost; however, it requires the lowest fare level when no debt financing is assumed because it has the lowest O & M costs. It should also be noted that the range of fares required between transportation modes is relatively small for a given method of financing. It is of interest to compare from Figure 2-1 the range of fares predicted for the UTACV for an average volume of patronage with those fares being charged patrons for existing airport access modes. Figure 2-2 is a plot of existing fares that are being charged at various airports versus the length of the trip. For a 10 mile system, which is the baseline assumed in Figure 2-1, it is evident that the projected UTACV fares will be well within the range of existing fares even assuming the most conservative method of financing.

2.3.2 System Length

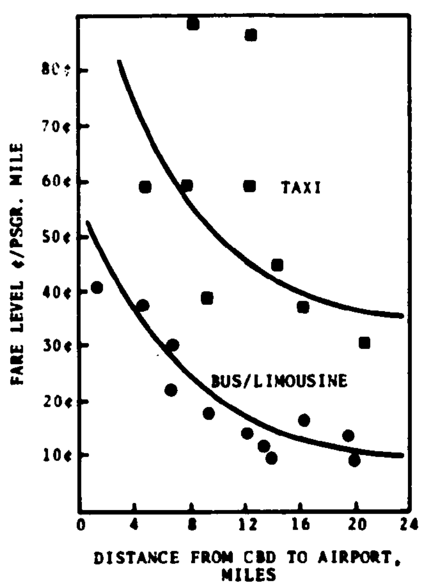
For a given volume of patronage, the fare level, in cents per passenger mile (¢/PM), required to defray the total annualized costs can be affected by the system length. The extent to which the fare level is length dependent is determined by the method of financing. Under the conditions of no debt financing, the system length has little affect on fare levels because the revenues are applied only to O & M costs which are relatively insensitive to length. When full debt financing is assumed, however, the fare level is influenced significantly as is shown in Figure 2-3. This figure shows that the fare level increases for the UTACV as the length of the system is reduced below 40 miles. The fare level shows a particularly sharp increase for lengths less than about 10 miles and represents the length below which a patron is charged an ever increasing amount for the same unit of service. For strictly financial reasons, therefore, 10 miles should be the minimum desirable length or distance between stops for the UTACV system. Other factors involving user benefits such as travel time and speed suggest an independent but complementary argument for maintaining UTACV system lengths greater than 10 miles. A UTACV system of 10 miles or less could become more economically justifiable if, at some future date, it were to be incorporated into a system of greater length.

The basic underlying factor contributing to the length dependency of the fare level is the ratio of vehicle costs to guideway costs. This relationship is illustrated in Figure 2-4 for the UTACV and Express Bus systems. As the figure shows, the vehicle



*10% INTEREST RATE
30 YEAR TERM, FIXED FACILITIES
12 YEAR TERM, VEHICLES

Figure 2-1. Break Even Fare Level vs. Total Annual Ridership



*Source, "Survey of Ground-Access Problems at Airports, "Transportation Engineering Journal Proceedings of the American Society of Civil Engineers, February 1969.

Figure 2-2. Existing Fare Structures at Major Airports*

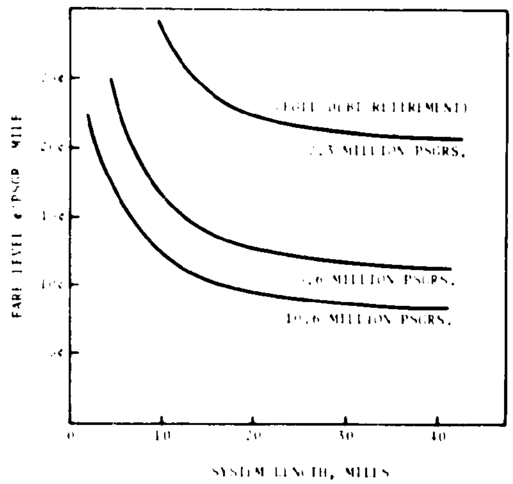


Figure 2-3. Break Even Fare Level for UTACV vs. System Length

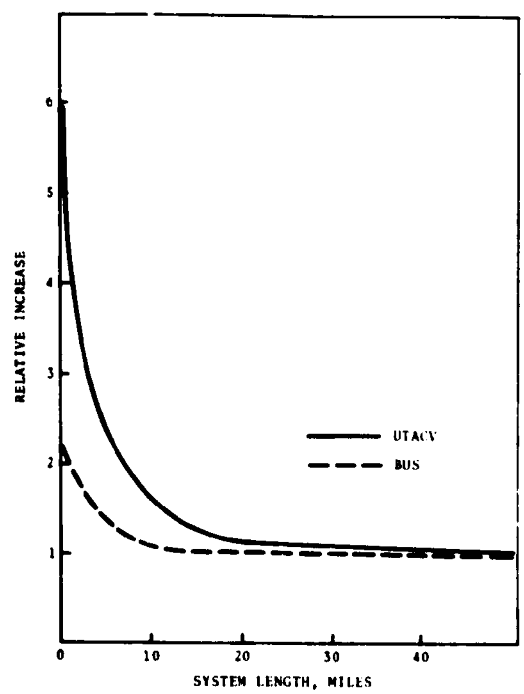


Figure 2-4. Relative Increase in Ratio of Vehicle to Guideway Cost vs. System Length

costs increase rapidly relative to the guideway costs as the systen length is decreased below ten and five miles respectively for the UTACV and express bus. This relative increase in vehicle costs is directly attributable to a corresponding decrease in the vehicles average speed for the shorter trip distances. Any reduction in guideway costs, therefore, tends to be offset by a relative increase in vehicle costs as the system length is reduced below the critical values mentioned above.

Referring back to Figure 2-1 which describes the fare level versus patronage for a ten mile system, note that the upper set of curves would be shifted downward if the same information was ploted for a longer system. For example, at a patronage level of 5.6 million the required fare is about 16.5¢/PM for the 10-mile system but is only 12.5¢/PM for a 20-mile system. The lower set of curves, however, indicate only O & M costs and will remain constant regardless of the system length.

2.3.3 System Patronage

Figure 2-1, shows that if a system is to be economically viable at existing fare levels a minimum volume of patronage is required. Specifically, if a conservative method of financing is assumed, at least four million passengers a year are necessary to support the system at an acceptable fare level. The actual patronage, which will ride the system, however, is largely determined by its specific application. For example, if the UTACV is to be used for airport access applications, the patronage will consist of airline passengers, vistors, airport employees and commuters. The airline passengers will normally represent the majority of passengers, but depending upon the specific situation, airport employees and commuters can contribute greatly to the overall patronage. This is particularly true for a system linking two CBD's to an airport as it can generate a large volume of intercity commuters entirely independent if the airport. Table 2-6 lists several airports with their forecasted enplanement and the estimated UTACV ridership which will occur by 1980. These systems represent the range of demands for the nations 20 largest airports. As can be seen, even the minimum forecasted ridership will be sufficient to support a UTACV system under the conditions of the most conservative method of financing.

2.4 CONCLUSIONS

In conclusion, the major parameters which affect the system costs for various modes of ground transportation have been defined. The impact of these parameters-method of system financing, system length, and system patronage has been demonstrated in terms of their affect on the ultimate fare level required to maintain economic viability. Based upon the assumption that a new guideway will be required for all of the compared systems as they are applied to the baseline situations previously described, the results

TABLE 2-6. FORECASTED UTACV RIDERSHIP FOR SELECTED AIRPORTS, MILLIONS

	FORECASTED ENPLANEMENT	FORECASTED UTACV RIDERSHIP
LOS ANGELES	41	14.2
DALLAS-FT. WORTH	16	6.0
MIAMI	16	6.0
HOUSTON	7	3.0
SEATTLE-TACOMA	7	4.0

of the comparative cost study can be summarized as follows:

1. The O & M costs for the UTACV are less than for the other systems compared and will become increasingly favorable as time progresses.

2. The capital costs for the UTACV are somewhat greater than for the other systems compared, but, this disadvantage can be effectively offset, as see through the fare levels, by means of non-revenue financing.

3. The method of system financing has a large impact on required fare levels, and adoption of methods currently in practive with existing ground transportation systems and encouraged by the 1964 UMTA Act tends to favor those systems such as the UTACV which are capital intensive and low in O & M costs.

4. The UTACV system in financially more suitable for applications involving long hauls or widely spaced station stops while the slower systems such as the express bus are more suitable for short haul applications.

5. It is estimated that, for the nation's 20 largest airports, there exist applications where a high speed ground access system can generate ridership sufficient to financially support the UTACV system.

3.0 DEVELOPMENT OF COMPUTER PROGRAM & UTACV SENSITIVITY ANALYSIS

3.1 INTRODUCTION

In Section 2.0 of this report, the UTACV system is compared with other modes of ground transportation on a cost basis. This section describes the development of the computer program which was utilized to perform the above cost studies. In addition, the results of a computerized parametric sensitivity analysis performed for the UTACV is discussed.

The computer program was developed in two parts to achieve the original objectives of the study. The first stage of development, Phase I, produced results in a format suitable for determining the costs involved in implementing various proposed transportation systems. The program for Phase I was arranged so that all of the system characteristics and costs for a wide range of operating conditions were printed out in logical format enabling trade-off studies to be made. The program, originally designed to analyze the UTACV, was written with sufficient flexibility to permit it to be adapted to entirely different transportation systems. This, in fact, was done for the comparative cost analysis which is described in Section 2.0.

Phase II of the analysis consisted of a detailed computerized sensitivity study of the UTACV. The results of Phase II are in the form of a series of plots which graphically describe the sensitivity of the various system parameters on the total system cost. The input function for this analysis was the annual airplane emplanement which is the basic contributor to revenues assuming an airport access system. The output function was the deficit or surplus resulting from the system's operation and is the basic criteria of its economic viability. The computer determined the sensitivity of a parameter by plotting ridership against profit for three different values of the parameter while the other system variables were held constant. Examples of both Phase I and Phase II print-out can be found in Appendix C.

3.2 COMPUTER PROGRAM DEVELOPMENT

3.2.1 Background

Development of the computer program required the analysis of three major areas of consideration: (1) physical operating characteristics, (2) passenger demand characteristics, and (3) financial characteristics. For each of these areas, it was necessary to determine the parameters to be investigated in terms of their having an impact on system costs and how they were to be mathematically formulated and incorporated into the computer program. The various parameters deemed to be of significant value in describing the system costs are listed according to their major area of influence below.

1. Operating characteristics

   a. System type (two or three terminals)
   b. System length
   c. Load factor
   d. Vehicle capacity
   e. Headway
   f. Acceleration & deceleration rates
   g. Maximum cruise velocity
   h. Station dwell time

2. Passenger demand characteristics

   a. Annual airplane enplanement
   b. Modal split, airline passengers
   c. Airport employment
   d. Modal split, airport employees
   e. Airport visitors
   f. Modal split, airport visitors
   g. Inter-airline transfers
   h. Fare level
   i. Peak hour ridership

3. Financial characteristics

   a. Fixed capital costs

      (1) cost of guideway
      (2) cost of vehicles
      (3) cost of stations & parking areas
      (4) cost of maintenance facilities
      (5) cost of right of way

   b. Operating & depreciation costs

      (1) cost of energy
      (2) cost of operation & maintenance
      (3) depreciation period, fixed systems
      (4) depreciation period, vehicles

   c. Debt financing

      (1) interest rate
      (2) debt period (same as depreciation period)
      (3) net project cost
      (4) government grants

3.2.2 Operating Characteristics

A significant problem in analyzing the system operating characteristics arose from the fact that a large number of system configurations were possible. As is discussed in Section 2.0 however, the UTACV system was primarily being considered for airport access situations where there are basically three baseline system configurations: CBD to airport, CBD to airport to CBD, and airport to airport. The first two configurations were chosen for this analysis while the airport to airport system was excluded primarily because of the difficulty in analyzing its passenger demand characteristics. Both systems analyzed in this section were assumed to utilized double elevated channel guideways, one maintenance facility, passenger terminals and turnarounds at each end. The CBD to airport system (identified at "two terminal" in the print-out) has one downtown check-in air terminal and one airport commuter terminal. The CBD to airport to CBD system ("three terminal") has two downtown check-in air terminals and one airport commuter terminal.

The length of the system, as it is indicated in the print-out represents the total guideway length either from the CBD to the airport, in the case of the two terminal system, or from one CBD to the other CBD, as in the three terminal system. In addition, for the three terminal system, it was assumed that the passenger demand was equally divided and that the airport was located exactly between the two CBDs.

The physical constraints assumed at the terminals for the two configurations investigated are indicated in Figure 3-1. Although the assumed total dwell time for a vehicle at the terminal was six minutes, the actual trip time that a passenger encounters in traveling from one terminal to another was based on only one minute loading time and one minute unloading time. The vehicle was assumed to accelerate uniformly to its maximum cruise velocity and remain at that speed until it decelerated for the next terminal.

Because of the loading and turnaround times assumed at the terminals, the minimum permissible headway was two minutes. If a specific system investigated resulted in a headway of less than two minutes, the computer program entrained the vehicles, thus increasing the headway. The total number of vehicles required for a given system was based upon the peak hour demand plus an additional 20% to provide for maintenance downtime

3.2.3 Passenger Demand Characteristics

Since the UTACV was to be analyzed for airport access situations, the potential ridership for the system was primarily based upon the demand generated by the airport. As a result, three groups of patrons were likely candidates to ride the UTACV to the airport: airline passengers, airport visitors and airport employees. For the CBD to airport to CBD application there was also a fourth

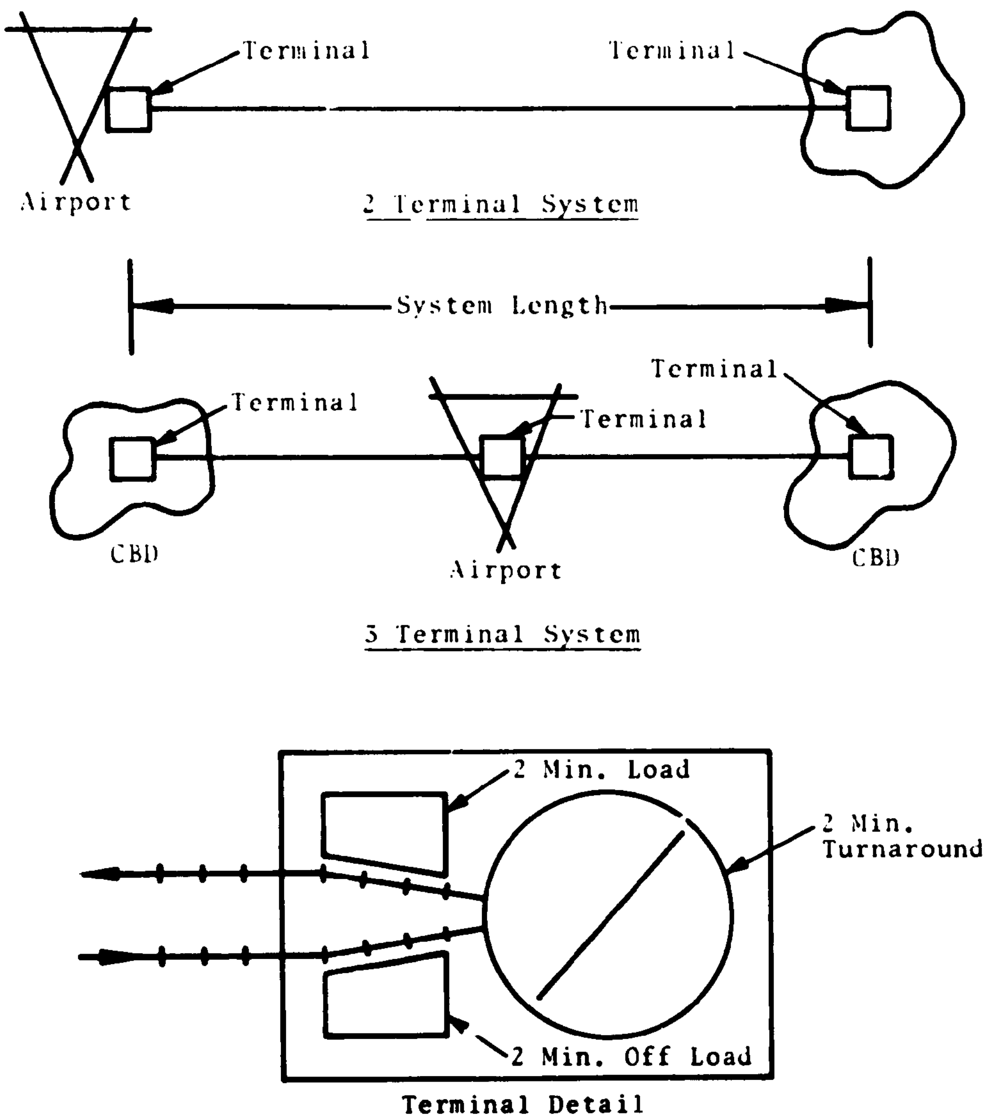


Figure 3-1. Baseline Airport Access Situations

group of potential patrons, intercity commuters. It was particularly difficult to formulate the possible ridership resulting from this group for a site independent situation, however, and consequently this group was not included in the sensitivity analysis. The enplaned airline passengers were used as the main input for the demand analysis as this group represents the major portion of the total UTACV patronage and is the figure most cited to describe total airport activity. To obtain the potential UTACV market for airline passengers desiring to travel to a particular airport, the interline transfers were subtracted from the total enplaned passengers to yield the actual originating airline passengers. The total number of visitors arriving at the airport were assumed to be equal to 80 percent of the originating airline passengers. The daily airport employment was chosen to represent the potential market for the employee group. Each of the three groups of potential UTACV riders were then reduced by modal split and peaking factors and added to arrive at the total peak hour UTACV ridership.

The actual numbers which were used as inputs for the passenger demand analysis section of the program represent typical values found at existing major airports. For example, the values used for the enplaned airline passengers and the daily airport employment cover a range of figures which can be found at the nation's 20 largest airports. Similarly an investigation was made to determine what range of modal splits and peaking factors should be utilized to be representative of those most likely to occur in actual practive.

3.2.4 Financial Characteristics

The assumptions made regarding the method of system financing for the cost analysis are described in Section 2.0 as having a significant impact on the results of the study. For this reason the financial assumptions which were incorporated into the computer program and reflected in the sensitivity analysis are described below.

1. Capital Costs - The capital items included in the program were the guideway structure (including electrification), vehicles, maintenance facilities and terminals. The sensitivity of right-of-way (ROW) costs were also determined; however for baseline situations ROW costs were assumed to be zero.

2. O & M Costs - All O & M costs including depreciation, were considered in the total annualized costs. The vehicles and other fixed capital items were depreciated on a straight line basis with a 10% salvage value for the vehicles. Although the assumption of a full depreciation allotment is unrealistically conservative for an actual situation, these costs were included so that their sensitivity could be determined.

3. Debt Financing - The computer program was designed to cover several different financing contigencies depending upon the revenues available. The program initially determined the total revenues produced and applied them first towards defraying all O & M costs. If a net revenue remained after deducting O & M costs, it was then determined how much, if not all, of the debt retirements costs could be covered. That portion of the total project cost which could not be financed through revenues (net project cost) was then determined. The program then computed the government and local grant required to support the project based on two-thirds and one-third respectively of the net project cost.

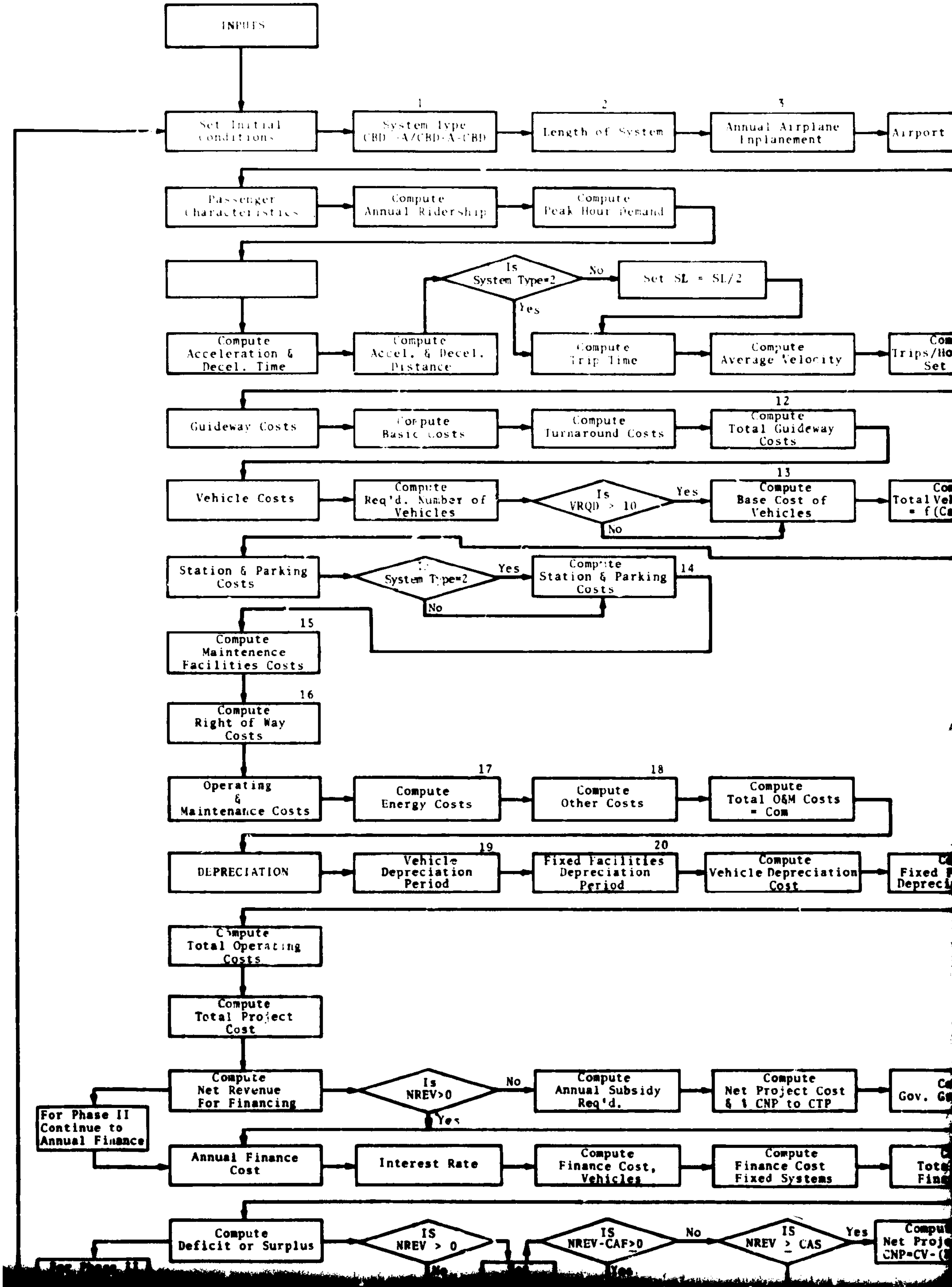
3.2.5 Calculated Values, Constants and Variables

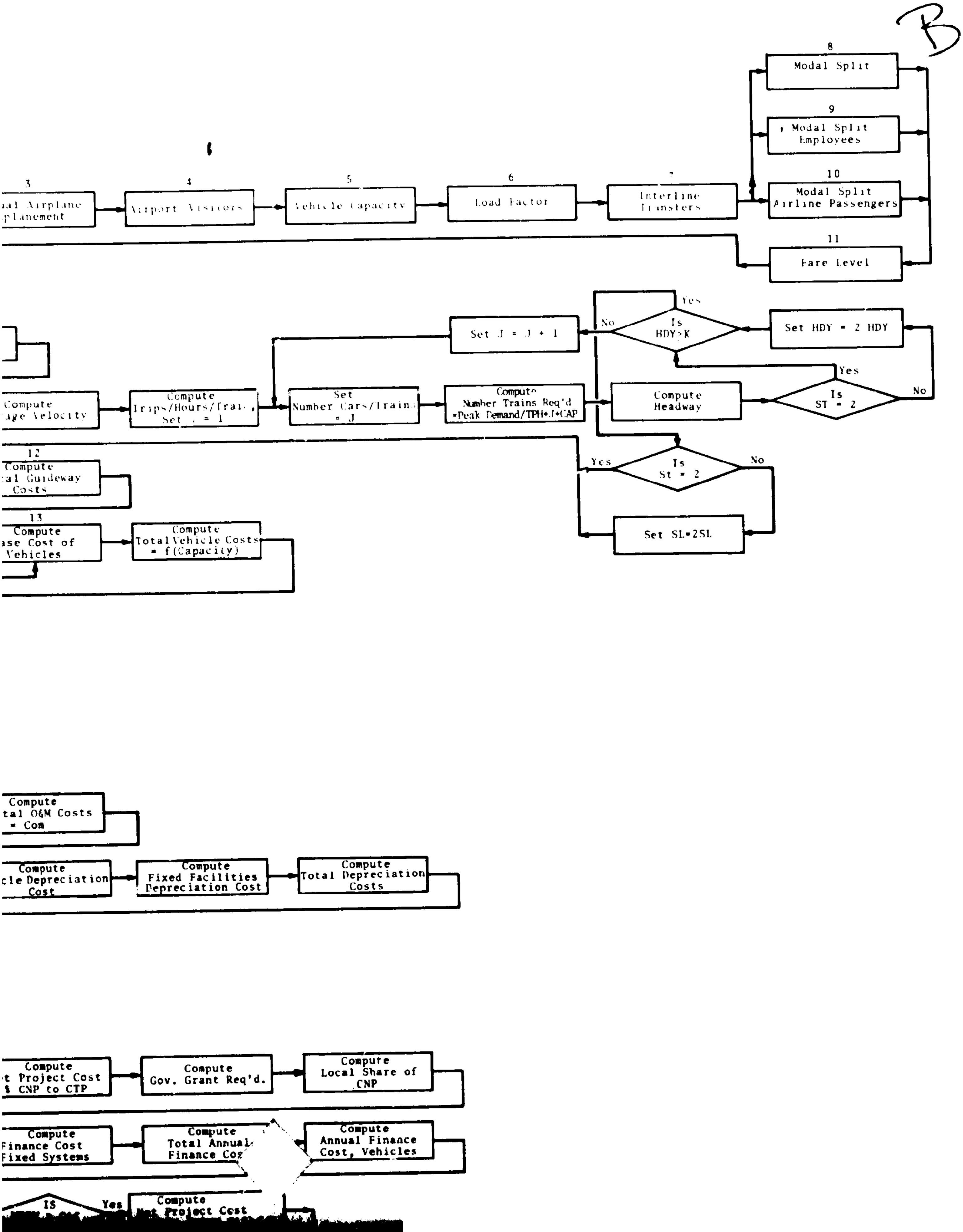
Based on the initial considerations discussed above, the values to be calculated by the computer program, its input constants, and the sensitivity variables were determined. The calculated values are listed in Table 3-1 and the program constants in Table 3-2, each with their corresponding program symbols and units of measure. Table 3-3 contains a list of the program variables and the range of values assigned to them for purposes of performing the sensitivity analysis. By assigning different values to these variables in a predetermined sequence, the sensitivity of each system parameter was determined. The underlined value assigned to variables numbered #4 through #21 was their baseline or normal value. The baseline value represented a reasonable estimate for the value of that particular variable if it was to be used as a constant. The other two values assigned to the variables represented the maximum and minimum deviation from the baseline value which could be reasonably expected in actual practice. It should be noted that in determining the sensitivity of any one variable it was changed from it maximum to minimum value while all the other variables were held constant at their baseline value.

3.2.6 Computer Logic

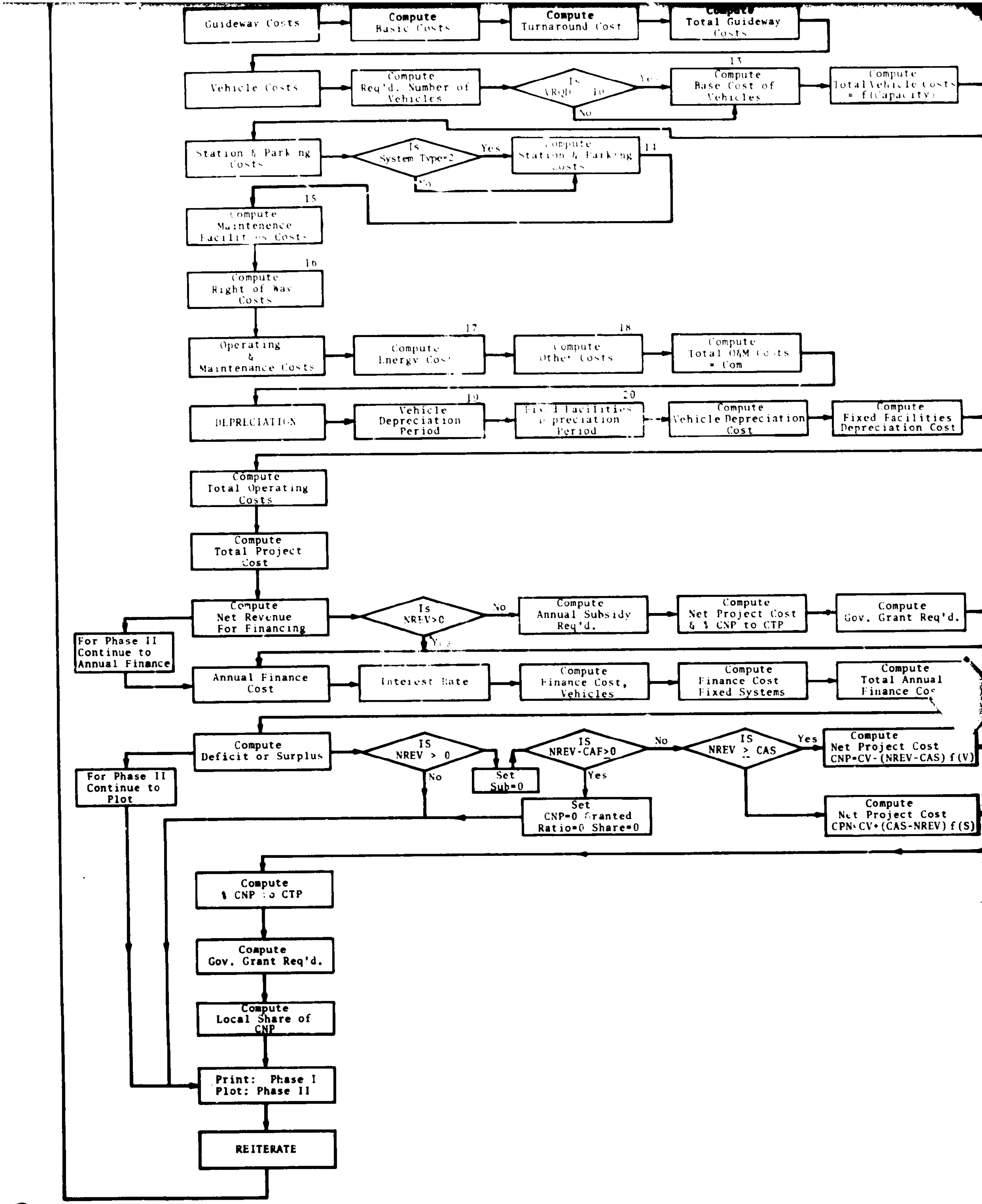
The basic sequence of computer operations in executing the program is illustrated by the flow diagram, Figure 3-2. To summarize the detailed procedures outlined by the flow diagram, the following simplified sequence of operations is listed.

1. Establish initial conditions - length, type, etc.
2. Compute annual and peak hour riderships
3. Based on peak hour ridership, compute operating characteristics and vehicle requirements
4. Determine total project cost


INPUTS
Set Initial Conditions
1
System Type CBD -A/CBD-A-CBD
2
Length of System
3
Annual Airplane Enplanement
Airport
Passenger Characteristics
Compute Annual Ridership
Compute Peak Hour Demand
Is System Type=2
No
Set SL = SL/2
Yes
Compute Acceleration & Decel. Time
Compute Accel. & Decel. Distance
Compute Trip Time
Compute Average Velocity
12
Guideway Costs
Compute Basic Costs
Compute Turnaround Costs
Compute Total Guideway Costs
13
Vehicle Costs
Compute Req'd. Number of Vehicles
Is VRQD > 10
Yes
No
Compute Base Cost of Vehicles
Station & Parking Costs
System Type=2
Yes
No
Compute Station & Parking Costs
14
15
Compute Maintenence Facilities Costs
16
Compute Right of Way Costs
17
18
Operating & Maintenance Costs
Compute Energy Costs
Compute Other Costs
Compute Total O&M Costs = Com
19
20
DEPRECIATION
Vehicle Depreciation Period
Fixed Facilities Depreciation Period
Compute Vehicle Depreciation Cost
Compute Total Operating Costs
Compute Total Project Cost
Compute Net Revenue For Financing
Is NREV>0
No
Yes
Compute Annual Subsidy Req'd.
Compute Net Project Cost & % CNP to CTP
For Phase II Continue to Annual Finance
Annual Finance Cost
Interest Rate
Compute Finance Cost, Vehicles
Compute Finance Cost Fixed Systems
Compute Deficit or Surplus
IS NREV > 0
IS NREV-CAF>0
No
IS NREV ≥ CAS
Yes
Yes



B
8
Modal Split
9
Modal Split Employees
3
Airplane planement
4
Airport Visitors
5
Vehicle Capacity
6
Load Factor
7
Interline Transfers
10
Modal Split Airline Passengers
11
Fare Level
Yes
Is HDY>K
No
Set J = J + 1
Set HDY = 2 HDY
Yes
Is ST = 2
No
Compute Velocity
Compute Trips/Hours/Train, Set J = 1
Set Number Cars/Train = J
Compute Number Trains Req'd =Peak Demand/TPH*J*CAP
Compute Headway
12
Compute Guideway Costs
Yes
Is St = 2
No
13
Compute Base Cost of Vehicles
Compute Total Vehicle Costs = f(Capacity)
Set SL=2SL
Compute Total O&M Costs = Com
Compute Vehicle Depreciation Cost
Compute Fixed Facilities Depreciation Cost
Compute Total Depreciation Costs
Compute Project Cost CNP to CTP
Compute Gov. Grant Req'd.
Compute Local Share of CNP
Compute Finance Cost Fixed Systems
Compute Total Annual Finance Cost
Compute Annual Finance Cost, Vehicles
IS
Yes
Compute Net Project Cost



Guideway Costs
Compute Basic Costs
Compute Turnaround Cost
Compute Total Guideway Costs
Vehicle Costs
Compute Req'd. Number of Vehicles
Is VRQD ... 10
Yes
No
13
Compute Base Cost of Vehicles
Compute Total Vehicle Costs = f(Capacity)
Station & Parking Costs
Is System Type=2
Yes
No
Compute Station & Parking Costs
14
15
Compute Maintenence Facilities Costs
16
Compute Right of Way Costs
Operating & Maintenance Costs
17
Compute Energy Cost
18
Compute Other Costs
Compute Total O&M Costs = Com
DEPRECIATION
19
Vehicle Depreciation Period
20
Fixed Facilities Depreciation Period
Compute Vehicle Depreciation Cost
Compute Fixed Facilities Depreciation Cost
Compute Total Operating Costs
Compute Total Project Cost
Compute Net Revenue For Financing
Is NREV>0
No
Yes
Compute Annual Subsidy Req'd.
Compute Net Project Cost & % CNP to CTP
Compute Gov. Grant Req'd.
For Phase II Continue to Annual Finance
Annual Finance Cost
Interest Rate
Compute Finance Cost, Vehicles
Compute Finance Cost Fixed Systems
Compute Total Annual Finance Cost
Compute Deficit or Surplus
IS NREV > 0
No
Set Sub=0
IS NREV-CAF>0
Yes
No
IS NREV ≥ CAS
Yes
Compute Net Project Cost CNP=CV-(NREV-CAS) f(V)
For Phase II Continue to Plot
Set CNP=0 Granted Ratio=0 Share=0
Compute Net Project Cost CPN=CV+(CAS-NREV) f(S)
Compute % CNP to CTP
Compute Gov. Grant Req'd.
Compute Local Share of CNP
Print: Phase I
Plot: Phase II
REITERATE

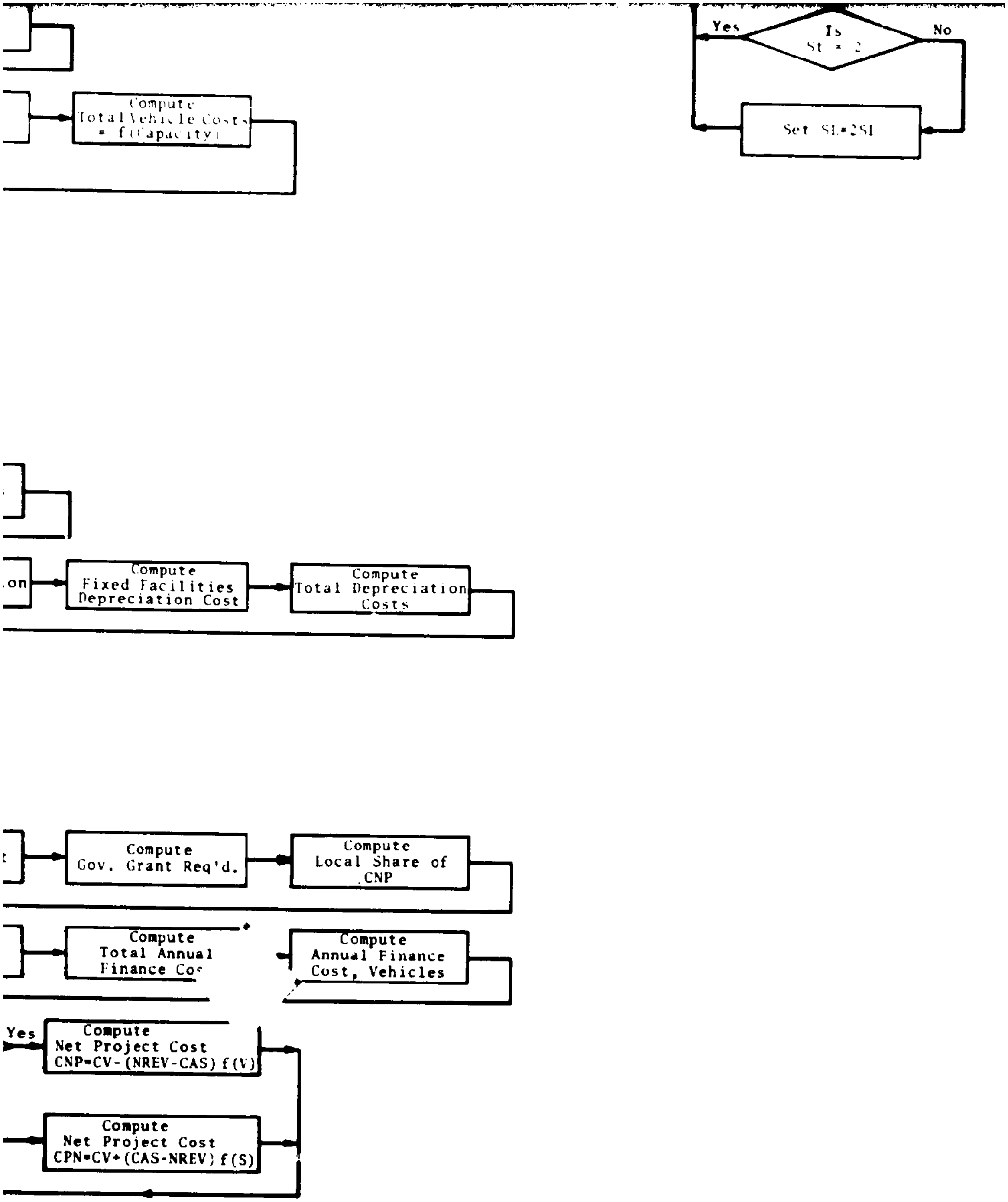


Figure 3-2. Computer Flow Diagram

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TABLE 3-1. CALCULATED VALUES

	SYMBOL	DESCRIPTION	UNIT
1.	AAV,	ANNUAL AIRPORT VISITORS	MILLION/YEAR
2.	AR,	ANNUAL RIDERSHIP	MILLION/YEAR
3.	PHR,	PEAK HOUR DEMAND	PASSENGERS
4.	TA,	ACCELERATION TIME	MINUTES
5.	TD,	DECELERATION TIME	MINUTES
6.	DA,	ACCELERATION DISTANCE	MILES
7.	DD,	DECELERATION DISTANCE	MILES
8.	TT,	ONE WAY TRIP TIME	MINUTES
9.	VA,	AVERAGE VELOCITY	MPH
10.	THT,	TRIPS PER HOUR PER TRAIN	ROUND TRIP
11.	TRQD,	NUMBER OF TRAINS REQUIRED FOR PEAK HOUR DEMAND	
12.	J,	NUMBER OF CARS PER TRAIN	
13.	HDY,	HEADWAY AT PEAK HOUR	MINUTES
14.	NCARS,	REQUIRED VEHICLES PLUS SPARES	
15.	CG,	COST OF GUIDEWAY	MILLIONS OF DOLLARS
16.	CV,	COST OF VEHICLES	MILLIONS OF DOLLARS
17.	CS,	COST OF STATIONS AND PARKING AREAS	MILLIONS OF DOLLARS
18.	CM,	COST OF MAINTENANCE FACILITIES	MILLIONS OF DOLLARS
19.	CRW,	RIGHT OF WAY COSTS	MILLIONS OF DOLLARS
20.	CTP,	TOTAL PROJECT COST	MILLIONS OF DOLLARS
21.	CERG,	COST OF ENERGY	MILLION DOLLARS/YEAR
22.	COPMT,	COST OF OPERATION & MAINTENANCE	MILLION DOLLARS/YEAR
23.	COM,	TOTAL OPERATING & MAINTENANCE COSTS	MILLION DOLLARS/YEAR
24.	CDS,	DEPRECIATION COSTS FOR FIXED SYSTEMS	MILLION DOLLARS/YEAR
25.	CDV,	DEPRECIATION COSTS FOR VEHICLES	MILLION DOLLARS/YEAR
26.	COMD,	TOTAL COST OF OPERATION, MAINTENANCE AND DEPRECIATION	MILLION DOLLARS/YEAR
27.	CD,	TOTAL DEPRECIATION COSTS	MILLION DOLLARS/YEAR
28.	CAS,	ANNUAL FINANCE COST FOR FIXED SYSTEMS	MILLION DOLLARS/YEAR
29.	CAV,	ANNUAL FINANCE COST FOR VEHICLES	MILLION DOLLARS/YEAR
30.	CAF,	TOTAL ANNUAL FINANCE COSTS	MILLION DOLLARS/YEAR
31.	REV,	TOTAL ANNUAL REVENUES	MILLION DOLLARS/YEAR
32.	NREV,	NET REVENUE FOR DEBT FINANCING	MILLION DOLLARS/YEAR
33.	DOS,	REMAINING REVENUE AFTER DEBT FINANCING	MILLION DOLLARS/YEAR
34.	CNP,	NET PROJECT COST	MILLION DOLLARS/YEAR
35.	GRANT,	GOVERNMENT GRANT TOWARDS NET PROJECT COST	MILLION DOLLARS
36.	SHARE,	LOCAL SHARE OF NET PROJECT COST	MILLION DOLLARS
37.	SUB,	ANNUAL SUBSIDY REQUIRED TO COVER COMD	MILLION DOLLARS/YEAR

TABLE 3-2. PROGRAM CONSTANTS*

	SYMBOL	DESCRIPTION	VALUE	UNIT
1.	VM,	MAXIMUM CRUISE VELOCITY	150	MPH
2.	GA,	ACCELERATION RATES	.0815	G's
3.	GD,	DECELERATION RATE	.0815	G's
4.	TS,	STATION DWELL TIME	6.0	MINUTES
5.	K,	MINIMUM HEADWAY TIME	2.0	MINUTES
6.	CB,	BASE COST OF GUIDEWAY	2.85	MILLION DOLLARS/MILE
7.	CEL,	ELECTRIFICATION COST	.344	MILLION DOLLARS/MILE
8.	CCI,	CONTROLS AND INSTRUMENTATION COST	.411	MILLION DOLLARS/MILE
9.	CSG,	SAFETY GUARD COST	.042	MILLION DOLLARS/MILE
10.	CSUB,	SUBSTRUCTURE COST	.244	MILLION DOLLARS/MILE
11.	CSITE,	SITE PREPARATION COST	.155	MILLION DOLLARS/MILE
12.	CRAIL,	REACTION RAIL COST	.165	MILLION DOLLARS/MILE
13.	CESUB,	ELECTRICAL SUBSTATION COST	.02	MILLION DOLLARS/MILE
14.	CEN,	ENGINEERING COST	4.5	PERCENT
15.	CTURN,	TURNAROUND COST	.05	MILLION DOLLARS
16.	SPARE,	FACTOR FOR SPARE VEHICLES	1.20	MILLION DOLLARS
17.	CVI,	COST FOR FIRST VEHICLE	2.6	MILLION DOLLARS
18.	CV2,	COST PER VEHICLE OVER TEN	1.85	MILLION DOLLARS
19.	CSI,	AIR TERMINAL BASE COST	7.5	MILLION DOLLARS
20.	CS2,	AIR TERMINAL VOLUME DEPENDENT COST	.006	MILLION DOLLARS
21.	CS3,	COMMUTOR TERMINAL BASE COST	.86	MILLION DOLLARS
22.	CS4,	COMMUTOR TERMINAL VOLUME DEPENDENT COST	.004	MILLION DOLLARS
23.	CLOT,	PARKING LOT COST	.275	MILLION DOLLARS
24.	CMI,	MAINTENANCE FACILITY BASE COST	5.0	MILLION DOLLARS
25.	CM2,	MAINTENANCE FACILITY VOLUME DEPEN. COST	.025	MILLION DOLLARS
26.	CGYI,	BASE ENERGY COST	.16	DOLLARS/VEHICLE MILE
27.	CREW,	BASE COST VEHICLE CREW	.16	DOLLARS/VEHICLE MILE
28.	CMV,	BASE MAINTENANCE COST VEHICLE	.22	DOLLARS/VEHICLE MILE
29.	CMG,	BASE MAINTENANCE COST, GUIDEWAY	1890	DOLLARS/LANE MILE
30.	CME,	BASE MAINTENANCE COST, ELECTRICAL	.26	DOLLARS/VEHICLE MILE
31.	COHD,	BASE COST OVERHEAD	.01	DOLLARS/PASSENGER MILE

*Values indicated above correspond to those used in the sensitivity analysis.

TABLE 3-3. VARIABLES

	SYMBOL	DESCRIPTION	VALUE	UNIT
1.	ST,	SYSTEM TYPE	2,3	TERMINALS
2.	SL,	SYSTEM LENGTH	5, 15, 25, 35, 50	MILES
3.	AAE,	ANNUAL AIRLINE ENPLANEMENT	5, 10, 20, 30	MILLION
4.	SMAP,	MODAL SPLIT, AIRLINE PASSENGERS	5, 15, 25	PERCENT
5.	AE,	AIRPORT EMPLOYMENT	5,000, 15,000, 30,000	PERSONS
6.	SMAE,	MODAL SPLIT, AIRPORT EMPLOYEES	1, 7, 12	PERCENT
7.	SMV,	MODAL SPLIT, VISITORS	1, 7, 12	PERCENT
8.	XFERS,	INTER-AIRLINE TRANSFERS	5, 20, 50	PERCENT
9.	FL,	FARE LEVEL	.08, .15, .35	DOLLARS
10.	FLOAD,	LOAD FACTOR	50, 65, 80	PERCENT
11.	VC,	VEHICLE CAPACITY	20, 60, 100	PASSENGERS
12.	CFG,	GUIDEWAY COST FACTOR	.5, 1, 2	
13.	CFV,	VEHICLE COST FACTOR	.5, 1, 2	
14.	CFS,	STATION COST FACTOR	.5, 1, 2	
15.	CFM,	MAINTENANCE FACILITY COST FACTOR	.5, 1, 2	
16.	CRWI,	RIGHT OF WAY COST	.01, 0, .1	MILLION DOLLARS/ACRE
17.	CFGY,	ENERGY COST FACTOR	.5, 1, 2	
18.	CFOM,	OPERATION & MAINTENACE COST FACTOR	.5, 1, 2	
19.	TERMV,	VEHICLE DEPRECIATION & DEBT PERIOD	8, 12, 16	YEARS
20.	TERMS,	FIXED SYSTEMS DEPRECIATION & DEBT PERIOD	20, 30, 40	YEARS
21.	RATE,	INTERST RATE	5, 7.5, 10	PERCENT

5. Determine total O & M costs

6. Determine debt retirement costs

7. Determine ability of system to finance its operations

8. Compute any grants required.

During execution of the program, the variables were changed in a logical sequence so that the output could be easily interpreted. Referring to Table 3-3, variables #1 through #3 (system type, system length, and annual airport enplanement) were branched so that all possible combinations of these variables could be considered. The remaining variables were changed one at a time in consecutive order from variable #4 through #21. When a variable was not being considered, it remained at its underlined or baseline value. Thus, for each possible combination of variables #1, #2 and #3, the sensitivity of anyone of the variables #4 through #21 was determined.

3.3 SENSITIVITY ANALYSIS

3.3.1 Description of Output

For each of the parameters for which sensitivity information was desired, a sensitivity plot was generated by the computer. Each sensitivity plot contains three curves indicating the system behavior for three different values assigned to the parameter under investigation. A typical sensitivity plot is shown in Figure 3-3 which describes the effect on system costs of changing the modal split for airline passengers from 5 to 15 to 25 percent. The deficit or surplus indicated on the vertical axis was based on the assumption that all O & M costs (including full depreciation) and all debt retirement costs were covered by revenues; i.e., no grant had been applied. The horizontal axis describes increasing levels of airline enplanement at the hypothetical airport where the system is being applied.

3.3.2 Results

The sensitivity study was conducted by running a series of sensitivity plots for each parameter investigated for two terminal systems of 5, 25 and 50 mile lengths. A summary of the results obtained from this analysis can be found in Table 3-4, which shows the rank and order of magnitude of each parameter for the three different lengths. The order of magnitude for a parameter represents the change in the system's deficit or surplus occurring as the result of changing the parameter's value by 100 percent. In each case the sensitivity was computed at an annual enplanement level of 15 million per year, which corresponds to an actual UTACV ridership of 5.6 million passenger trips.

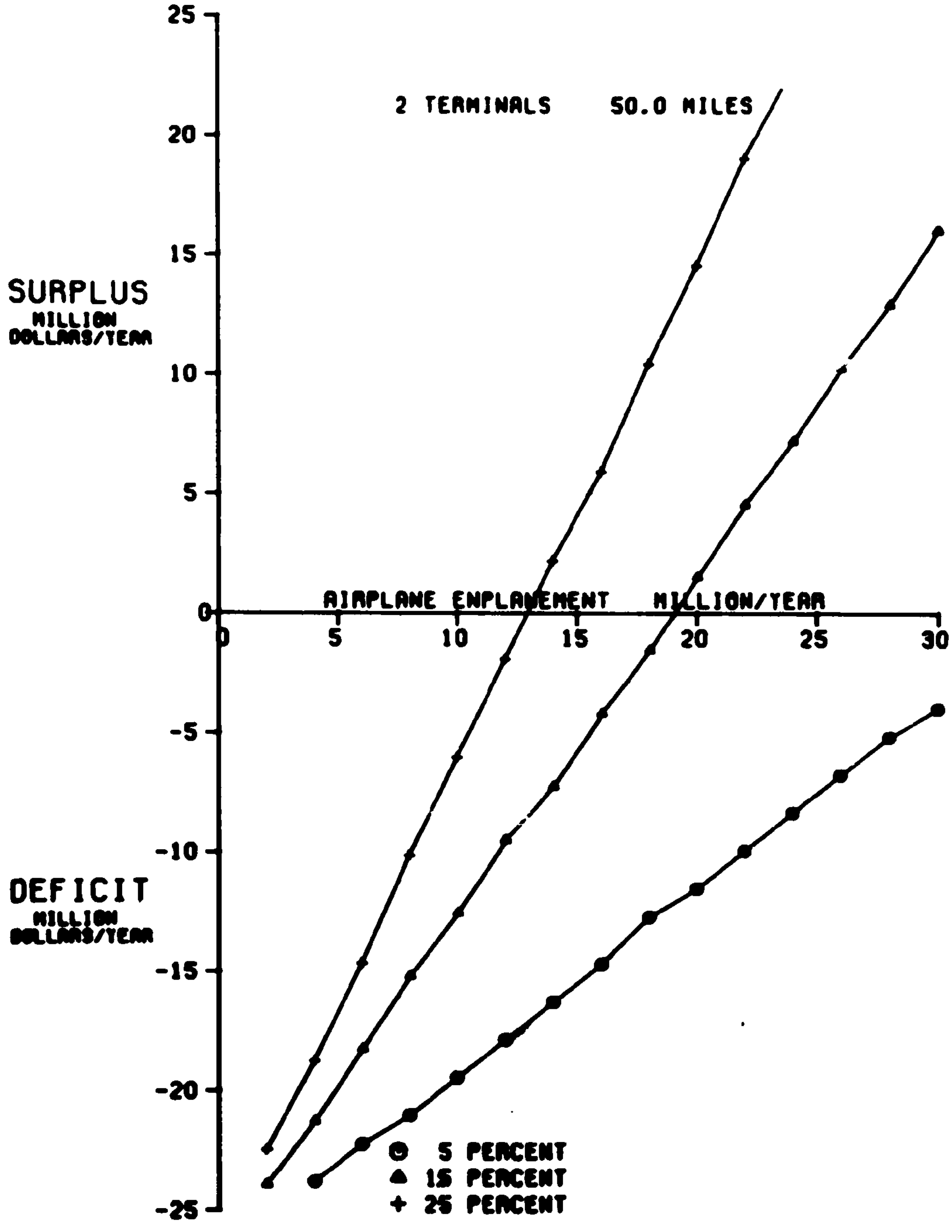

Figure 3-3. UTACV Parametric Analysis Sensitivity of Modal Split, Airline Passengers

TABLE 3-4. SUMMARY OF SENSITIVITY ANALYSIS RESULTS

	5 MILES		25 MILES		50 MILES	
	ORDER OF MAGNITUDE	RANK	ORDER OF MAGNITUDE	RANK	ORDER OF MAGNITUDE	RANK
Modal Split Airline Passengers	.37	16	6	6	15	7
Airport Employment	.9	10	.3	18	.6	19
Modal Split Airport Employment	.63	12	.32	17	.63	17
Modal Split Airport Visitors	.63	13	3.2	11	6.3	12
Interline Transfers	.22	18	2.2	13	10	9
Fare Level	3.9	3	22	1	44	1
Load Factor	4.4	1	11	4	17	6
Vehicle Capacity	3.7	5	11	3	19	3
Guideway Cost	2.7	8	13	2	27	2
Vehicle Cost	4	2	8	7	11	8
Station Cost	2	9	2	14	2	14
Maintenance, Facility Cost	.67	11	.67	15	.67	16
Right-of-Way Cost	.56	14	2.8	12	5	13
Energy Cost	.33	17	.67	16	1.4	15
O & M Costs	.56	15	4	10	8	11
Debt Period, Vehicles	3	6	6	9	10	10
Debt Period, Fixed Facilities	3	7	9	6	17	5
Interest Rate	3.8	4	10	5	18	4

Table 3-4 shows that the parameters vary in their rank of importance as a function of the system length. In Section 2.0 of this report it is explained that the system length affects costs primarily because of its influence on the ratio of vehicle costs to guideway costs. As is indicated by Table 3-4, therefore, those parameters directly affecting vehicle costs, such as the load factor and the vehicle purchase price, are more sensitive for the five-mile system than for the 50-mile system. The sensitivity of system length is also illustrated in Figure 3-4, which describes the net effect of an increasing vehicle to guideway cost ratio as a tendency to negate any extra revenues created from increased passenger demand.

Through appropriate use of the Phase II sensitivity plots and the Phase I digital print-out, the sensitivity of various other combinations of parameters can be determined resulting in a better appreciation of the financial characteristics of the system. As an example, Figure 3-5 is a plot of the break-even fare level versus guideway cost for several different levels of a government grant. Similarly, in Figure 3-6 the break-even government grant is plotted against the UTACV ridership for several valves of fare level. In both figures the financial impact of a small increase in fares or government assistance can be seen as being quite significant.

3.4 SUMMARY

This section describes the computer program used for conducting comparative cost studies and sensitivity analyses. The computer program can be easily modified to analyze various types of line haul systems, as was done for the comparative analysis in Section 2.0. The results obtained from its use are particularly applicable during the development stage of a prototype system. The Phase I digital print-out will permit initial estimates to be made of the physical and financial resources required in implementing either a series of hypothetical situations or an actual application. The Phase II results will then yield an appreciation of the system elements, physical and financial, having the most impact on the systems financial success. It will also suggest where effort should be concentrated to modify system costs or characteristics so as to make the system more suitable for a given application.

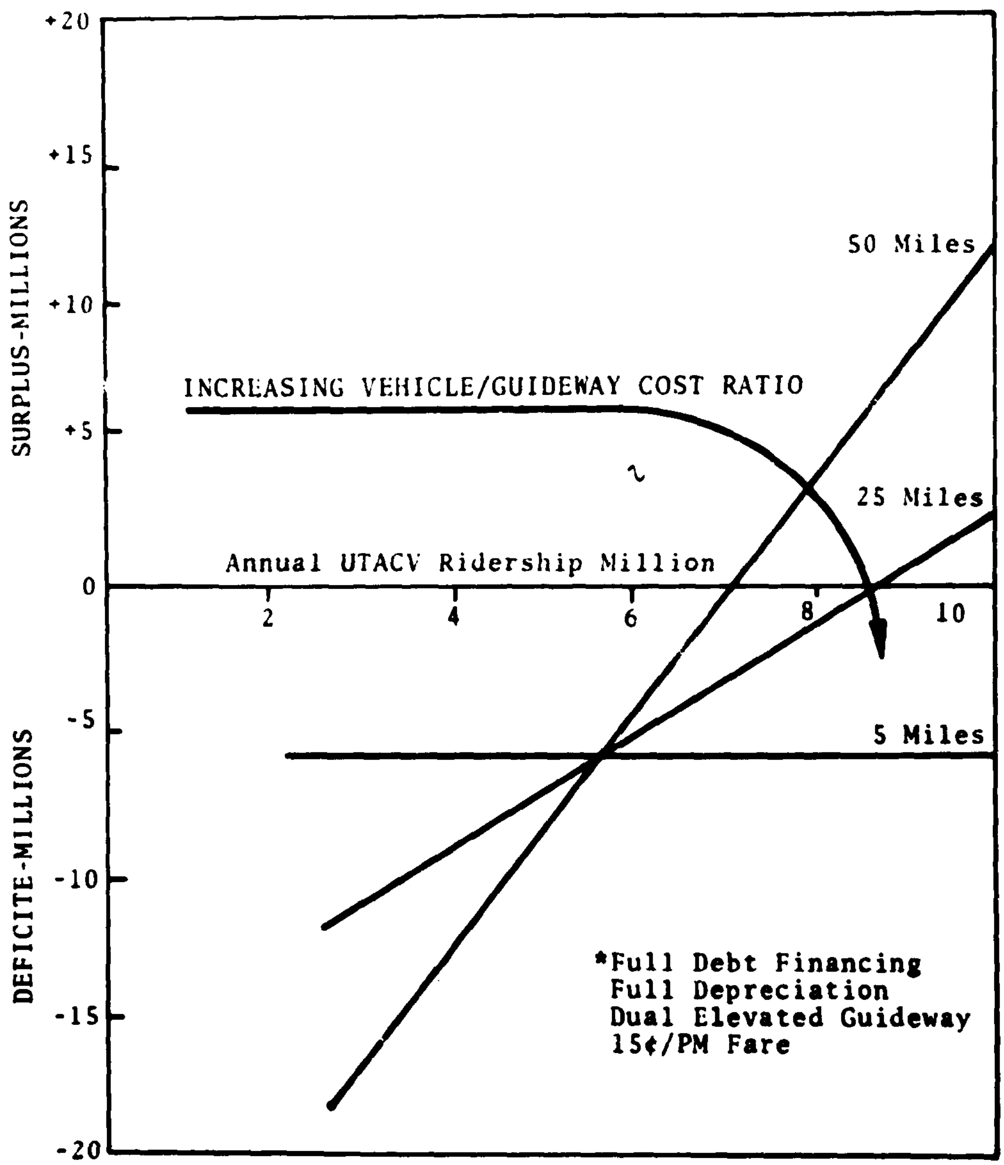

Figure 3-4. Deficit/Surplus vs. Ridership for Various System Lengths*

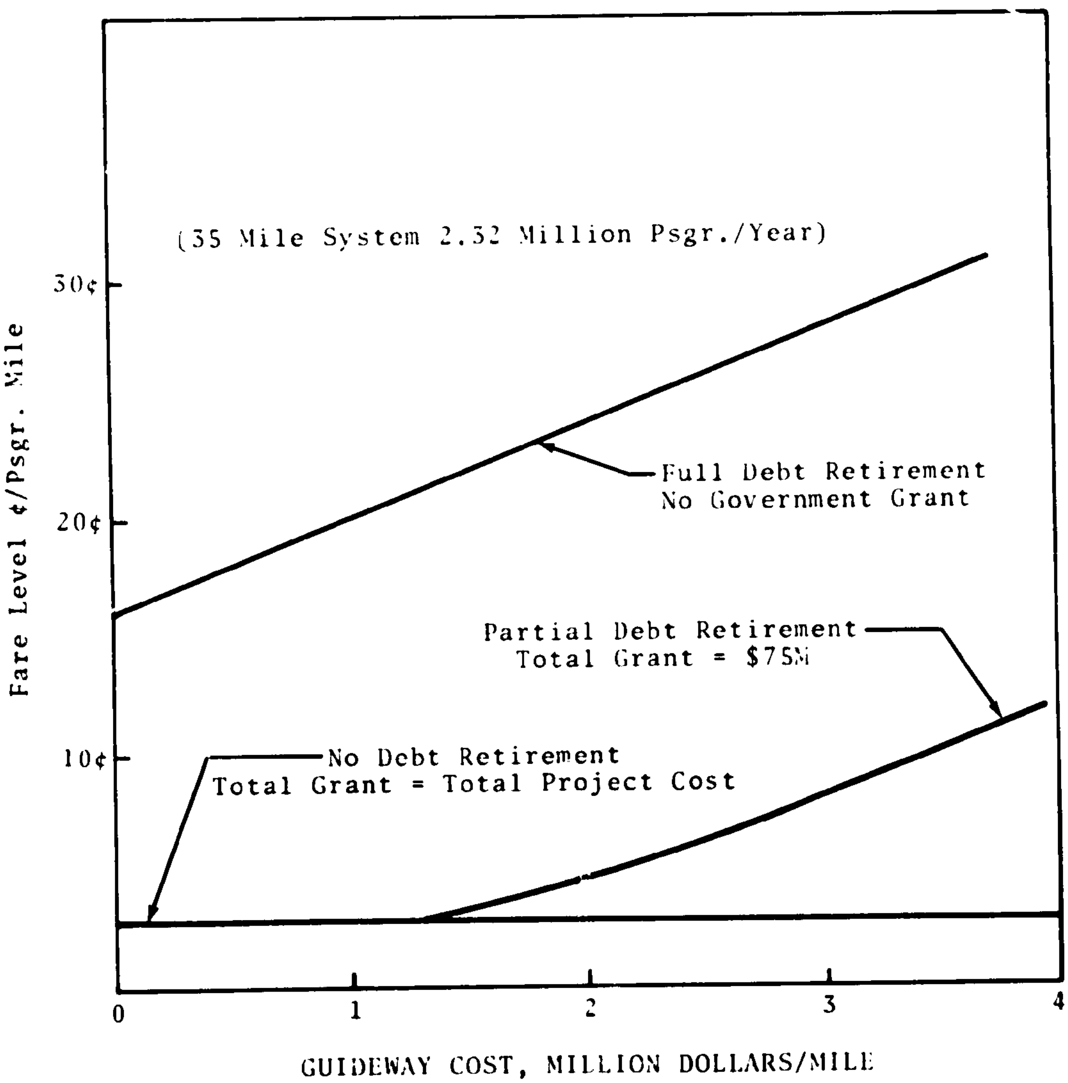

Figure 3-5. Required Fare Level to Break-Even vs. Guideway Cost for Various Financing Methods

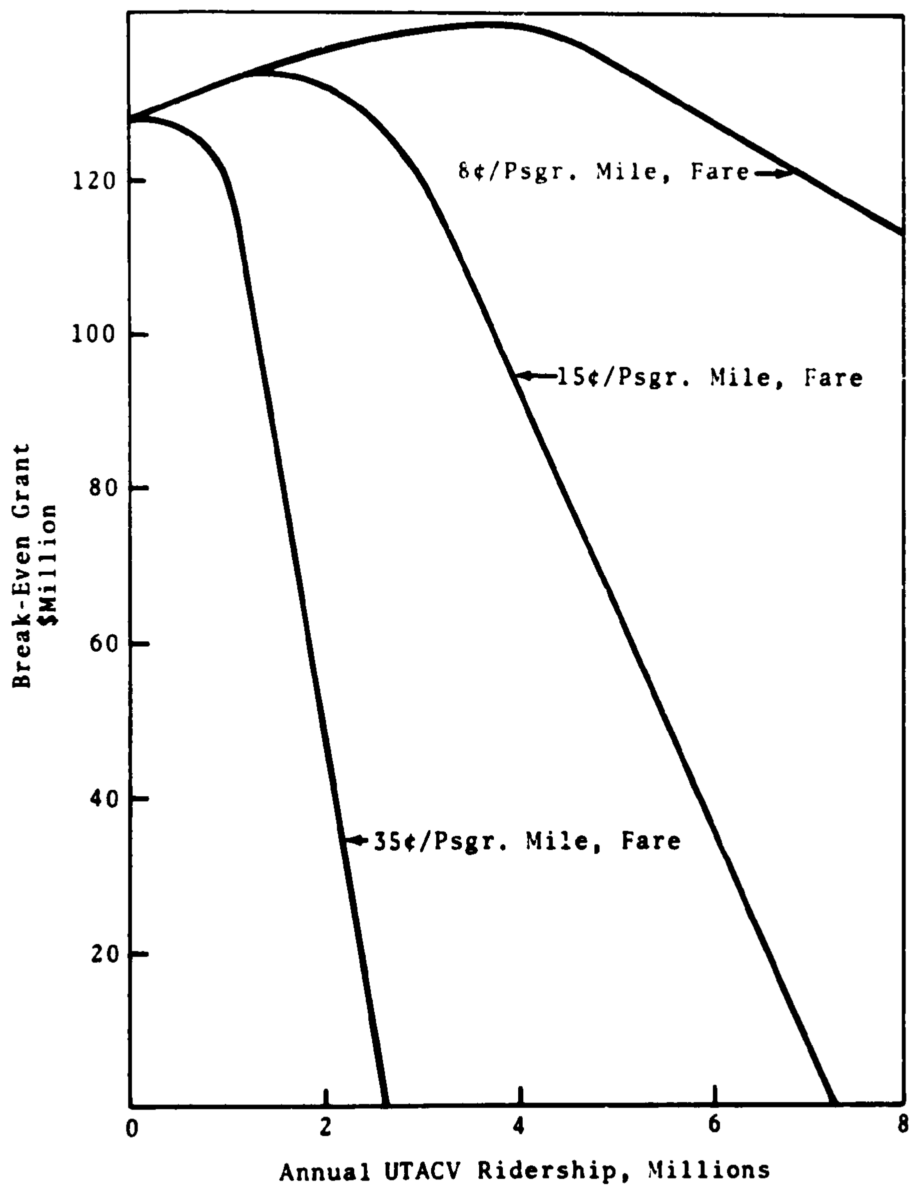

Figure 3-6. Break-Even Federal Grant vs. UTACV Ridership for Various Fare Levels (35-Mile System)

APPENDIX A

DEVELOPMENT OF PROGRAM EQUATIONS

COMPUTE ANNUAL RIDERSHIP

The number of originating airline passengers is determined by eliminating from the annual enplanements the number of interline transfers:

$$AP = AAE\ (1 - XFERS)$$

The number of airport visitors is considered to be 80% of the annual originating airline passengers:

$$AAV = .8\ AAE\ (1 - XFERS) \qquad (A\text{-}1)$$

The number of annual airport employees is taken as 320 times the daily employment:

$$AEA = 320\ AE$$

The total annual UTACV ridership is then the sum of the originating airline passengers, the annual airport visitors, and the annual airport employees, each multiplied by their respective modal splits:

$$AR = (AAE(1 - XFERS)\ SMAP \times 10^6 + .8\ AAE\ (1 - XFERS)\ SMV \times 10^6 + 320\ AE \times SMAE)/10^6 \qquad (A\text{-}2)$$

COMPUTE PEAK HOUR RIDERSHIP

The peak hour ridership is derermined by multiplying the annual demands by factors to convert to daily and then peak hour levels:

$$PHR = AAE\ (1 - XFERS) \times 10^6 \times .0043 \times .07\ SMAP + .8\ AAE\ (1 - XFERS) \times 10^6 \times .0043 \times .04 \times SMV + AE \times .27 \times SMAE \qquad (A\text{-}3)$$

COMPUTE ANNUAL REVENUES

In determining annual revenues it is assumed that the return annual ridership is the same as the airport destined ridership. The annual revenues then become equal to total annual passenger miles times the fare level in dollars per mile:

$$REV = AR \times 2 \times SL \times FL \qquad (A\text{-}4)$$

COMPUTE ACCELERATION & DECELERATION TIMES

TA (Min.) = VM x .00076/GA (A-5)

TD (Min.) = VM x .00076/GD (A-6)

COMPUTE ACCELERATION & DECELERATION DISTANCE

DA (Miles) = VM x TA/120 (A-7)

DD (Miles) = VM x TA/120 (A-8)

COMPUTE TRIP TIME

The trip time between stops is a function of station dwell time, acceleration and deceleration times, and cruising time:

TT = TS + TA + TD + (SL - DA - DD)60/VM (A-9)

COMPUTE AVERAGE VELOCITY

The average velocity is based on the time between leaving one station and leaving the next station, hence:

VA = 60 SL/TT (A-10)

COMPUTE TRIPS PER HOUR PER TRAIN

Based on the average velocity the number of round trips a train can make in one hour is:

THT = VA/2SL (A-11)

COMPUTE TRAINS REQUIRED FOR PEAK HOUR DEMAND

The number of trains required to meet peak hour demand is a function of the peak hour ridership, vehicle capacity, a number of cars per train, load factor, and the number of trips per hour per train:

TRQD = PHR/(VC x THT x FLOAD) (A-12)

COMPUTE HEADWAY

The headway is a function of the system length, average velocity, and number of trains:

HDY = SL x 60/(VA x TRQD) (A-13)

COMPUTE GUIDEWAY COSTS

The total guideway cost is the result of adding the costs of the various subsystems; base cost (CB), electrification (CEL), control and instrumentation (CCI), safety guards (CSG), substructure (CSUB), site preparation (CSITE), reaction rail (CRAIL), and electrical substations (CESUB): the engineering costs (CEN), and the turnaround costs (CTURN), times a variable used to adjust the total costs, for sensitivity analyses (CFG):

$$CG = (SL\ (CB + CEL + CCI + CSG + CSUB + CSITE + CRAIL + CESUB)\ (1 + CEN)\ CFG + 2\ CTURN)CFG \quad (A\text{-}14)$$

COMPUTE VEHICLE COSTS

The vehicle costs are based on the assumption that the cost per vehicle will reduce on a straight line function from one to 10 vehicles. Beyond 10 vehicles the price per vehicle will remain constant. The vehicle costs are further modified by a linear function to account for any changes in vehicle capacity. The total vehicle costs are then multiplied by a variable to adjust the costs by a fixed amount for sensitivity analyses:

NCARS = TRQD x J x SPARE, (number of vehicles required plus 20 % spares) (A-15)

CVB = NCARS (CV1-((CV1-CV2)/10)(NCARS)) (for less than 10 vehicles) (A-16)

CVB = NCARS x CV2, (for more than 10 vehicles) (A-17)

CV = CVB (1 + .5/60 (VC - 60))CFV, (A-18)

(modification for capacity and sensitivity analysis)

COMPUTE COSTS OF STATIONS & PARKING LOTS

The station costs are composed of base costs for air terminals, commuter terminals, and parking lots plus additional costs which are passenger level dependent. Several different combinations of terminals are possible depending upon the type of system being investigated; i.e., CBD to airport or CBD to airport to CBD. Totals costs are adjusted by a variable for sensitivity analyses:

CS = (CS1 + CS3 + PHR (CS2 + CS4) + CLOT)CFS (A-19)

COMPUTE COST OF MAINTENANCE FACILITIES

Maintenance facility costs are composed of a base cost and an additional cost factor which is dependent on the number of vehicles. The total cost is adjusted by a variable for sensitivity analyses.

CM = (CM1 + CM2 (NCARS - 10))CFM (A-20)

COMPUTE RIGHT OF WAY COSTS

Right of way costs are a function of system length and cost per acre of land which is a variable:

CRW = SL (20 x CRW1) (A-21)

COMPUTE OPERATING & MAINTENANCE COSTS

The operating and maintenance costs are broken down into energy costs and all other costs. The total energy cost is a function of the cost of energy per mile, the total vehicle miles per year and a variable modification factor for sensitivity studies:

CERGY = (CGY1 x AR x SL x 2/(VC x FLOAD))CFGY (A-22)

The other operation and maintenance costs are the sum of: the crew vehicle maintenance, and electrical maintenance costs per vehicle mile times total vehicle miles; the guideway maintenance cost per mile times guideway length; and the overhead cost per passenger mile times the annual passenger miles. Total costs are adjusted by a variable for sensitivity analyses:

$$\text{CCPMT} = ((\text{CREW} + \text{CMV} + \text{CME})\ \text{AR} \times \text{SL} \times 2/(\text{VC} \times \text{FLOAD}) + \text{CMG} \times 2\ \text{SL}/10^6 + \text{COHD} \times \text{AR} \times 2 \times \text{SL})\ \text{CFOM} \quad \text{(A-23)}$$

COMPUTE DEPRECIATION COSTS

The depreciation costs for the vehicles are computed on a straight line zero salvage value basis over a variable period of time:

CDV = CV/TERMV (A-24)

The fixed capital cost items (right-of-way excluded) are depreciated on a straight line 10% salvage basis over a variable period of time:

CDS = .9 (CG + CS + CM)/TERMS (A-25)

COMPUTE TOTAL OPERATING COSTS

The total operating costs are taken as being the sum of all energy, operating, maintenance, and depreciation costs:

$$COMD = CERGY + COPMT + CDV + CDS \qquad (A\text{-}26)$$

COMPUTE TOTAL PROJECT COST

The total project cost is the sum of all capital cost items described by equations A-14, A-18, A-19, A-20, and A-21:

$$CTP = CG + CS + CM + CRW + CV \qquad (A\text{-}27)$$

COMPUTE NET REVENUE FOR FINANCING

The net revenue for financing is the remaining revenue which can be applied to debt financing after total operating costs are deducted:

$$NREV = REV - COMD \qquad (A\text{-}28)$$

COMPUTE ANNUAL FINANCING COST

The annual financing cost is the sum of the vehicle and fixed systems (right of way included) debt finance costs. Both are a function of their respective debt periods which are the same as the depreciation periods and the interest rate.

$$CAV = (CV \times RATE\ (1 + RATE)^{TERMV})/((1 + RATE)^{TERMV}-1) \qquad (A\text{-}29)$$

$$CAS = (CG + CS + CM + CRW)\ RATE\ (1 + RATE)^{TERMS})/((1 + RATE)^{TERMS}-1) \qquad (A\text{-}30)$$

$$CAF = CAV + CAS \qquad (A\text{-}31)$$

COMPUTE DEFICIT OR SURPLUS

The deficit or surplus is the revenue remaining from the net revenue after total annual financing cost have been deducted:

$$DOS = NREV - CAF \qquad (A\text{-}32)$$

COMPUTE NET PROJECT COST

The net project cost is the total cost of capital items which cannot be financed by the net revenue. Because the vehicle debt period is less than for the fixed systems; i.e., a dollar of vehicles costs more to finance than a dollar of fixed systems, the net revenue will always be applied first to finance the fixed systems. Two possible cases must be considered in determining the net project cost depending on whether the net revenue is greater or less than the annual finance cost of the fixed systems:

$$CNP = CV - (NREV - CAS)\ ((1 + RATE)^{TERMV} - 1)/ (RATE)\ (1 + RATE)^{TERMV}, \text{ (Case for NREV greater than CAS)} \quad (A\text{-}33)$$

$$CNP = CV + (CAS - NREV)\ ((1 + RATE)^{TERMS} - 1)/ (RATE)\ (1 + RATE)^{TERMS}, \text{ (case for NREV less than CAS)} \quad (A\text{-}34)$$

COMPUTE PERCENT OF NET TO TOTAL PROJECT COST

$$RATIO = 100\ CNP/CTP \quad (A\text{-}35)$$

COMPUTE GOVERNMENT GRANT REQUIRED TO BREAK-EVEN

The required government grant is always taken as being equal to two-thirds of the net project cost:

$$GRANT = CNP \times 2/3 \quad (A\text{-}36)$$

COMPUTE THE LOCAL GRANT REQUIRED TO BREAK-EVEN

The required local grant is always taken as being equal to one-third of the net project cost:

$$SHARE = CNP \times 1/3 \quad (A\text{-}37)$$

COMPUTE THE SUBSIDY REQUIRED TO BREAK-EVEN

The subsidy required is taken to be the annual amount required to cover total operating expenses (COMD) when the revenue produced is less than COMD:

$$SUB = COMD - REV, \text{ (when REV is less than COMD)} \quad (A\text{-}38)$$

APPENDIX B

SUPPORT DATA ON COSTS FOR UTACV SENSITIVITY STUDY

1.0 <u>Guideway and Related Costs</u>

1.1 Base Costs

1.1.1 ⊥, single, on-grade, 500K/Mile

1.1.2 ⊥, single, elevated, 1,300K/Mile

1.1.3 ⊥, double, on-grade, 950K/Mile

1.1.4 ⊥, double, elevated, 2,470K/Mile

1.1.5 ⊔, single, on-grade, 716K/Mile

1.1.6 ⊔, single, elevated, 1,500K/Mile

1.1.7 ⊔, double, on-grade, 1,360K/Mile

1.1.8 ⊔, double, elevated, 2,850K/Mile

1.2 Electrification (Power Rail & Transmission Line): 184K/Mile & 160 K/Mile

1.3 Controls & instrumentation: 411K/Mile or 600K Minimum

1.4 Safety guard (security fences): 42K/Mile

1.5 Substructure:

1.5.1 Pilings: 370K/Mile

1.5.2 Piers: 144K/Mile

1.5.3 Spread footings: 100K/Mile

1.6 Reaction rail: 165K/Mile

1.7 Site preparation: 155K/Mile

1.8 Turnaround 50K/Site

1.9 Electrical substations 20K/Mile

1.10 Engineering: 4.5% of capital costs

2.0 Vehicle Costs

2.1 Base cost of vehicles:

2.1.1 From one to ten vehicles:

cost = no. vehicles $(2.6 \times 10^6 - ((2.6 \times 10^6 - 1.85 \times 10^6)/10)$no. vehicles)

2.1.2 Over ten vehicles

cost = no. vehicles (1.85×10^6)

2.2 Cost factor for passenger capacity:

cost = cost for 60 passengers ((1 + .5(capacity - 60/60)

2.3 Cost for double ended vehicle:

cost = cost, single end x 1.33

2.4 Cost increase for spare vehicles:

number of spares = required number x .20

3.0 Stations and Parking Lots

3.1 CBD air terminal with baggage checking and interface with feeder systems:

7,5000K + 6K (peak hour demand)

3.2 Commuter terminal: 860K + 4K (peak hour demand)

3.3 Parking lot: 275K

4.0 Maintenance Facilities

cost = 5,000K, 25K (number vehicles - 10)

5.0 Right of Way Costs

5.1 Base costs:

- 5.1.1 Urban (city), 300K/Acre
- 5.1.2 Suburban, 20K/Acre
- 5.1.3 Country, .5K/Acre
- 5.1.4 Remote woodland, .2K/Acre

5.2 Cost relationship:

For 200 ft. wide right of way, cost/mile = 20 x cost/acre

6.0 Operating and Maintenance Costs

6.1 Energy: 16¢/vehicle mile

6.2 Crew: 16¢/vehicle mile

6.3 Maintenance:

- 6.3.1 Vehicle, 22¢/vehicle mile
- 6.3.2 Guideway, $1890/lane mile
- 6.3.3 Electrical, 26¢/vehicle mile

6.4 Overhead: 1¢/passenger mile

APPENDIX C

SAMPLE PHASE I & PHASE II PRINT-OUT

ARACTERISTICS		
ST, SYSTEM TYPE	3.000	TERMINALS
SL, SYSTEM LENGTH	35.000	MILES
AAE, ANNUAL AIRPLANE ENPLANEMENT	5.000	MILLION/Y
SMAP, MODAL SPLIT, AIRLINE PASSENGERS	15.000	PERCENT
AE, AIRPORT EMPLOYMENT	15000.000	PERSONS/[
SMAE, MODAL SPLIT, AIRPORT EMPLOYEES	7.000	PERCENT
AAV, ANNUAL AIRPORT VISITORS	3.200	MILLION/Y
SMV, MODAL SPLIT, VISITORS	7.000	PERCENT
XFERS, AIRLINE TRANSFERS	20.000	PERCENT
FL, FARE LEVEL	0.150	DOLLARS/
FLOAD, LOAD FACTOR	65.000	PERCENT
VC, VEHICLE CAPACITY	60.000	PASSENGER
CHARACTERISTICS		
AR, ANNUAL RIDERSHIP	1.160	MILLION/Y
PHR, PEAK HOUR RIDERSHIP	503.000	PASSENGER
TA, ACCELERATION TIME	1.399	MINUTES
TD, DECELERATION TIME	1.399	MINUTES
DA, ACCELERATION DISTANCE	1.749	MILES
DD, DECELERATION DISTANCE	1.749	MILES
TT, ONE WAY TRIP TIME FOR PASSENGERS	10.399	MINUTES
THT, TRIPS PER HOUR PER TRAIN (ROUND TRIP)	2.084	TRIPS
TROD, TRAINS REQUIRED FOR PEAK HOUR RIDERSHIP	7.000	TRAINS
HDY, HEADWAY	8.229	MINUTES
J, NUMBER CARS PER TRAIN	1.000	CARS/TRAI
NCARS, REQUIRED VEHICLES PLUS SPARES	9.000	VEHICLES
OSTS		
CG, COST OF GUIDEWAY	154.849	MILLION [
CV, COST OF VEHICLES	17.325	MILLION [
CS, COST OF STATIONS AND PARKING AREAS	19.931	MILLION [
CM, COST OF MAINTENANCE FACILITIES	4.975	MILLION [
CRW, COST OF RIGHT OF WAY	0.000	MILLION [
CTP, TOTAL PROJECT COST	197.080	MILLION [
COSTS		
CERG, COST OF ENERGY	0.333	MILLION [
COPMT, COST OF OPERATION AND MAINTENANCE	2.277	MILLION
COM, TOTAL COST OF OPERATION, MAINTENANCE, AND ENERGY	2.610	MILLION
TERMS, DEPRECIATION PERIOD FOR FIXED SYSTEMS	30.000	YEARS
TERMV, DEPRECIATION PERIOD FOR VEHICLES	12.000	YEARS
CDS, COST OF DEPRECIATION FOR FIXED SYSTEMS	5.393	MILLION [
CDV, COST OF DEPRECIATION FOR VEHICLES	1.444	MILLION
CD, TOTAL COST OF DEPRECIATION	6.836	MILLION [
COMD, TOTAL COST OF OPERATION, MAINTENANCE, AND DEPRECIATION	9.446	MILLION [
NCING		
REV, ANNUAL REVENUES	12.190	MILLION
NREV, NET REVENUE FOR DEBT FINANACING	2.734	MILLION
RATE, INTEREST RATE ON DEBT	7.500	PERCENT
CAV, COST OF ANNUAL FINANCING, VEHICLES	2.240	MILLION
CAS, COST OF ANNUAL FINANCING, FIXED SYSTEMS	15.220	MILLION
CAF, TOTAL COST OF ANNUAL DEBT FINANCING	17.460	MILLION
DDS, REMAINING REVENUE AFTER DEBT FINANCING	-14.726	MILLION
CNP, NET PROJECT COST	164.794	MILLION
RATIO, PERCENT NET TO TOTAL PROJECT COST	83.618	PERCENT
GRANT, GOVERNMENT GRANT TOWARD NET PROJECT COST	109.863	MILLION
SHARE, LOCAL SHARE OF NET PROJECT COST	54.931	MILLION
SUB, ANNUAL SUBSIDY REQUIRED TO COVER COMD	0.000	MILLION

ARACTERISTICS		
ST, SYSTEM TYPE	3.000	TERMINALS
SL, SYSTEM LENGTH	35.000	MILES
AAE, ANNUAL AIRPLANE ENPLANEMENT	30.000	MILLION/
SMAP, MODAL SPLIT, AIRLINE PASSENGERS	15.000	PERCENT
AE, AIRPORT EMPLOYMENT	15000.000	PERSONS/
SMAE, MODAL SPLIT, AIRPORT EMPLOYEES	7.000	PERCENT
AAV, ANNUAL AIRPORT VISITORS	10.200	MILLION/
SMV, MODAL SPLIT, VISITORS	7.000	PERCENT
XFERS, AIRLINE TRANSFERS	20.000	PERCENT
FL, FARE LEVEL	0.150	DOLLARS/
FLOAD, LOAD FACTOR	65.000	PERCENT
VC, VEHICLE CAPACITY	60.000	PASSENGE
CHARACTERISTICS		
AR, ANNUAL RIDERSHIP	5.290	MILLION/
PHR, PEAK HOUR RIDERSHIP	1599.000	PASSENGE
TA, ACCELERATION TIME	1.399	MINUTES
TD, DECELERATION TIME	1.399	MINUTES
DA, ACCELERATION DISTANCE	1.749	MILES
DD, DECELERATION DISTANCE	1.749	MILES
TT, ONE WAY TRIP TIME FOR PASSENGERS	10.399	MINUTES
THT, TRIPS PER HOUR PER TRAIN (ROUND TRIP)	2.094	TRIPS
TROD, TRAINS REQUIRED FOR PEAK HOUR RIDERSHIP	20.000	TRAINS
HDY, HEADWAY	2.930	MINUTES
J, NUMBER CARS PER TRAIN	1.000	CARS/TRA
NCARS, REQUIRED VEHICLES PLUS SPARES	24.000	VEHICLES
OSTS		
CG, COST OF GUIDEWAY	154.949	MILLION
CV, COST OF VEHICLES	44.400	MILLION
CS, COST OF STATIONS AND PARKING AREAS	27.603	MILLION
CM, COST OF MAINTENANCE FACILITIES	5.350	MILLION
CRW, COST OF RIGHT OF WAY	0.000	MILLION
CTP, TOTAL PROJECT COST	232.202	MILLION
COSTS		
CERG, COST OF ENERGY	1.516	MILLION
COPMT, COST OF OPERATION AND MAINTENANCE	9.894	MILLION
COM, TOTAL COST OF OPERATION, MAINTENANCE, AND ENERGY	11.410	MILLION
TERMS, DEPRECIATION PERIOD FOR FIXED SYSTEMS	30.000	YEARS
TERMV, DEPRECIATION PERIOD FOR VEHICLES	12.000	YEARS
CDS, COST OF DEPRECIATION FOR FIXED SYSTEMS	5.634	MILLION
CDV, COST OF DEPRECIATION FOR VEHICLES	3.700	MILLION
CD, TOTAL COST OF DEPRECIATION	9.334	MILLION
COMD, TOTAL COST OF OPERATION, MAINTENANCE, AND DEPRECIATION	20.744	MILLION
NCING		
REV, ANNUAL REVENUES	55.440	MILLION
NREV, NET REVENUE FOR DEBT FINANACING	34.696	MILLION
RATE, INTEREST RATE ON DEBT	7.500	PERCENT
CAV, COST OF ANNUAL FINANCING, VEHICLES	5.740	MILLION
CAS, COST OF ANNUAL FINANCING, FIXED SYSTEMS	15.901	MILLION
CAF, TOTAL COST OF ANNUAL DEBT FINANCING	21.641	MILLION
DOS, REMAINING REVENUE AFTER DEBT FINANCING	13.055	MILLION
CNP, NET PROJECT COST	0.000	MILLION
RATIO, PERCENT NET TO TOTAL PROJECT COST	0.000	PERCENT
GRANT, GOVERNMENT GRANT TOWARD NET PROJECT COST	0.000	MILLION
SHARE, LOCAL SHARE OF NET PROJECT COST	0.000	MILLION
SUB, ANNUAL SUBSIDY REQUIRED TO COVER COMD	0.000	MILLION

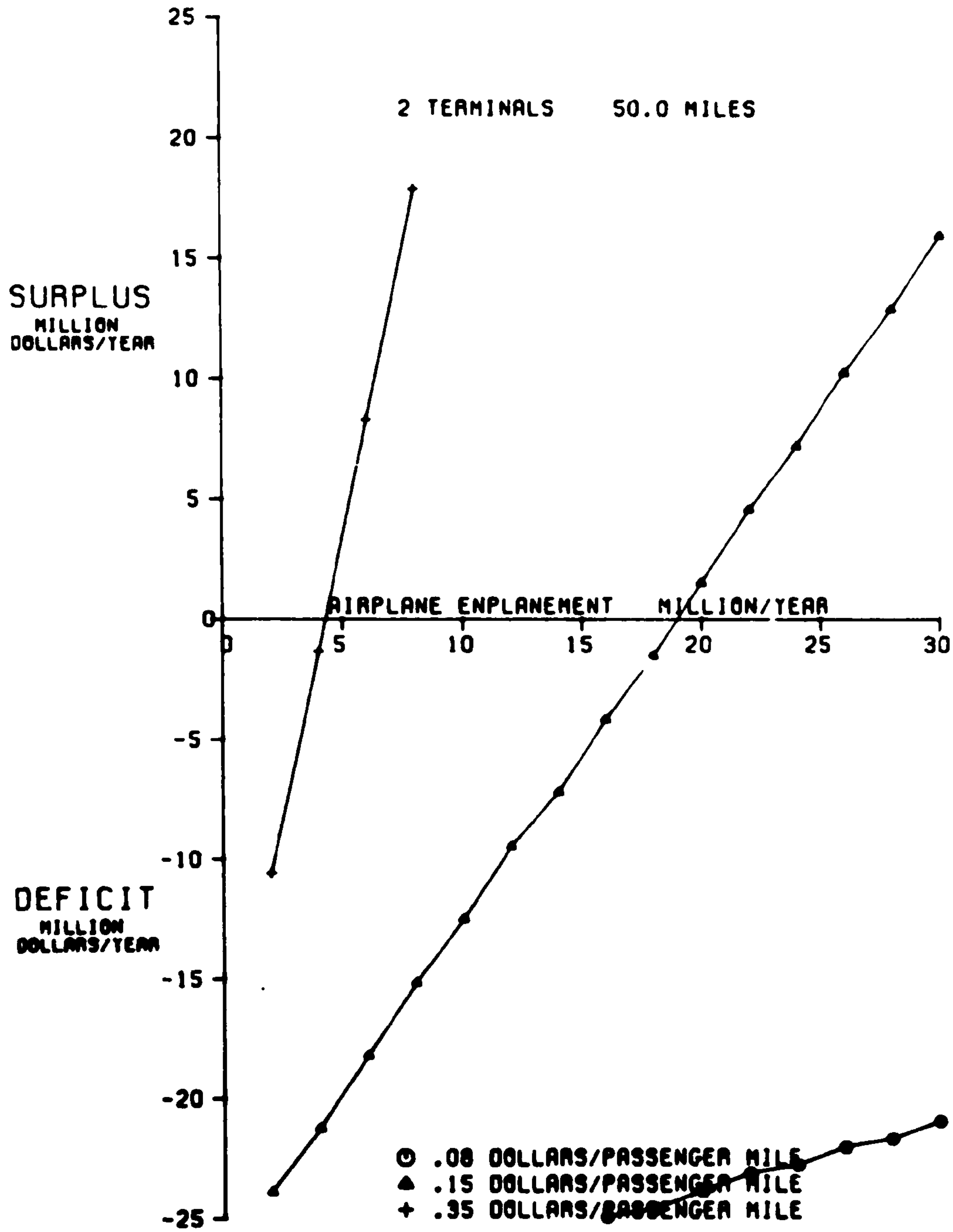

Figure C-1. UTACV Parametric Analysis Sensitivity of Fare Level

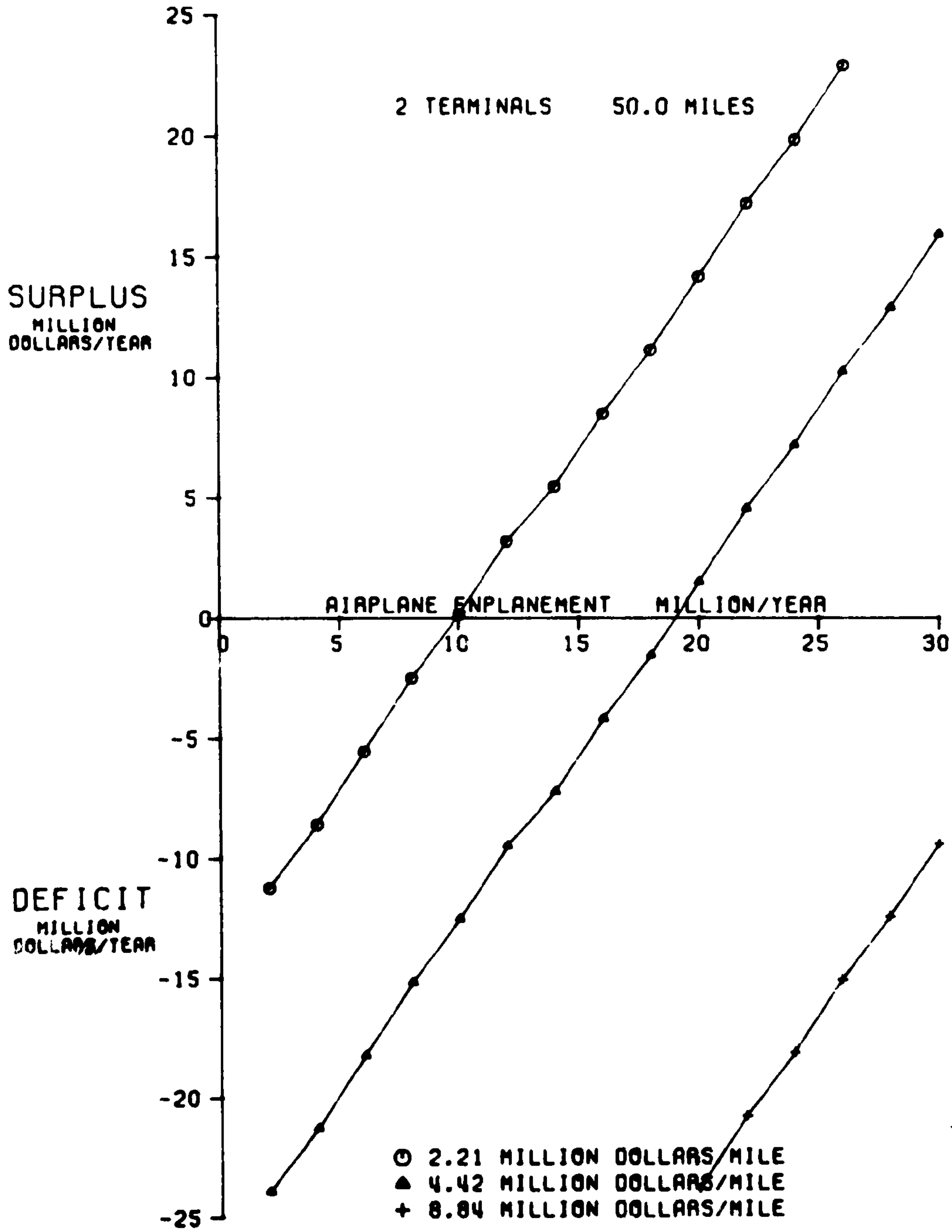

Figure C-2. UTACV Parametric Analysis Sensitivity of Cost of Guideway

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