Automated People Mover System Planning Cost Model Using Visual Basic

SRINIVASA R. MANDALAPU AND WILLIAM J. SPROULE

Cost models were developed for a research project to examine fixed rail service to airports. One proposal for a station located on a rail line near the airport called for an automated people mover (APM) system or shuttle buses that would link this station with the airport terminal area. A model was developed and used in the research to determine planning parameters and cost for an APM system. The model is used to calculate the total cost, annual operating cost, equivalent annual cost, cost per passenger, and other operational details such as average operating speed, travel time, number of cars required, and guideway configuration (single or dual shuttle, pinched loop). The inputs to the model can be grouped into four categories: general information, construction details, operational characteristics, and operating hours and passenger information. Default values based on historic and typical data are incorporated in the model, but the user can specify or change individual values. The model was written using Visual Basic 3.0. Menus make the model user-friendly. The model gives planners an easy-to-use method for determining planning costs and characteristics for an APM system. The model, its limitations, and an example application are described.

Automated people mover (APM) systems are often considered for major activity centers and airport applications. These systems provide circulation and distribution capabilities in high-density developments (*1,2*). During the preliminary planning of such systems, it is necessary to consider various options. An analysis will usually include an approximate cost of each option, and operational requirements. A model was developed for planners to use during the conceptual planning stage. This paper describes features and limitations of the model.

The model was developed for a research project that examined fixed rail service to airports. The efficacy of APM links between nearby rail station(s) and airport terminal(s) (*3*) was studied. Although the model was developed for an airport, it can easily be adapted for other major activity centers.

APM SYSTEMS

APM systems are a class of transit systems in which fully automated unmanned vehicles operate on fixed guideways along an exclusive right-of-way. The electrically powered vehicles may operate either as single units or in trains (*4*).

More than 60 APM systems operate around the world, and several more are under construction or are being planned. APMs have found applications in major activity centers such as inner cities, airports, and amusement parks. APM systems reduce walking distances and ease congestion in and around high-density developments. One of the most common applications of APM systems has been at airports. Of the 18 airports with APM systems, 3 link terminals with fixed rail stations: (Birmingham, U.K.; London Gatwick; and Paris Orly airports) (*2,4,5*). Several airports, such as Oakland, San Francisco, and Boston Logan International, are considering similar links to rail lines.

The basic components of an APM system include right-of-way, guideway, stations, power supply and distribution systems, control and communication systems, vehicles, and maintenance facilities. The guideway is typically elevated or in-tunnel as an exclusive right-of-way is required. The costs of control and communication systems are higher than other transit systems because of the degree of automated operations. The cars or vehicles on APM systems are typically about the size of a standard urban bus. Generally, less seating is provided and more area is allocated for standing as the ride is usually short. The operating and maintenance costs include guideway maintenance costs, such as heating and cleaning of the guideway, energy costs, vehicle maintenance costs, and administrative costs. Because of the differences in physical configurations and operating characteristics, it is difficult to estimate costs for a typical installation. However, the average unit costs of North American APM system components that were used in the model are presented in Table 1 (*2,6*). The costs were adjusted to 1993 dollars using the *Engineering News Record* Cost Index (*7*).

VISUAL BASIC

Visual Basic is one of the programming systems to create event-driven applications in the Windows environment. This system allows a user to create attractive applications with graphic interface. In traditional procedural application, execution starts with the first line of executable code and follows a determined path through the application and call procedures as needed. In event-driven programs (or Visual Basic applications), a user action or system event executes an event procedure. At different stages of the application, the user will have various choices and the application responds to the user's choice. This creates a friendly interface with the application (*8*). Although other programming systems are available to create event-driven programs, Visual Basic was chosen to create the APM Cost Model because of its simplicity and flexibility.

Visual Basic Version 3.0 is used to develop the model. This is Microsoft Windows (3.1 Version) application developed on an IBM-compatible 386 computer with a super VGA card. The model can be run on a similar or higher configuration.

MODEL

The objective of the model is to calculate the total cost of the project, equivalent annual cost, annual operating cost, cost per passen-

Department of Civil Engineering, University of Alberta, Edmonton, Alberta T6G 2G7, Canada.

TABLE 1 Unit Capital Costs and Operating and Maintenance Costs of North American APM Systems

	Cost (millions, 1993 U.S.)
Capital Costs	
Right-of-way cost (per km)	5.69
Guideway underground (per km)	7.41
Guideway at-grade/elevated	3.99
Stations (per station)	1.05
Vehicle (per vehicle)	1.01
Control and communication systems (per km)	2.40
Power Utilities (per km)	0.54
Maintenance and support facilities (per km)	1.45
Operating and Maintenance Costs	
$/Passenger.km	0.19
$ /Veh. km	6.00
$ /Veh.hour	123.00

Source: Characteristics 1992, Tsukio 1985.

ger, and other operational details such as number of cars required during peak hours of operation, and number of trains required for peak-hour and off-peak-hour operation. The flow chart shown in Figure 1 presents the general interaction of different components of the model. The inputs to the model are grouped in four categories:

- General information,
- Construction details,
- Operational characteristics, and
- Operating hours and passenger information.

The general information includes length of the route, numbers of stations planned, prevailing interest rate, and inflation rate. The number of stations can be entered directly; the default value is 2. The default interest and inflation rates are set at 7 percent and 3 percent, respectively. These rates change periodically. Since these rates are applicable for the life of the project, generally accepted rates for the life of the project may be chosen. The effect of these rates is not as significant if the project life is long, and the effect is not critical when comparing different alternatives with the same interest and inflation rates. The interest rate and inflation rate are used to calculate the capital recovery factor (Equation 1). The expected life of components of APM systems used in this research are presented in Table 2 (*9*). Equivalent annual costs were determined using the capital recovery factor (*10*).

$$\text{CRF} = I_{ef}\,(1 + I_{ef})^{n}/[(1 - I_{ef})^{n-1}] \tag{1}$$

where

CRF = capital recovery factor,
n = expected life of component in years, and
I_{ef} = combined interest-inflation rate

$$= (1 + I_p) * (1 + i_{in}) - 1 \tag{2}$$

where I_p is the prevailing interest rate, and I_{in} is the inflation rate.

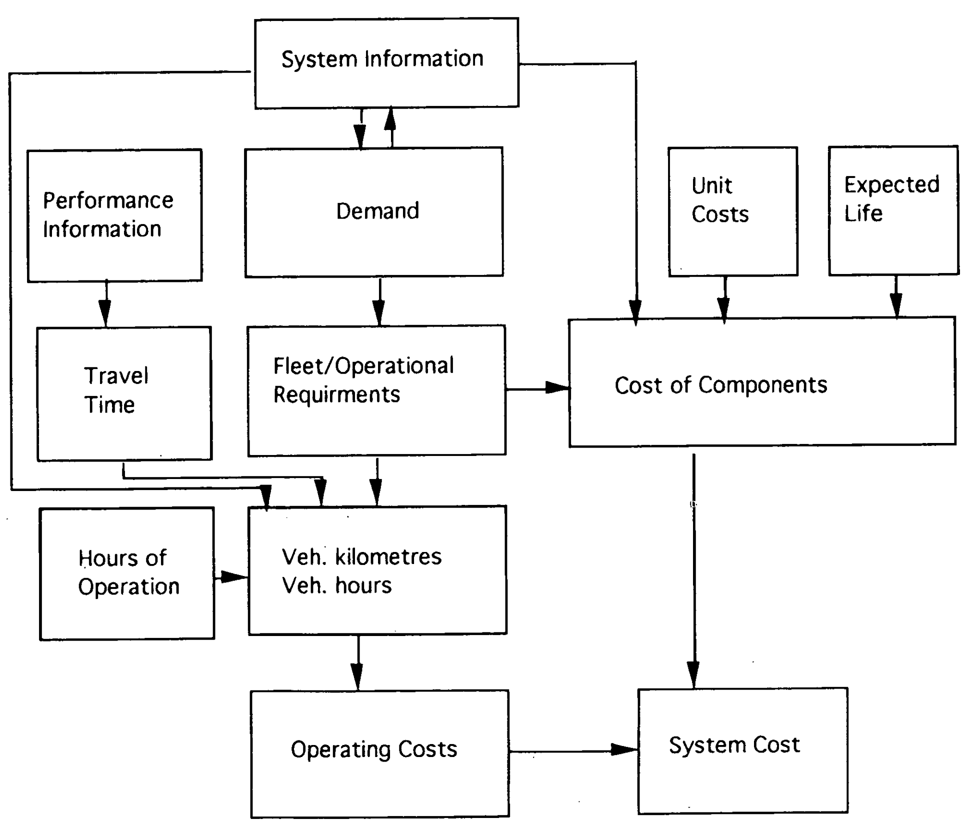

FIGURE 1 Cost model flow chart.

TABLE 2 Expected Life of APM System Components

Component	Expected life (years)
Tunnel, Elevated, or Cut and Cover structures	100
At-grade stations	50
Underground stations	100
Track structure	30
Power supply and distribution system	30
Control and communications	25
Vehicles	25
Maintenance and storage facilities	50

The second category identifies the percentage of the guideway that would be underground, elevated, or at-grade. The number of underground stations is calculated from the length of construction below-grade, and the number of elevated stations is calculated from the length of the elevated construction. The remaining stations are assumed to be at-grade.

The third category requires performance characteristics of the proposed system. The round-trip time is calculated based on the performance characteristics of the system using the equations of dynamics. The characteristics needed are (*a*) dwell time at stops, (*b*) maximum speed of the train, and (*c*) acceleration and deceleration rates of the train. The default values for these characteristics are chosen from the existing systems and are set at 30 sec, 42 km/hr, 1.1 m/sec^2, and 1.1 m/sec^2, respectively. The hours of operation of peak-hour service and off-peak hour service are defaulted at 4 and 16 hr, respectively.

The fourth category identifies average daily passengers, the percentage of average daily passengers in the peak hour, headway information, vehicle capacity, round-trip time, and hours of operation. The default for the peak-hour passengers of the average daily passengers is set at 10 percent. The defaults for peak and off-peak headways are set at 10 and 15 min, respectively. Since cars at most existing airport systems have a capacity of about 80 passengers, the same was chosen as default.

Peak-hour passenger demand is calculated by considering the peaking, directional split, and occupancy rate. Fleet calculations are done based on the round-trip times and passenger demand. The vehicle kilometers are calculated by considering both peak and off-peak operations, and weekday and weekend operations. The operating and maintenance cost is calculated based on vehicle kilometers traveled.

The model takes the cost data of the components and calculates the equivalent annual cost and average total cost of the system. The number of cars required for operation and trains during peak and off-peak hours is calculated. The model assumes 90 percent occupancy of cars, 60-40 split between the peak and off-peak direction of traffic. Ninety percent of fleet size was assumed to be required for peak-hour operation. The model calculates number of car kilometers, operating cost, cost per passengers, number of trains during peak and off-peak hours, number of cars required for peak-hour operation, and number of cars per train during peak hours and off-peak hours. It also determines the travel time for a single trip.

The model also selects the type of guideway and operation, such as shuttle operation on a single guideway, double shuttle on a dual guideway, or pinched loop operation on a dual guideway. If a system operation requires one train, the model selects a shuttle service on a single guideway. If two trains are required for operation, a dual guideway is selected with either double shuttle operation or pinched loop operation. If more than two trains are required, the pinched loop operation is selected. The total cost of guideway depends on which guideway (single, dual, or pinched loop) is selected for the operation.

The model output is displayed in two parts. The first part displays the operating requirements, such as type of guideway required, travel time, fleet requirements, number of cars per train, and number of trains per day. The second part displays the annual passengers, total cost of system, operating and maintenance costs, equivalent annual cost, and cost per passenger. File options such as file open, file close, save data, and save results are also available.

LIMITATIONS

The model calculates the approximate costs of an APM system, which are useful for preliminary planning purposes. In detailed planning, more specific information and data will be available and may not match the assumptions made in the model.

The defaults used in the model and typical range of values are presented in Table 3. The length of guideway and passenger information must be entered to run the program, however, other input data can be set to default values by option.

EXAMPLE

The following example is chosen to demonstrate the model:

- Guideway length: 4.0 km.
- Number of stations planned: 6 (includes 4 en route stations).
- Interest rate: 10 percent.
- Inflation rate: 4 percent.
- Percentage of tunnel construction: 10 percent.
- Percentage of elevated construction: 70 percent.

TABLE 3 Model Defaults and Possible Range for APM Characteristics

Characteristic	Default Value in Model	Range
Interest rate (%)	7	prevailing rate
Inflation rate (%)	3	prevailing rate
Number of stations	2	> 1
Underground construction (%)	0	0 to 100
Elevated construction (%)	100	0 to 100
At-grade construction (%)	0	0 to 100
Peak hour factor	0.1	0.05 to 0.2
Peak headway (min.)	10	1.5 to 30
Off-Peak headway (min.)	20	1.5 to 60
Capacity of car	80	36 to 100
Dwelling time (sec.)	30	20 to 60
Cruise speed (kmph)	42	25 to 47
Acceleration rate	1.1	0.5 to 1.1
Deceleration rate	1.1	0.5 to 1.3
Peak hour operation (hrs.)	4	2 to 6
Off-peak operation (hrs.)	16	15 to 20

- Percentage of at-grade construction: 20 percent.
- Expected average daily passengers: 8,000.

The remaining input data assume default values.

Figures 2 through 6 show the input windows of the model. The model is run for these data, and results are presented in Figures 7 and 8.

CONCLUSIONS

A simple tool for estimating the costs of APM systems is presented for preliminary planning purposes. The model can be used to calculate total cost, annual operating cost, equivalent annual cost, cost per passenger, and other operational details for a proposed APM system.

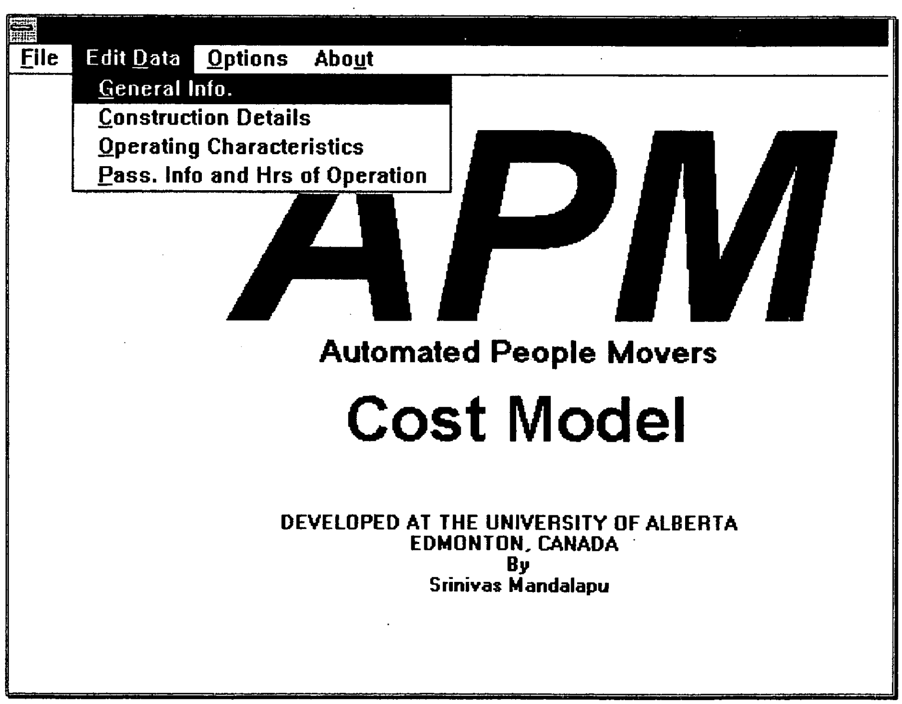

FIGURE 2 Opening window of model.

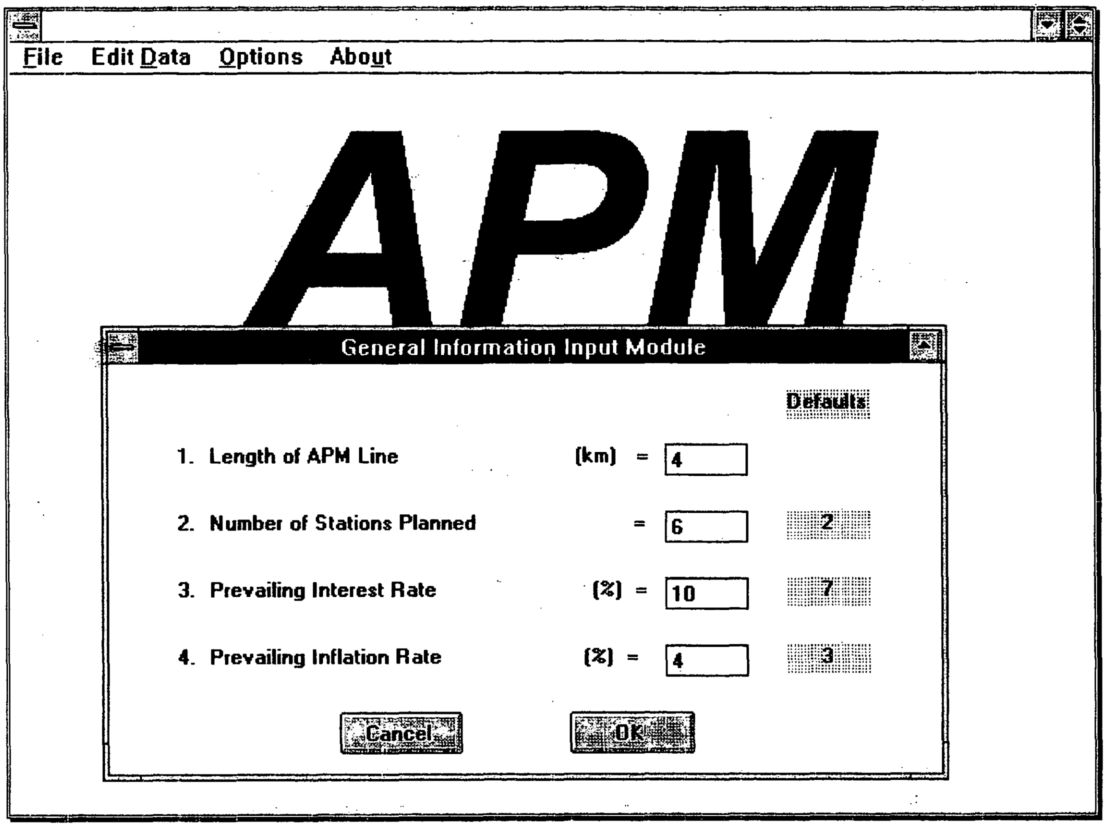

FIGURE 3 General information input window.

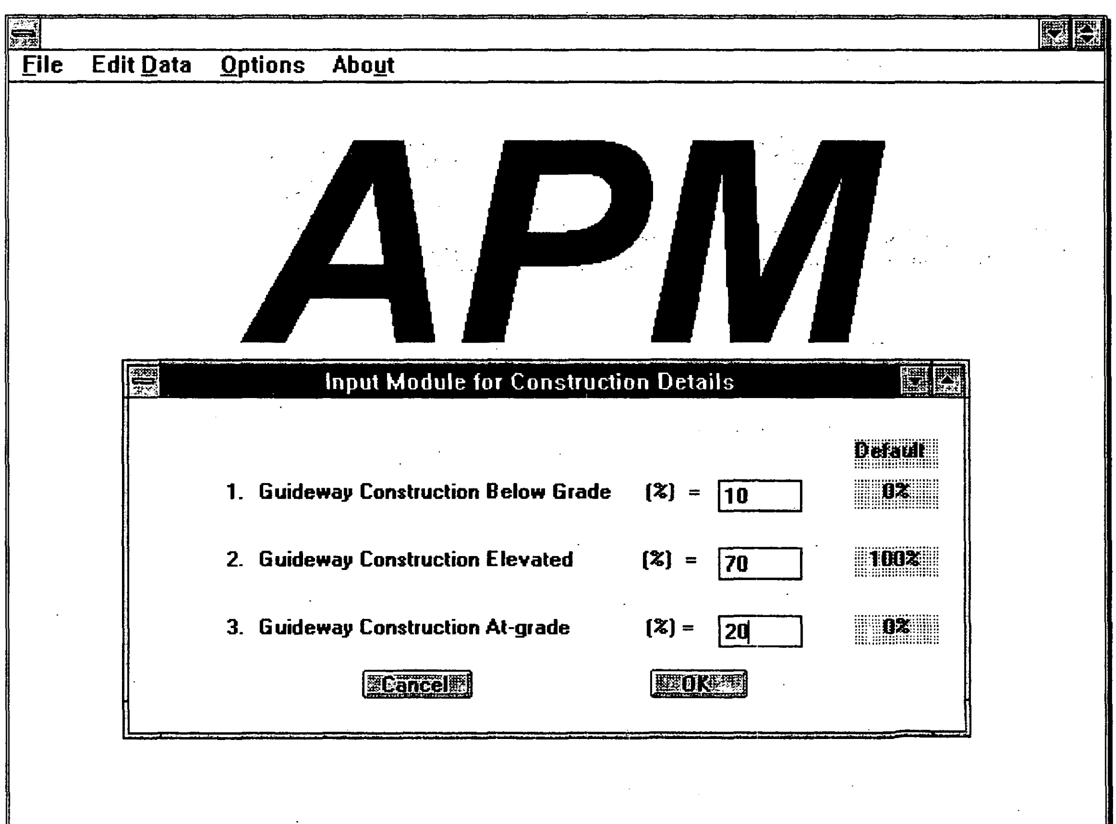

FIGURE 4 Construction details input window.

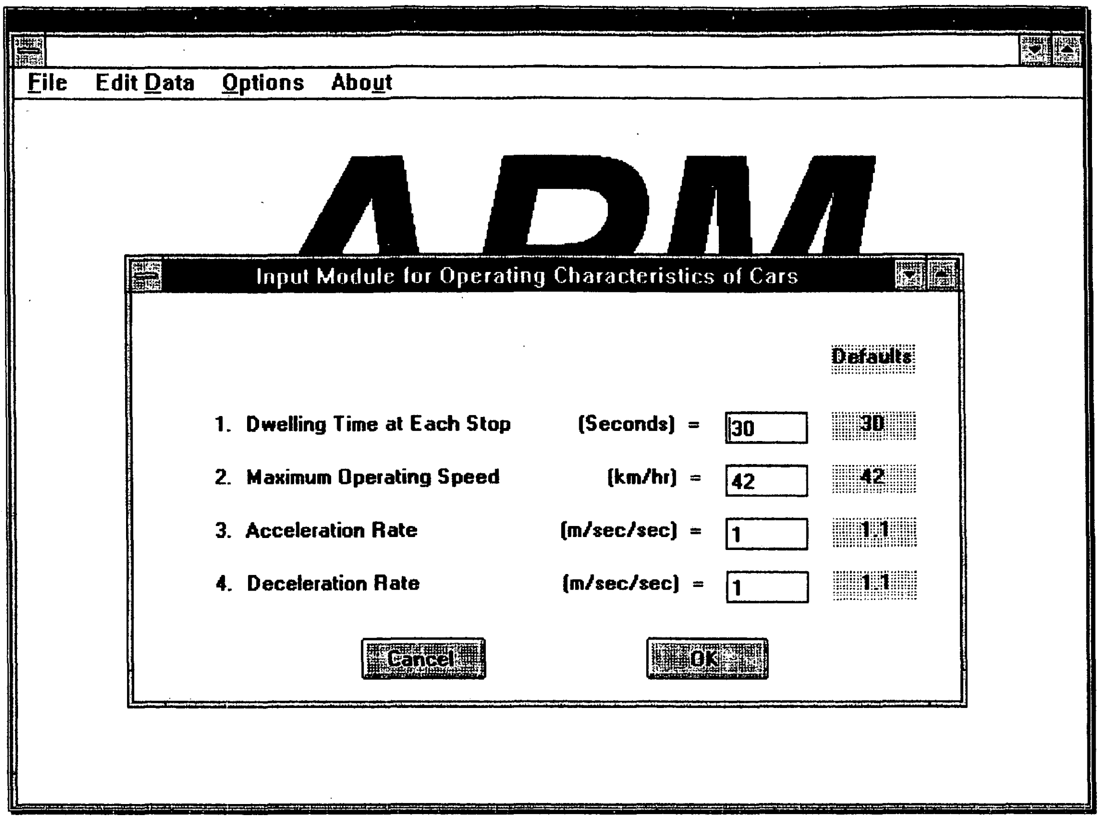

FIGURE 5 Operating characteristics input window.

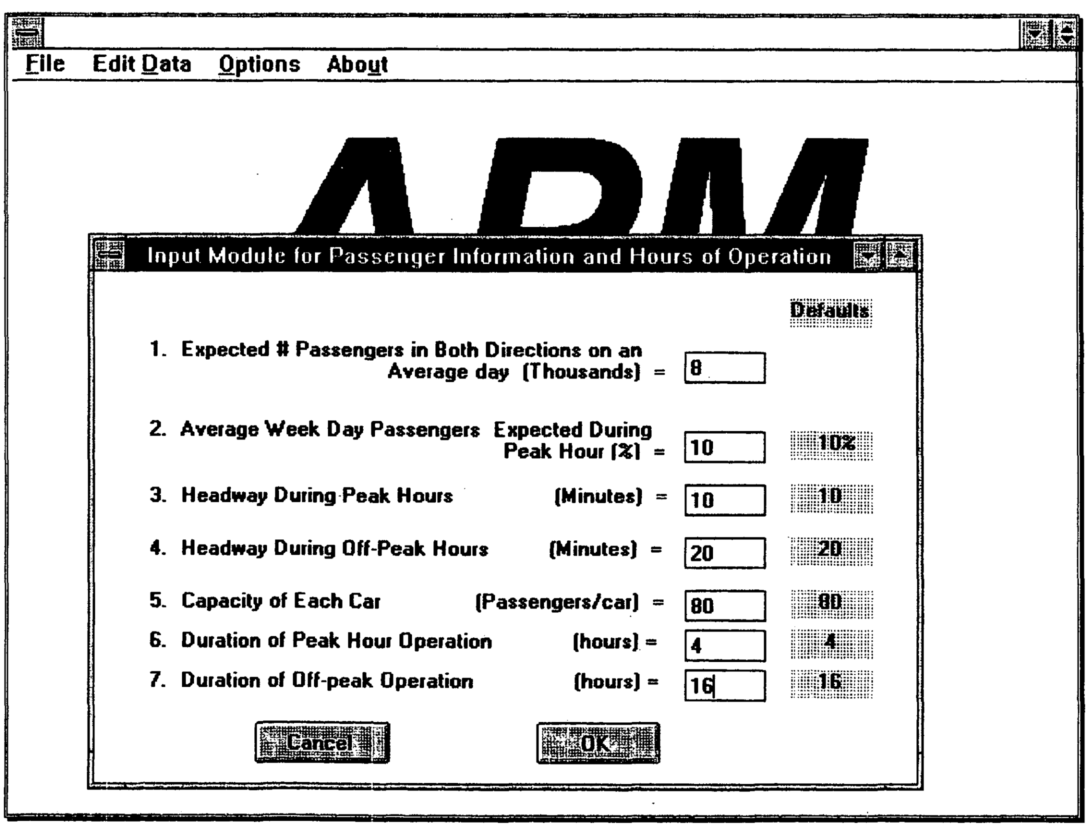

FIGURE 6 Operating hours and passenger information input window.

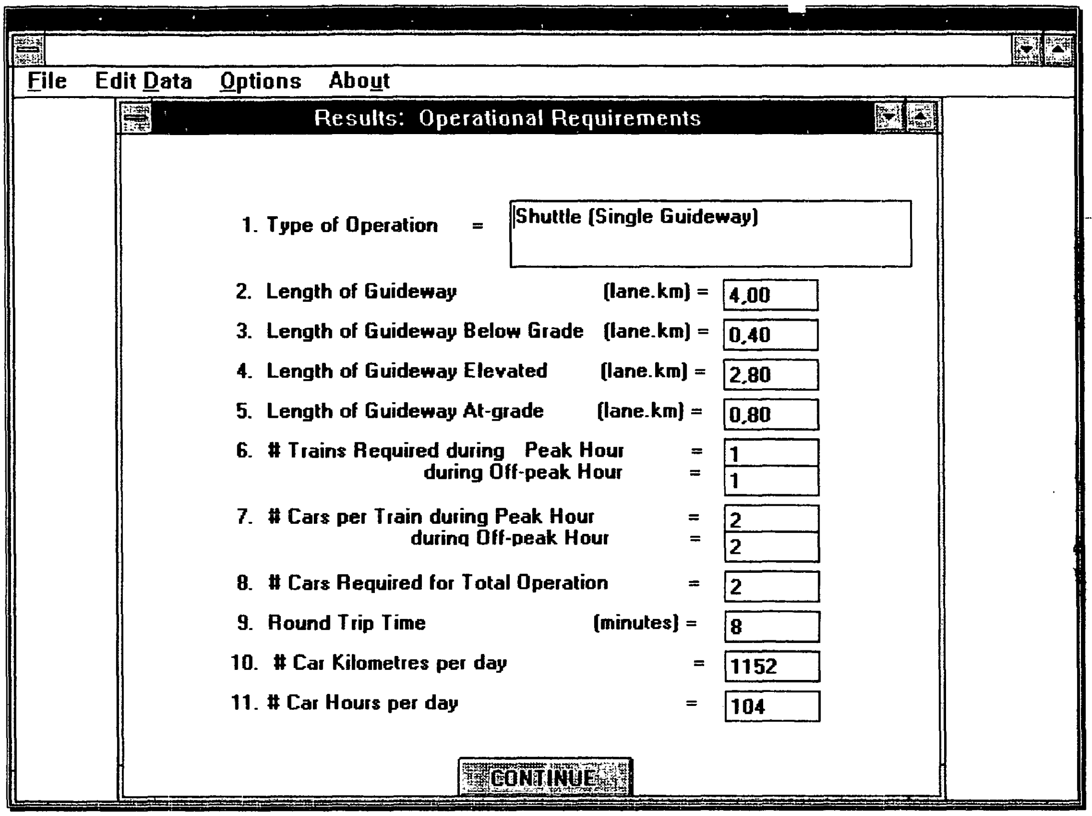

FIGURE 7 Output window for operating details.

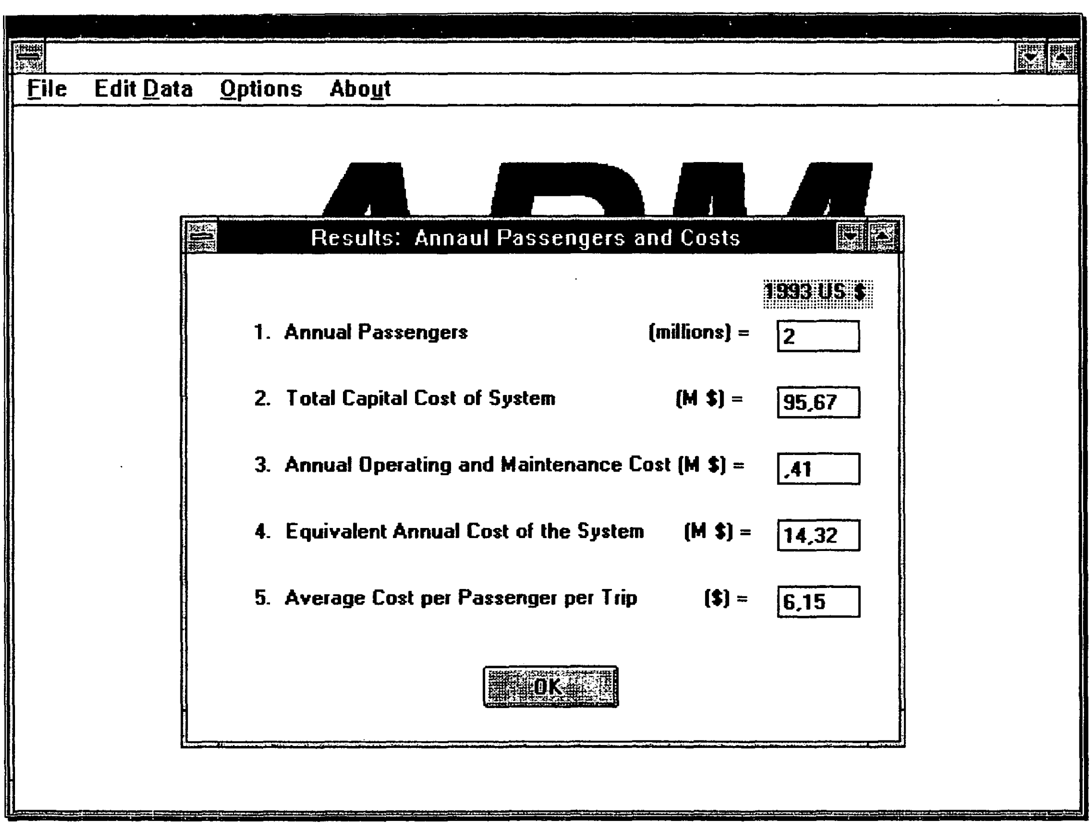

FIGURE 8 Output window for cost details.

REFERENCES

1. Sproule, W. J. Automated People Movers—Innovative Transit for Special Applications. *Proc., National Conference on Advanced Technologies in Public Transportation,* TRB, San Francisco, Calif. 1992.
2. Cambridge Systematics et al. *Characteristics of Urban Transportation Systems.* Report DOT-T93-07. FTA, U.S. Department of Transportation, 1992.
3. Mandalapu, S. R. *Multicriteria Evaluation of Rail Transit Connections to Airports.* Ph.D. dissertation. University of Alberta, Edmonton, Canada, 1994.
4. *International Transit Compendium: Automated Guideway Transit,* Vol. 4, No. 1. Lea Transportation Research Corp., Washington, D.C., 1983.
5. Casselman, D. M., and D. D. Little. Planning for Airport APM Systems—New Applications. In *Automated People Movers, IV—Enhancing Values in Major Activity Centers: Proc., 4th International Conference,* ASCE, Irving, Tex., 1993, pp. 332–343.
6. Moore, H. L. A Comparison of Japanese and North American Automated People Movers. In Automated People Movers III—Future Prospects for APMs: *Proc. 3rd International Conference,* Japanese Society of Civil Engineers, Yokohama, 1991, pp. 255–279.
7. Grogan, T. Cost History. *Engineering News Record,* March 28, 1992, pp. 46–53.
8. *Microsoft Visual Basic 3.0—Programmer's Guide.* Microsoft Corp., Redmond, Wash., 1993.
9. Armstrong-Wright, A. *Urban Transit Options—Guidelines for Examining Options.* Technical Paper 52. Urban Transport Series, World Bank, Washington, D.C., 1986.
10. Riggs, J. L., and T. M. West. *Engineering Economics.* McGraw-Hill, New York, 1986.

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