

FRACAS: A Strategic Planning Model for Bus Transit Systems

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ABSTRACT

The Fare and Route Analysis Computer Aided System (FRACAS) is a strategic planning model for transit systems. It is implemented on an Apple II microcomputer. FRACAS both generates and evaluates service and fare options for local transit systems, helping the analyst achieve system goals. It accepts data on objectives, operating conditions, and existing service and market sensitivities, and it computes the best number of routes, route length, headway, and fare for the time periods and area analyzed. The user can override the model in any service or fare aspect. FRACAS also computes a set of 33 performance measures as part of its output. The model is a flexible approach to the problems of adjusting service and fares to meet budget constraints, and it also treats express service, vehicle size issues, and peak versus off-peak service issues, which are important elements of strategic planning in many systems. To enhance its usability, FRACAS is entirely menu driven with extensive error checking and recovery; no programming knowledge is required of the user.

The Fare and Route Analysis Computer Aided System (FRACAS) program is a strategic planning tool designed to interactively help transit managers and planning staff with the task of establishing fare and service policy. For a given transit system, corridor, or route, FRACAS computes a combination of service and fare that best achieves system objectives. The service is defined by the number of routes in the analysis, their average length, the average headway, and the fare. Express and local service and peak and off-peak time periods can be treated jointly. FRACAS computes the service levels, ridership, revenues, and costs of options and provides statistics on bus-miles, bus-hours, and passenger-miles, for example. These results are displayed in a four-page report on the computer monitor and can also be printed out.

Specification of the service area is quite general: a corridor within the system or even a particular route can be specified. In addition, the objective the model works toward can be varied, as well as the number and choice of variables that the model is given control over. For example, the model can specify the optimum headway with routes and fares fixed, or it can find the best headway and routes, given a fixed fare. In the extreme, all variables can be user specified. In this case, FRACAS simply operates as an evaluation tool, estimating ridership, revenue, cost, and service impacts. In all cases, FRACAS estimates a full set of financial and performance statistics for the service specified.

Because the output procedure typically takes 90 sec or less, the model can be run repetitively to

develop an understanding of the fundamental choices affecting the performance of a particular transit system. FRACAS uses system-, corridor-, and route-level data typically available in a transit agency. No additional data collection is required. All data entry is through the five FRACAS input menus, which are user oriented and provide data checking and help in real time. FRACAS is a stand-alone program, not linked directly to any other program or package. No special skills are required to operate it; it is a "turnkey" system that requires no programming knowledge.

INFORMATION FLOW

The flow of information between the user and FRACAS is described in this section. Because one of the goals in designing FRACAS was to produce a system that was user friendly, there was a substantial amount of effort expended to organize the input data into intuitive groups and to present the outputs in an easily interpretable set of tables.

In designing FRACAS, several questions had to be answered. First, what variables need to be determined by the system to make it an effective strategic planning tool? Second, what data are readily available? And third, what level of detail should the model cover? In other words, where on the scale between a sketch-planning model and a network model should this model lie?

The basic approach is to use an optimization model to solve for the best service and fare levels using a small set of input variables described in this section. The decision variables are the number of routes in the corridor studied, the average route length, the average fare, and the average headway.

The model applies only to a transit system consisting primarily of radial routes extending from the central business district (CBD). The analyst may optimize the system with respect to one of three objectives: (a) the minimization of deficit, (b) the maximization of weighted ridership minus deficit, or (c) the maximization of ridership subject to a deficit constraint. Fares and route structures may be constrained if desired. It is also possible to specify all the service and fare variables and use the model only to determine the ridership and calculate the resulting cost of service, revenue, benefit, and deficit. The analyst may consider peak or off-peak, or both peak and off-peak service within the model, setting constraints (such as equal fare) between the two periods. Likewise, express or local service, or both may be considered.

The model consists of nine cases, each optimizing the system given data on what objective is desired, what combination of local or express service during the peak or off-peak period is to be analyzed, and whether service or vehicle loading constraints exist. Thus the data needed for the specification of a case are

- The objective;
- Whether each decision variable is constrained to a preset value, constrained to be equal in

the peak and off-peak periods, or free to vary; and

- Which combinations of service (express, local) and time periods (peak, off-peak) to analyze.

These data are entered on the OBJECTIVES menu in the program. The preset values (if any) are recorded on the CONSTRAINTS menu.

Data are required of the current transit operations, to establish a base from which to estimate changes in ridership, service, and cost. For a corridor analysis, the following data are needed:

- Current number of routes,
- Current route length,
- Current fare,
- Current number of bus trips,
- Current ridership,
- Current percentage going to and from the CBD (determines relative CBD and non-CBD market potential),
- Current percentage of passengers moving in the peak direction, and
- Current market share for transit into and out of the CBD.

This information is entered on the EXISTING menu.

The analysis requires the user to specify the following data about ridership characteristics and overall market conditions for transit, entered on the MARKET menu:

- Average walking speed;
- Maximum walk distance;
- Average peak and off-peak CBD parking costs;
- Ratio of wait time to headway; and
- Sensitivities of ridership to service and fare; these relate ridership to fare, running time, walk time, and wait time for each service and time period.

Last, the following operating characteristics are required on the OPERATING menu:

- Maximum policy headway;
- Length of the analyzed corridor along typical traveled streets;
- Width of the corridor at its outer edge;
- Number of expressways in the corridor;
- Size of the CBD;
- Average bus operating speed for each service and time period;
- Length, in hours per day, of each time period;
- Fixed costs per day of each time period;
- Operating costs per bus-hour by time period; and
- Maximum number of passengers per bus by service and time period.

The transit system will have almost all of these numbers at hand. The model manual provides curves and defaults to select the market sensitivities, and the CBD market share is obtained from the regional planning agency if not known. Other variables are either known from collected data or can be estimated fairly well from experience. No special data-collection efforts are needed to support this model.

FRACAS calculates 33 different outputs for each service and time period. This information is organized in a two-screen Management Report, which contains the decision variables and the overall financial results, and a two-screen Technical Report, which contains derived performance and productivity data. The analyst can study these screens freely--it is easy to return to a screen that has already been viewed. The outputs provided are given in Table 1.

TABLE 1 FRACAS Outputs

Management Report	Technical Report
Service and Fare:	Performance Statistics:
o Number of Routes	o Bus-Miles
o Average Route Length	o Bus-Hours
o Average Headway	o Number of Bus-Trips
o Average Fare	o Number of Buses
	o Passengers Per Bus-Mile
Overall Impacts:	o Passenger-Miles
o Load Per Bus	o Passenger-Miles Per Bus-Mile
o Mode Share (CBD)	o Cost Per Passenger
	o Revenue Per Passenger
Daily Impacts:	o Deficit Per Passenger
o Cost	o Benefit Per Passenger
o Revenue	o Operating Cost
o Deficit	o Fixed Cost
o User Benefit	o Revenue/Cost Ratio
o Ridership	o Average Passenger Travel Time
	o Average Passenger Walk Time
Annual Impacts:	o Average Passenger Wait Time
o Cost	
o Revenue	
o Deficit	
o User Benefit	
o Ridership	

In response to the question posed at the beginning of this section, FRACAS operates with a relatively large set of decision variables, which is appropriate for a strategic planning function. Transit systems do consider strategic issues such as route consolidation, differential pricing, express service, and use of articulated buses, and FRACAS is designed to perform these analyses. FRACAS does this at a relatively low level of data, not requiring trip tables, networks, on-off counts, or other specialized data collection. The data on which strategic planning is based must be current and easy to maintain, so FRACAS relies on data that should be available in all organizations for basic planning and management functions. By not incorporating detailed data, however, FRACAS gives up the ability to look at most "fine-tuning" issues. FRACAS can be used at a single-route level for general headway and fare design issues, but it cannot prepare schedules. Likewise, at the corridor level, it can indicate the best number of routes to operate, but it is up to the analyst to specify the detailed routing. Key assumptions and limitations of FRACAS are discussed in a later section.

USING FRACAS

When FRACAS starts, the analyst is presented with the MAIN menu (Figure 1). From the MAIN menu, one can select the OBJECTIVES menu, any of the data menus (CONSTRAINTS, AREA, EXISTING, MARKET), the STORAGE page, or the OUTPUT routine. Each will return to the MAIN menu on termination except QUIT, which ends the program.

The STORAGE page gives the analyst the ability to store the information on each of the interactive screens in one named file. With this feature, all the screens can be reset to the values of a previous session that was stored. When the STORAGE page is selected, a screen appears with a menu of storage options and a catalog of all the files currently on disk. This catalog is kept current through all stor-

Main Menu		File: EXAMPLE
	Objectives	: Select objective to be used in this analysis.
	Constraints	: Definition of the user constraints.
D	Operating	: Input of data describing the service area.
A	Existing	: Input of data describing existing services.
T	Market	: Input of rider sensitivities to fares, etc.
A	Output	: Display model output to screen and/or print.
	Storage	: Data storage and retrieval to diskette.
	Quit	: Terminate this worksession.
Use <-, -> to move cursor Cntl-C to select		

FIGURE 1 MAIN menu.

age and retrieval activity. The options available to the analyst include storing, replacing, loading, and deleting a file, plus printing a list of the data sets on disk. The disk drive to be used for storage and retrieval of data can be specified for the convenience of FRACAS users with more than two floppy drives or a hard disk.

Selecting OUTPUT from the MAIN menu will cause about 90 sec of activity from the computer, ending with the first page of the Management Report being displayed. Using the arrow keys, the user can look through all four pages of output, returning to pages that have already been viewed if desired.

The last option on the MAIN menu is the QUIT option. This option brings FRACAS to an orderly halt.

FRACAS thus operates with six interactive screens. Each screen displays a related body of data or choices that can be entered, modified, or verified by the user. The computer model verifies all data for completeness and correctness before computing any results. Although most errors are detected when the analyst "accepts" a screen, some error-checking requires data across several accepted screens--this checking is done before FRACAS processes the input data. Any errors or omissions detected will cause the program to temporarily return to the affected screen and position the cursor on the problem. A message will be displayed at the bottom of the screen.

Each location to which the cursor moves on the OBJECTIVES menu and the four data menus is a data entry location. For a typical run, the system may need about 50 pieces of information in the data entry locations. When analyzing a variation on a previous run, the user may only need to modify a few values. Data are entered only for items that are used in the analysis. For example, when a peak-period analysis is being done, all off-peak values may be left blank. No zeros or other numbers need be entered.

There is also a "help" facility in FRACAS, which will display a full screen of information for any data item on the five screens containing input data. The help screen will describe the name, type, decimal places, and range of the data value, and give a prose description of the variable.

Running FRACAS is straightforward: the user pages through the interactive screens and inputs the data needed. When finished, the OUTPUT selection is made and the results are displayed. Any information available on any screen can be printed at any time.

Any data in the work space can be stored under a unique name at any time.

FRACAS STRUCTURE AND CODING

The first decision to be made in implementing the FRACAS software specification was to choose a micro-computer for FRACAS. Because the program would be relatively large (more than 4,000 lines), there was a temptation to use a powerful machine. However, there were other considerations.

Costs to the end user can be minimized by implementing the system on a small and inexpensive machine, such as the Apple II. The Apple II is likely to be a machine that is often available in transit agencies. For these reasons, the Apple II was chosen as the hardware for FRACAS, even though FRACAS could have been coded more quickly and would run faster on a larger machine.

The second decision to be made concerned the language to use for program development. The two languages that are currently popular with the Apple II are Pascal and Basic. Pascal is a version of University of California, San Diego (UCSD) Pascal. UMTA suggests Pascal as an appropriate language for microcomputers, and the UTPS Screen Handler, on which FRACAS' interactive screens are based, will operate only with software written in Pascal. Apple Pascal, version 1.1, was chosen for FRACAS.

The number of columns available on the screen will obviously affect the amount of information that can be put on one screen and consequently the ease of use of the system. Because both the Pascal system and the UTPS Screen Handler support the addition of hardware to the Apple II that expands the number of displayed columns from 40 to 80, an 80-column card was also specified as part of the hardware package that runs FRACAS. The Videx Videoterm was used in developing FRACAS because it is one of the most common 80-column boards available and would be most likely to be part of existing equipment belonging to transit operators. FRACAS also makes use of the simple, nonstandard line graphics available to the Videx board.

The FRACAS menu screens use a software product called the UTPS Screen Handler. The UTPS Screen Handler is both a set of utilities and a library of procedures for the easy implementation of interactive screens and menus. All of the interactive screens except the REPORT screens were designed with

Screen Handler utilities and operate by calling the Screen Handler procedures. They are internal to FRACAS and transparent to the user.

The FRACAS system is divided into four programs responsible for the input menus, calculations, and output reporting. FRACAS passes control from program to program internally, storing any needed data on disk.

The first program, SYSTEM.STARTUP, is only run when the system is turned on. This program displays the title and calls the input program, FRACAS. The input program handles the interactive input screens, runs the STORAGE page, checks the input data, and writes it on disk before chaining to the output program (OUTPUT). The output program reads the input data from disk, calculates the output variables, and writes the output data to disk before chaining to the reporting program (REPORT). This program reads the output data from disk and displays it on the screen. The reporting program chains back to the input program. This overall structure is shown in Figure 2. It is the need for chaining among programs and for storing intermediate data on disk that accounts for most of the execution time of the FRACAS system. The actual computation time is quite small and if FRACAS were implemented on a larger and more expensive microcomputer, it would run considerably faster. These trade-offs are difficult to assess in system development; experience will show whether the slower, cheaper Apple II implementation is acceptable or whether a faster, more expensive machine would have been better.

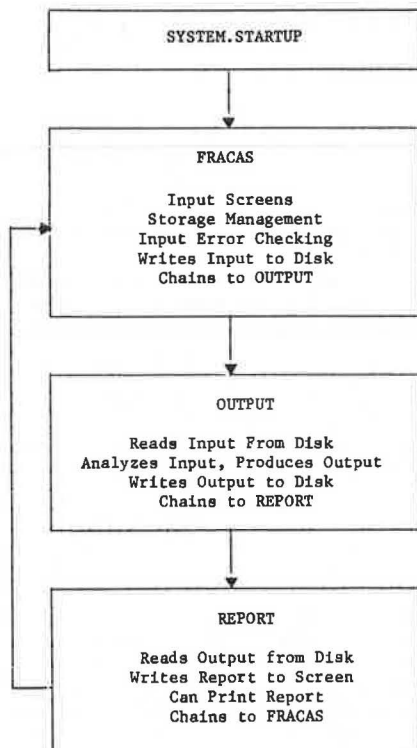


FIGURE 2 Program tasks.

EXAMPLE RUN

In this section, a step-by-step example of the FRACAS model is run. After turning on the system, the user is presented with a title page, automatically followed by the MAIN menu. The MAIN menu contains no data; it is used solely for the selection

of the other screens. In this session, the objective screen and the four data screens will be selected and used, and the output of the model will be examined.

MAIN Menu

As shown in Figure 1, the MAIN menu displays the screens and options available in FRACAS, which are selected by moving the cursor to the desired option using the arrow keys on the keyboard and pressing the "accept" key, or "control" C. The cursor can also be made to move up to the work file name. This allows the user to change the name of the file at any time. In this example, the OBJECTIVES menu, which is then displayed on the screen, is selected.

OBJECTIVES Screen

The instructions at the bottom of Figure 3 indicate that the arrow keys will move the cursor; the ESCAPE key will return the user to the MAIN menu; Cntl-P will print the screen; and Cntl-C will "accept" data. Accepting data means that the data on the screen are accepted by the user for storage in the work space. Both ESCAPE and Cntl-C will return the user to the MAIN menu, but only Cntl-C will put the entered data into memory. Thus ESCAPE can be used to leave a menu if users get into trouble changing data that they did not intend to change. The data that were shown when the screen was started will be left in memory.

The cursor starts on the position asking "Analyze local service?" This prompt is requesting that the user enter the periods of local service that should be analyzed with this run. In this example, only examining peak-period local service is of interest, so "1" is selected for this first data entry location. The cursor automatically advances to the next position. Because no express service fits into the plans for analysis, "4" is selected here.

It is also necessary to indicate what services are currently being operated. Data describing these services will be entered at a later point and used in the analysis. For this reason, existing data are required in the same time periods (peak or off-peak) as the service or services to be examined although, for example, peak express service can be analyzed even if only local service exists in the peak currently. In this example, there is both peak and off-peak local service already existing, so "3" is entered for the third question. There is no existing express service, so "4" is entered for the fourth question.

Next Objective 2 is chosen from the four possibilities. In this objective, an additional (or lost) rider has a value to the transit operator above and beyond the fare paid. A value of \$0.50 will be set on the CONSTRAINTS page to reflect the judgment that the region would be willing to support up to a \$0.50 per rider extra deficit for new patronage. The sensitivity to this number can be tested by repeating the analysis with several different values per rider.

The other options for the objective include minimizing the deficit (Objective 1) or maximizing the ridership within a user-specified deficit limit (Objective 3). This deficit limit is entered on the CONSTRAINTS page. By selecting Objective 4, all of the service and fare variables could be specified and the system would report performance data on the design.

The constraints for the output variables are then specified. Because it is desired that the model choose all of the variables, a "1" is entered for

Objectives, Constraints, Time Periods		File: EXAMPLE
Time Periods & Service Types:		
1 Analyze Local Routes?	1 - Peak	
4 Analyze Express Routes?	2 - Offpeak	
1 Existing Local Routes?	3 - Both	
4 Existing Express Routes?	4 - None	
2 Objective	1 - Minimize Deficit	
	2 - Max Weighted Riders-Deficit	
	3 - Max Riders w/Deficit Constraint	
	4 - All Predetermined	
Constraints:		
1 No. of Routes	1 - Model Chooses, Separate	
1 Route Length	2 - Model Chooses, Equal (2 periods)	
1 Fare	3 - Predetermined	
Use <-, -> to move cursor		Esc to MAIN menu
Cntl-C to accept data		Cntl-P to print screen

FIGURE 3 Example OBJECTIVES screen.

these data. In this case, "1" and "2" are equivalent. If both peak and off-peak service were being looked at, choosing "2" for a variable would constrain the model to pick one value for that variable that worked best for both periods. A variable can be prespecified by entering a "3" here. In this case, the value of that variable would also be entered on the CONSTRAINTS page.

The screen is now finished and can be accepted by pressing Cntl-C. From the MAIN menu, the next option is selected--the CONSTRAINTS screen. FRACAS anticipates that the user will go to the next screen and moves the cursor down one step on the MAIN menu.

CONSTRAINTS Screen

This screen shown in Figure 4 is similar to the previous screen, but more complicated; as many as 25 data items may be specified here, and the screen accepts multidigit real numbers.

Not all of the data that can be entered on this screen are needed for this run, although the user may put in additional information so that it will be there if needed for future analysis. To determine what is needed, the user needs to look at the line on the screen labeled "used this run."

Data are needed in the boxes that have a bar on this line. Data are needed for the value of rider if there is a bar above it. Notice that for this run data need to be entered only for "Fixed Costs" and for "Value of Rider." In fact, data need to be entered only for the peak-local cell for fixed costs, because this is all that is being analyzed. If the user wishes to prespecify some of the output variables, that can be done here under "Predetermined Values."

Values entered are "278" for fixed costs and "50" for the value of the rider; then Cntl-C is pressed to return to the MAIN menu and Cntl-C is pressed again to move on to the next menu.

OPERATING Screen

The operating data reflect many of the characteristics of the area and the transit system. Some of the area characteristics are described in greater depth in Kocur (1) and care must be taken in setting their values in actual analyses. They are discussed only briefly here.

The area dimensions must be entered, so the length of the corridor is selected as 8 miles (Figures 5 and 6), beyond which there is little develop-

DATA Constraints, Objectives		File: EXAMPLE				
Predetermined Values						
.....!						
used this run) peak: offp:	Number of Routes	Route Lngth (mi.)	Fare (cents)	No. of Trips	Max Deficit (\$/day)	Fixed Costs (\$/day)
	loc exp	loc exp	loc exp	loc exp	loc exp	loc exp
						278
Value of a Rider : 50.0 (cents)						
Use <-, -> to move cursor					Esc to MAIN menu	
Cntl-C to accept data					Cntl-P to print screen	

FIGURE 4 Example CONSTRAINTS screen.

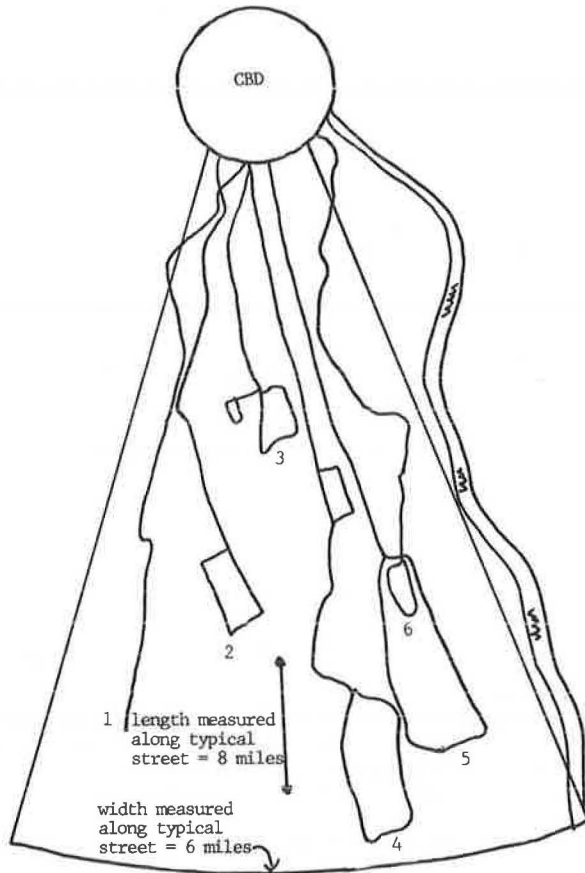


FIGURE 5 Map of example area.

ment. Maximum width of the corridor at its outer edge is about 6 miles. The number of expressways in the corridor is 1, although this number is used only in express analysis. The length of the CBD is also used only in express analysis to determine the time spent in CBD distribution. The distribution run for expresses would be 0.5 miles. The number of analysis days per year is used only to convert from daily to annual statistics.

The expected ratio of total bus-hours to in-service hours is estimated by the user. Total bus-

hours include layovers, deadhead time, and other nonservice time. In-service hours are those the bus is actually in revenue service operating along the route. A ratio of 1.4 is used in this example to estimate total bus-hours and the bus fleet size.

The bus operating cost varies between peak and off-peak periods. Although the model will accept a uniform cost for peak and off-peak service, it is generally better to estimate the two separately. For the peak period, the cost of a peak-only bus, computed as the average cost per in-service hour over trippers, split shifts, and other driver assignments for peak-only runs is used. In off-peak periods, the cost per in-service hour of a vehicle operated all day is used. In both periods, costs are strictly for in-service time, not including layover or deadhead times. A peak cost of \$36 per hour is used here. The off-peak cost is not needed in the example.

The length of the analysis periods is the number of hours each day with peak or off-peak service. For the example, there are 4 hr of peak service each day.

The maximum load per bus reflects the equipment type and the loading standards of the property. Different equipment types can be reflected by varying the values of the maximum load per bus, cost per bus-hour, and speed. Because maximum load is a constraint on the average load in a peak or off-peak period at the peak load point, it should be lower than the ultimate capacity of the vehicle. Forty passengers per bus are used in this example.

For local service, the average bus speed includes delays for boarding and alighting. The speed chosen for this example is 12 mph in the peak.

EXISTING Screen

This screen (Figure 7) allows the user to enter data for eight variables describing existing service.

The number of routes, six, is determined from the map. The average route length is found by adding the total length of all routes counted and dividing by the number of routes. The average route length calculation gives 7 miles.

The average fare should be estimated for each of the service and time periods for which data are required. If the average fare paid in each service and time period is not known, the nominal adult fare should be used. The fare for this example is \$0.70.

The current number of bus trips in the peak direction is calculated from the current schedules.

DATA	Operating	File: EXAMPLE	
Corridor Length (mi):	8.0	Maximum Passenger Load/Bus	
Corridor Width (mi):	6.0		
No. of Expressways:	1.0	Local	Express
CBD Length (mi):	0.5	peak:	40.00
Analysis days/year:	250.0	offpeak:	
Total/Serv. Bus-Hrs.:	1.40		
Bus Operating Cost		Average Segment Speed (mph)	
(\$/hr) peak-only:	36.00		
base period:		Local	Express
Length of Period (hrs)		(w/stops)	(w/o stops)
for peak analysis:	4.00	peak:	12.00
for offp analysis:		offpeak:	
Use <-, -> to move cursor		Esc to MAIN menu	
Cntl-C to accept data		Cntl-P to print screen	

FIGURE 6 Example OPERATING screen.

DATA Existing Service		File: EXAMPLE	
No. of Routes	Local Express	Total Ridership	Local Express
peak: 6.0		peak: 5185	
offpeak:		offpeak:	
Route Length (mi)		% to/from CBD	
peak: 7.0		peak: 82.0	
offpeak:		offpeak:	
Fare (cents)		% in Peak Direction	
peak: 70.0		peak: 80.0	
offpeak:		offpeak:	
No. of Bus Trips		Transit CBD mkt shr %	
peak: 90.0		peak: 20.0	
offpeak:		offpeak:	
Use (-, -) to move cursor		Esc to MAIN menu	
Cntl-C to accept data		Cntl-P to print screen	

FIGURE 7 Example EXISTING screen.

Short-turns are counted as fractional values. In this example, the number of bus trips over the six routes is 90. This is the number of inbound trips in the morning peak plus the number of outbound trips in the evening peak.

The total ridership over all routes is found from revenue or passenger count data. Ridership for the example is 5,165 in both directions over the two peaks. The fraction of current transit riders bound to or from the CBD, including transfers in the CBD, is estimated from ridership counts or from experience. In this case, the value is 0.80.

The current mode share of all CBD trips captured by transit is generally obtainable by dividing transit ridership to the CBD by the total person trips to and from the CBD. The total flow of persons to and from the CBD is usually obtainable from regional transit planning agencies, state departments of transportation, or downtown associations. For this example, 0.20 is used.

MARKET Screen

These data (Figure 8) pertain to the market characteristics of the geographic area. Along with the EXISTING data, these data tend not to change much after they have been set.

The average walk speed is generally considered to be 3 mph; this is what is used here. The maximum distance beyond which no persons are willing to walk is based on operator experience and judgment. A value of 0.5 mile is used in the example.

The average CBD parking cost is entered for both peak and off-peak users. A peak CBD parking cost of \$1.50 is used here.

The maximum policy headway is set by the analyst on the basis of either formal or informal service standards. These standards will not typically be binding in the peak period. Maximum policy headway is 60 min in this example.

The standard value for the ratio of average passenger wait time to route headway is 0.5. It can be greater than 0.5 for poorly kept, short headways and less than 0.5 for well-kept long headways. Because good schedule adherence is expected in the example, this ratio is set at 0.4.

The market sensitivities in the second column are set by examining the graphs shown in Figure 9. Typically, the market coefficients will differ between peak and off-peak period travel and may differ between local and express traffic. Choose a coefficient that represents a curve in the figure that is believed to represent the true changes in ridership that would occur in the corridor being studied. The user may interpolate between the curves if neces-

DATA Market		File: EXAMPLE	
Avg. Walk Speed (mph)	: 3.0	SENSITIVITIES	
Max. Walk Distance (mi)	: 0.5	select from graphs in the manual	
Avg. CBD Parking Cost			
(cents/trip)	peak: 150	Local	Express
	offp:		
Max. Headway Policy	Local Express	Fare	pk: .001000
(in min)	peak: 60.0		offpk:
	offp:	Running Time	pk: .003000
Wait-to-Headway Ratio			offpk:
	peak: 0.40	Walk Time	pk: .010000
	offp:		offpk:
		Wait Time	pk: .010000
			offpk:
Use (-, -) to move cursor		Esc to MAIN menu	
Cntl-C to accept data		Cntl-P to print screen	

FIGURE 8 Example MARKET screen.

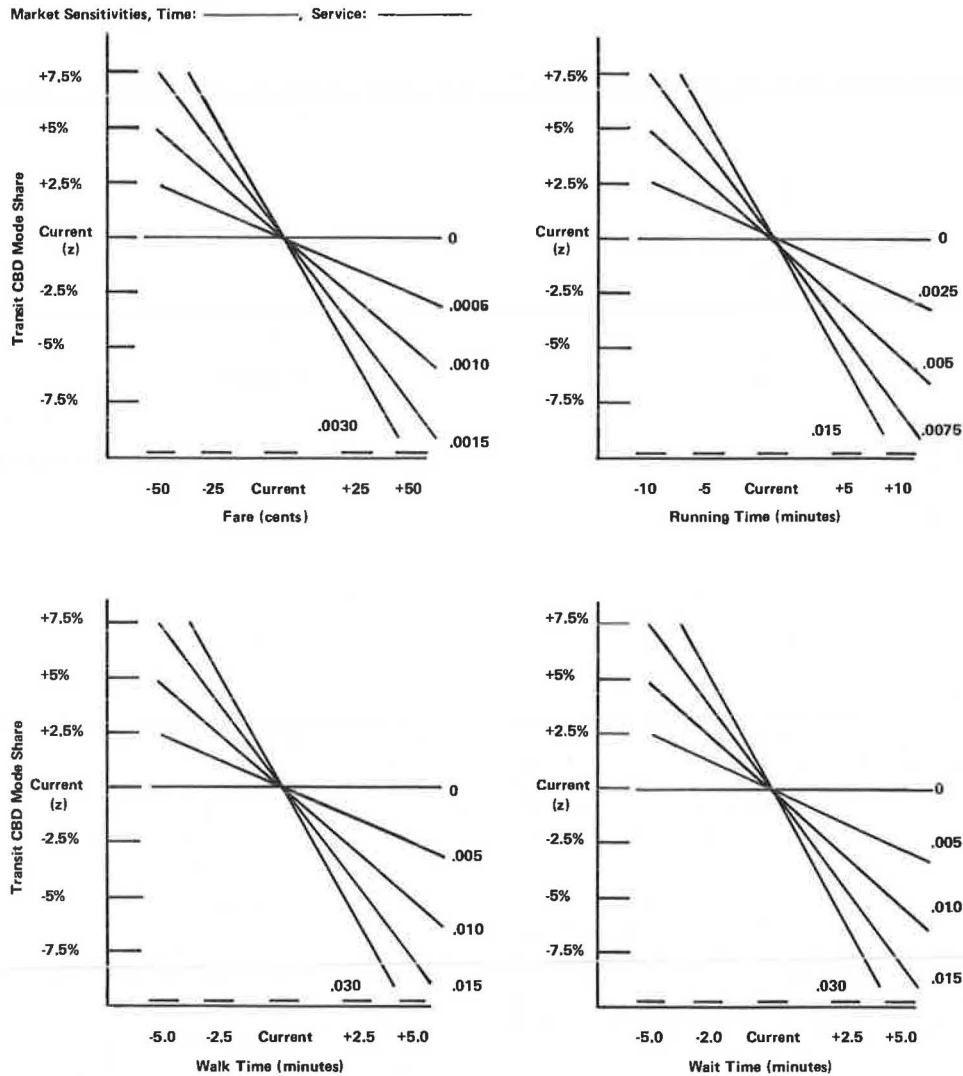


FIGURE 9 Market sensitivity curves.

sary. Alternatively, the demand coefficients can be found from the corresponding elasticities if known. Values are entered from the curves, as shown, and the screen is accepted. OUTPUT is then selected from the MAIN menu because all input is complete.

Output

When the calculation messages have finished, the report screen will show the results. Notice the changes that were made in the system (Table 2). The fare has increased from \$0.70 to about \$1.00; headway is reduced from 16 to 12 min; the number of routes comes down from 6 to 4.

These optimal values are indicative of directions that produce ridership increase, deficit decrease, or productivity increase. In this example, the value per extra rider is rather low (\$0.50), so service is expanded only until the deficit for the last rider reaches \$0.50. Because the deficit per rider increases as marginal patronage is sought, most riders cost the system less than \$0.50 deficit. With a \$0.70 current fare, this means that a high revenue-to-cost ratio is implicitly required. The model suggests the best way to achieve this. Note that headways actually improve, although routes are cut and

fares increase sharply. This strategy differs from those many systems may follow. If the user wishes to alter portions of the solution, they can be constrained by returning to the OBJECTIVES screen and setting the variables as predetermined and then moving to the CONSTRAINTS page to specify a value. For example, the fare could be locked in at \$0.80 if that was the maximum value the operator felt could be implemented. The model can be rerun, and the new results obtained. Using this iterative process, the user of FRACAS should be able to achieve a better intuitive understanding of the transit system than was previously possible.

If the operator found all the changes in this run satisfactory (which is not expected for a first run, but was assumed for sake of example), the design and impacts of the best service to achieve the system's goals are set. In this example, approximately four routes at 12- to 13-min average headways will be operated; a fare of approximately \$1.00 will be charged; the routes will be run out about 7 miles in the corridor. The specific design of the four routes is left to the analyst and his local knowledge; this is a hard task for a computer. A possible revised route pattern is shown in Figure 10. It uses four routes instead of the current six, and they are slightly longer. They are spaced as evenly as pos-

TABLE 2 Output Report

File: EXAMPLE						
		PEAK		OFFPEAK		TOTAL
		Local	Express	Local	Express	
Service						
& Fares:	No. of Routes:	3.81	0.00	0.00	0.00	
	Route Length (mi):	7.14	0.00	0.00	0.00	
	Avg. Headway (min):	12.45	0.00	0.00	0.00	
	Avg. Fare (cents):	102.81	0.00	0.00	0.00	
Impacts:	Load Per Bus:	40.00	0.00	0.00	0.00	40.00
	Mode Share (CBD):	0.17	0.00	0.00	0.00	0.17
Daily						
Impacts:	Cost(\$):	3421.85	0.00	0.00	0.00	3421.85
	Revenue(\$):	4332.29	0.00	0.00	0.00	4332.29
	Deficit(\$):	-910.64	0.00	0.00	0.00	-910.64
User	Benefit(\$):	2890.48	0.00	0.00	0.00	2890.48
	Ridership:	4214.08	0.00	0.00	0.00	4214.08
Annual						
Impacts:	Cost(\$):	855.41	0.00	0.00	0.00	855.41
(000's)	Revenue(\$):	1083.07	0.00	0.00	0.00	1083.07
	Deficit(\$):	-227.88	0.00	0.00	0.00	-227.88
User	Benefit(\$):	722.62	0.00	0.00	0.00	722.62
	Ridership:	1053.52	0.00	0.00	0.00	1053.52
Daily						
Statistics:	Bus-Miles:	1047.88	0.00	0.00	0.00	1047.88
	Bus-Hours:	122.25	0.00	0.00	0.00	122.25
	No. Bus Trips:	73.43	0.00	0.00	0.00	73.43
	No. Buses:	30.56	0.00	0.00	0.00	30.56
	Psg. /Bus-Mile:	4.02	0.00	0.00	0.00	4.02
	Psg. -Miles:	15034.3	0.00	0.00	0.00	15034.3
	Psg. -Mile/Bus-Mile:	14.35	0.00	0.00	0.00	14.35
	Avg. Travel Time (min):	17.84	0.00	0.00	0.00	17.84
	Avg. Walk Time (min):	4.98	0.00	0.00	0.00	4.98
	Avg. Wait Time (min):	4.98	0.00	0.00	0.00	4.98
Daily						
(in \$)	Cost/Passenger:	0.81	0.00	0.00	0.00	0.81
	Revenue/Passenger:	1.03	0.00	0.00	0.00	1.03
	Deficit/Passenger:	-0.22	0.00	0.00	0.00	-0.22
	Benefit/Passenger:	0.69	0.00	0.00	0.00	0.69
	Operating Cost:	3143.65	0.00	0.00	0.00	3143.65
	Fixed Cost:	278.00	0.00	0.00	0.00	278.00
	Ratio Revenue/Cost:	1.27	0.00	0.00	0.00	1.27

sible and operate over existing route segments whenever possible.

There are some major implementation issues in making such a routing change, and these have to be weighed carefully. However, the model does point out that even under the objective used in this example, which places tight financial bounds on the operator, headway increases are self-defeating. Obviously, fares go up; but the key is to increase walk times a little, by adjusting route structure, instead of increasing wait times a lot through headway increases. These conclusions are dependent on the market sensitivities of wait and walk time, which should be varied to examine the robustness of the result.

Under objectives that place more value on ridership or allow larger deficits, route restructuring is likely to be more acceptable. In such cases, the fares will be at or even below current levels; headways will improve; travel time will improve (due to elimination of loops and probably more widely spaced stops, treated elsewhere in the model); but walk

times will increase. Thus the operator can argue that the disadvantage of slightly longer walk distances is more than offset by the other improvements. Express service can also aid in this argument.

The "profit" of \$911 earned in the example is only a peak-period surplus; off-peak losses will more than offset it. The ridership of 4,214 is a 19 percent decrease from current ridership. Combined walk and wait times are almost the same in the current and redesigned systems, although the mix is different: wait times decrease from 6.4 to 5 min, and average walk times increase from 3.8 to 5 min. The fare increases from \$0.70 to about \$1.00. With a fare elasticity of about 0.35, the expected ridership decrease is about $0.35 \times 30/70$ or 15 percent. A slight further decrease is caused by the slightly shorter route lengths and correspondingly smaller service area. Thus the model results "check" against all the parameters.

This would not be the only model run for the corridor, of course. It could be rerun setting the number of routes to exactly four, or the fare could be

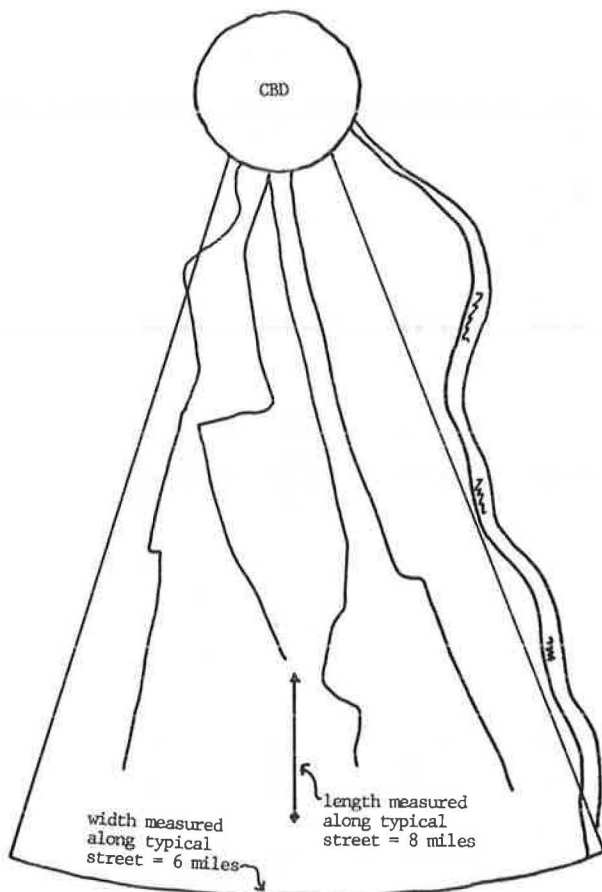


FIGURE 10 Revised route pattern.

constrained to something less than \$1.00, and so forth. Express and off-peak services could also be considered, and routes could be examined one by one if they varied greatly in their ridership and operating characteristics. The model is a design and analysis aid, but the analyst must use it creatively to develop good, implementable, strategic options, which always require detailed local knowledge.

ASSUMPTIONS AND LIMITATIONS

Corridor Characteristics

The FRACAS model requires only data that are generally available to or can be estimated by a transit operator. It uses no networks, trip tables, statistical demand models, or other conventional data sources in transportation planning. Nonetheless, it generates acceptable alternatives and evaluates a wide range of impacts. To do this, the model makes assumptions about the difficult-to-measure data items that it does not use.

FRACAS is a so-called "continuous" model that treats each route or corridor as operating in an area of slowly varying population density and operating characteristics. FRACAS assumes that population (and trip) density declines approximately piecewise linearly from the CBD outward.

Route ridership data (from which trip density is inferred) can be entered for two segments if route boardings vary greatly. If boardings follow a relatively smooth, increasing pattern, a single ridership number will produce a good "fit" with the observed boarding pattern.

The model treats the corridor as having fairly continuous development with most of the area occupied. If development is very concentrated with much undeveloped space in between (e.g., a set of small towns with open farmland in between), the model is not appropriate. In urban areas, even if there are clusters of development or concentrations along particular streets, the model is adequate as long as the remaining development is continuous.

The corridor is assumed to have enough through streets to operate the desired number of routes and it is assumed that the rest of the street network is well enough connected to allow users to walk a moderately circuitous path to a bus route. In some suburban areas, this may be a problem. In that case, the bus operating speeds and user walk speeds are reduced to reflect circuitry.

Population density is assumed to be the same in different portions of the corridor at the same distance from the CBD. If this is not the case, the corridor-average optimal service levels may not reflect route averages very well (although the corridor summary statistics will still be fairly good estimates in all but the most extreme cases). To deal with this problem, single-route analyses should be done in the corridor, or the corridor can be broken into more uniform parts.

The route structure suggested by the model is laid out by the analyst. The model assumes equally spaced routes in making its assessments, but moderate departures from equal spacing have little effect. The analyst should choose the routing for the selected number of routes that is believed to be best. If the route spacing is extremely nonuniform, rerun the model at a single-route level to confirm the results.

Transit Market

The model selects whether the primary market for transit is CBD trips only or both CBD and non-CBD trips. It does this by comparing the value of objective functions that can be achieved in either case. Three possibilities emerge:

1. The service is designed and priced strictly with the CBD travel market in mind; non-CBD transit trips essentially are not made. This occurs particularly if high fares are set, which CBD users will pay because of high parking costs, but non-CBD travelers will not pay.

2. The service is again designed and priced for the CBD travel market, but residual non-CBD transit travel remains. Here the non-CBD market is not large enough to affect the design, but the pricing and service are still attractive to some non-CBD travelers.

3. The service is designed and priced for both CBD and non-CBD travel, because both are potentially significant. In this instance, the fares, headways, and route structure are a compromise for both markets.

The non-CBD travel included in the model is within-corridor travel along the radial routes plus transfers through the CBD. This version of FRACAS treats radial routes only. (An extension to cross-town and grid routes is being prepared.) Specific service to non-CBD destinations within a corridor cannot be treated except as a deviation of the CBD-bound routes passing by it. A diagonal or crosstown route cannot be treated. Transfer trips through the CBD are treated as CBD trips for simplicity.

To predict ridership for new options, the model uses an internal linear demand function based on the

coefficients input by the analyst. The model predicts changes from the base ridership using these coefficients, instead of generating an estimate from scratch. It is similar to an elasticity or (logit) pivot point approach, except that it uses the linear approximation because it is easier to compute. (As in logit pivot point, the elasticity in the linear model is not constant but varies with market share and service level.) All transit users are assumed to be choice users. They may not all have driving as a choice, but they can walk, get a ride, move, or make some other change if transit service changes. Travelers are assumed to react to travel time, walk time, wait time, fare for transit, and automobile parking cost (for CBD travelers). The times and costs of non-transit options are implicit in the model and are assumed not to change. Travelers are assumed to use the transit route nearest their home.

Operating Characteristics

The model treats costs on a per minute (or hour) basis only, because labor is the most important component. Two cost levels are used: those for buses that operate in the peak only (split duties or trippers, or both) and those that operate all day. Detailed timing and scheduling issues are not considered, such as whether vehicles on long routes can make two round trips in a peak period. For example, substituting express for local service on a long route will decrease running time and cost in the model, while it may or may not eliminate vehicles or drivers in the actual schedule. These issues are beyond the scope of FRACAS.

The variation of passenger loadings within a peak or off-peak period is treated only indirectly in FRACAS. The bus capacity constraint is applied to the average load over the period, as is done by many transit properties today. To consider variations in passenger flow more explicitly, the period must be subdivided into shorter time periods and the model rerun for each (with constrained route structure and fare) to find the best headway and meet short-term demand peaks. The trip density (computed from existing ridership), cost, speed, and loading standard can vary for each period.

Use of Approximations

The number of routes that emerges as the optimum from FRACAS is not an integer. Either round up or down (or try both) and rerun the model with predetermined routes to find an integer answer. The best number of routes will always be the next smallest or next largest integer from the initial solution. Generally, either one will be quite good.

The optimal values of all the fare and service variables are found from approximate solutions of complex equations. Occasionally, by playing with the model, the user may be able to improve on the optimal solution given by FRACAS. Usually the improvement will be quite small. The one exception is that

the route length calculation does not take fare or route spacing constraints into account. If severe constraints exist, the best route length will generally be somewhat shorter than the model indicates.

These are the major assumptions and limitations of FRACAS. It is a design tool to aid operators in coming up with their own service, routing, and fare plans for specific corridors and routes, as well as a strategic planning model at the systemwide level. Some of the input data are judgment based, and there are approximations and assumptions in the model that may not hold in every case. Its output should not be taken as absolute, but as a guide to local transit decisions. However, FRACAS can generate and evaluate options for a wide range of circumstances and goals in a flexible manner, and it represents a substantial advance in the ability to do transit fare and route analysis.

CONCLUSIONS

An overview of a microcomputer-based strategic planning model for bus transit systems has been presented. The model is entering its field test stage, so no implementation results are yet available. It has the promise of allowing flexible analysis of routing, pricing, vehicle size, express service, and headway options in a user-friendly environment and without the collection of additional data. It operates at a level of detail that is more approximate than most current service planning analyses, which are focused on route-level detail. FRACAS seems most appropriate for strategic planning (and general learning about trade-offs), and it may support certain (though not all) service planning functions well.

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