

# Travel Demand Forecasting with the Quick-Response Microcomputer System: Application and Evaluation of Use

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## ABSTRACT

A description, application, and evaluation of the quick-response microcomputer system (QRS) are presented. QRS is found to be a well-programmed computer version of the manual techniques presented in NCHRP Report 187. The system is, with few exceptions, easy to understand and operate. Observations about QRS operation include the following: (a) Some data files must be laboriously re-entered every time the model is run; (b) screen prompts and written documentation sometimes fail to give sufficient guidance; (c) the gravity model output is never transformed into an origin-destination matrix, although it is labeled as such; (d) the mode-choice model has several undesirable features, the most troublesome being the lack of an explicit transit penalty, making calibration difficult; (e) the software may be so easy to apply that it can be used without much thought; and (f) the best application of QRS might be for local traffic analysis and not for corridor or regional studies.

In 1978 a two-phase research effort of NCHRP culminated with publication of two volumes in the NCHRP Report series. Phase I consisted of identifying travel-related urban policy issues and assessing existing methods and procedures that could be used to respond to these issues quickly. The results of Phase I were presented in NCHRP Report 186 (1). Phase II included developing a User's Guide "to describe transferable parameters, factors, manual techniques, and the like, to enable the user to carry out a simplified [travel demand] analysis without the necessity of reference to other sources" (2). Phase II results were published in NCHRP Report 187 (2). These reports will henceforth be referred to as NCHRP Reports 186 and 187.

In the years following its publication, NCHRP Report 187 has become a popular reference and planning tool (3) along with such standards as Characteristics of Urban Transportation Demand (4), Characteristics of Urban Transportation Systems (5), and the Institute of Transportation Engineers' trip generation manual (6).

Some years after publication of NCHRP Report 187, FHWA established funds for the creation of microcomputer software that would incorporate the report's quick-response techniques for travel demand forecasting. The resulting software, called the quick-response microcomputer system (QRS), was released into the public domain in February 1984.

The following description of QRS is not intended as a substitute for the user's manual; rather, it is meant to be a supplement. This paper provides a summary of QRS format and application; however, readers who wish to use QRS should begin with the study of NCHRP Report 187 (2) and the QRS user's manual (7).

## HARDWARE AND SOFTWARE REQUIREMENTS

QRS has been written and compiled in two versions, one for the Apple microcomputer and the other for

the IBM PC. In either case, the computer must be configured with a minimum of 64K random access memory (RAM), two disk drives (for 5 1/4-in. floppy disks), and a video monitor capable of displaying 24 lines and 80 columns. A printer is optional because users can copy output from the monitor. However, copying is a tiresome procedure, so a printer is strongly recommended. Users of the Apple II+ or Apple IIe also need a language card.

QRS is written in UCSD PASCAL, and its programs run within the UCSD p-system. Users must purchase the UCSD p-system and use the file management facilities of the p-system to run QRS. Purchase of the full p-system represents a substantial software investment; a "run-time" version may be purchased more cheaply, and it has all the capabilities required to operate QRS. However, users of the run-time version will not be able to modify files or programs.

All the modules within QRS are menu-driven; that is, a list of possible responses is presented for the user's choice. The following paragraph is excerpted from the user's manual (7):

The QRS has been designed to be user friendly. Users direct the system by selection of functions from a menu. Ease of data entry has been incorporated in the system's basic design. After review of this manual and NCHRP Report 187, the system should provide sufficient prompting information at the screen to allow operation with minimal reference to printed material.

In its present form, application of QRS is subject to upper bounds on certain parameters. These include

- Maximum number of zones, 50;
- Maximum number of assignment links, 800; and
- Maximum travel time, 40 min.

## GENERAL DESCRIPTION

Trip Generation

QRS calculates trip productions based on the number of dwelling units in each zone. Users are free to use their own trip rates or to use QRS default values. Attractions are calculated for each zone according to default equations or user-specified values.

After users have established production and attraction rates, they must provide zonal data. For each zone, the following data are required:

- Average income or average automobile ownership per household,
- Retail employment,
- Nonretail employment, and
- Total dwelling units.

Trip Distribution

The gravity model in QRS is the traditional formulation. Required input for each of the three trip purposes includes the following:

- Productions and attractions for each zone,
- Travel time/friction factor relationship,
- Intrazonal travel times, and
- Interzonal travel times for each ij interchange.

Users may input productions and attractions directly or may recall the file saved after trip generation. Travel times may be entered directly for each interchange. Alternatively, QRS will calculate interzonal travel times, given the following data:

- Zone type for each zone [central business district (CBD) or suburb],
- X and Y coordinates for each zone centroid (measured in inches),
- Map scale (miles per inch),
- Circuity factor to convert airline distance to over-the-road distance, and
- For each interchange, the following percentages: (a) distance in CBD, (b) distance (a) on arterials, (c) distance in central city, (d) distance (c) on arterials, (e) distance in suburbs, and (f) distance (e) on arterials.

Users may elect to use default values for friction factors, which are available for each of the four population groups. If users have area-specific factors, these may be directly entered into the gravity model. In either case, the program forces users to begin with a travel time of 1 min and to increase by 1-min increments up to a maximum of 40 min. Corresponding friction factors are needed for each of three trip purposes.

Mode Choice

QRS calculates mode split based on previously saved files of person trips and travel times and new data required for calculation of impedances.

QRS employs travel times calculated for trip distribution as in-vehicle times for automobile impedance. In-vehicle time for transit, excess time for both modes, and travel cost for both modes are calculated based on the following new data:

- For each origin zone the following: automobile occupancy, income, automobile access time, and walk or drive time for transit access;

- For each destination zone the following: parking cost and time to walk to destination after leaving automobile or transit; and

- For each origin-destination (OD) interchange the following: transit speed, circuity, headway, fare, and transfer time.

These values may be held constant for all interchanges, may be unique for each interchange, or may be constant for all but a selected group of interchanges. The user should know that travel times calculated for trip distribution include OD terminal times. If the travel time file is used without modification for mode choice, special care must be given to definition of automobile access times.

Traffic Assignment

The QRS traffic assignment model is basically a bookkeeping function. Users supply trip tables that were created in the trip-distribution or mode-choice models. Any number of trip tables may be combined so long as the tables are all of equal size. Normally users combine the tables for the three trip purposes and make a single assignment of total daily traffic.

Summary

Figure 1 shows the required data for and output from the four basic modules: trip generation, trip distribution, mode choice, and traffic assignment.

## APPLICATION OF QRS

The authors used QRS to forecast the demand for light rail transit (LRT) in Spokane, a medium-sized city in Washington State. Figure 2 shows the study corridor. In keeping with the time and budget constraints of the feasibility study, and in view of the fact that the study was one of only feasibility versus a complete-alternatives analysis, the authors decided that the LRT forecast could best be accomplished with QRS.

The Study Area

The maximum number of zones that QRS will accommodate is 50; therefore it was necessary to aggregate the region's 286 zones into new groupings. The results of aggregation are shown in Figure 3. Forty-six districts were formed; the four extra ones were intended to be used as external zones.

Trip Generation Results

QRS default trip rates and default trip purpose shares were used as a starting point for calculation of productions and attractions. The results were compared with local totals for the three trip purposes in each of the 46 zones. An iterative process was then used to adjust the production rates for each income category until the resulting production and attraction zonal totals were acceptably close to the local totals.

Trip Distribution

One major input to the gravity model was a travel time matrix, representing minutes of in-vehicle and out-of-vehicle time for every automobile interchange

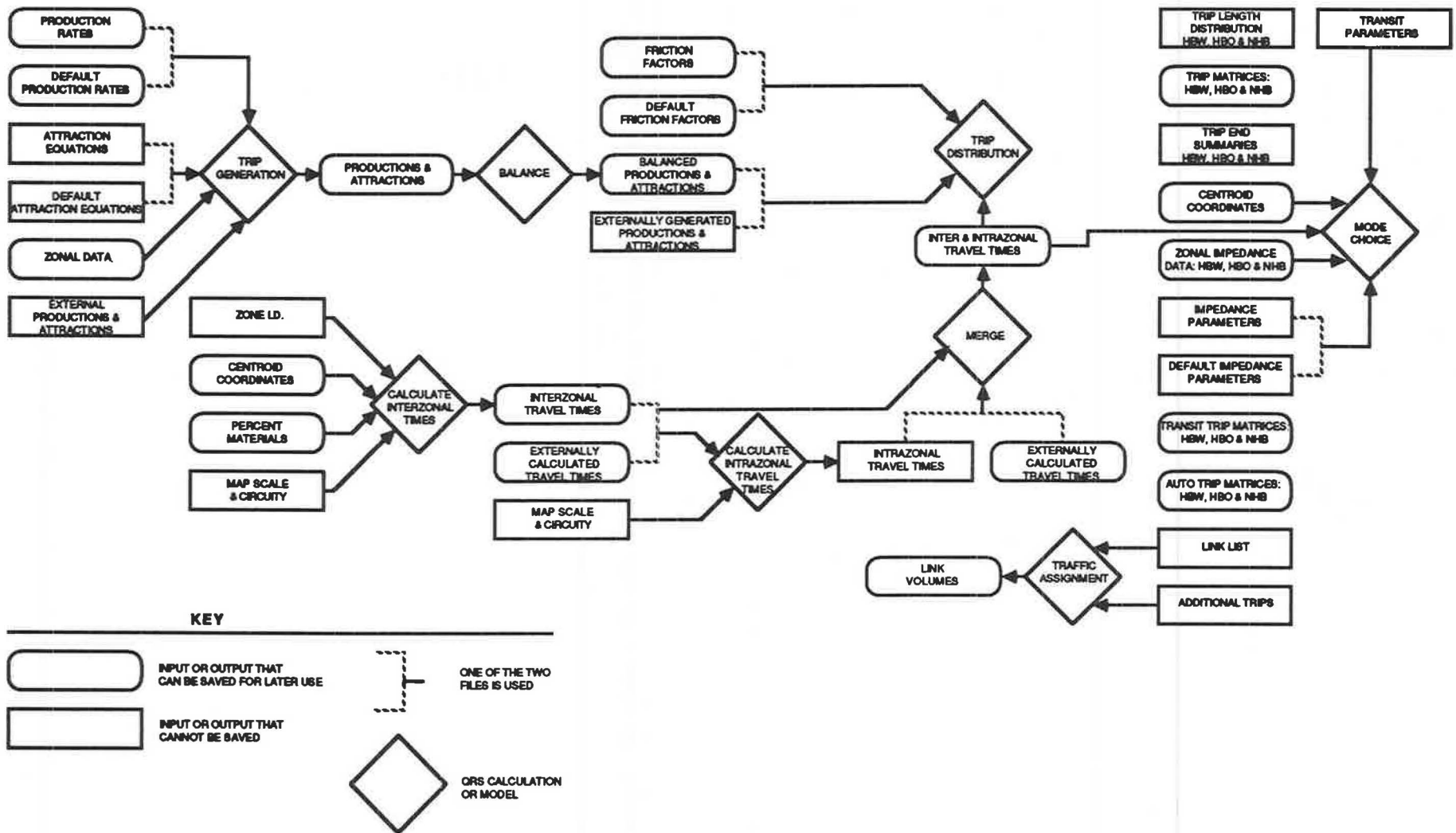


FIGURE 1 QRS: flowchart.

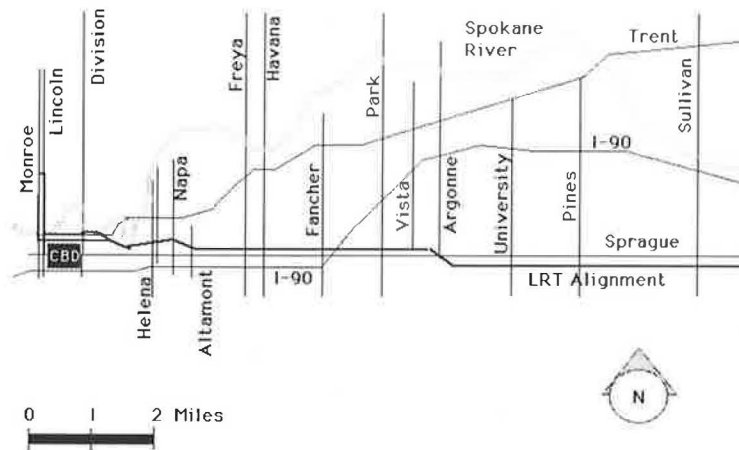


FIGURE 2 Spokane, Washington, East Valley Corridor.

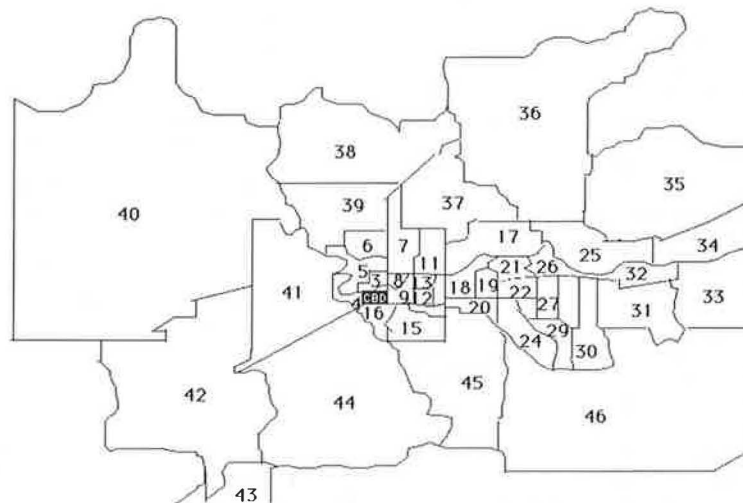


FIGURE 3 Spokane region: zones for LRT study.

in the 46-zone region. Centroids were assigned to each zone on the basis of demographic density; a land use map was used to estimate the most likely center of activity for each zone. Each centroid was assigned X-Y coordinates (in inches) so that QRS could use centroid coordinates and a user-supplied circuitry factor to convert airline distance to over-the-road distance. Actual driving distances for several interchanges were compared with the distances that resulted with a circuitry factor of 1.22 (the QRS default factor), and the comparison indicated that the default factor was acceptable.

In addition, each zone was assigned to one of three zone-type categories: CBD, central city, or suburban. Zones 1 and 2 were CBD, zones 3 through 16 were central city, and the remaining zones were suburban.

In a region of 46 zones, there are 2,116 possible interchanges. This number can be reduced to 1,058 because travel time in one direction is assumed equal to travel time in the opposite direction. The number can be further reduced to 1,012, because QRS calculates the 46 intrazonal travel times on the basis of interzonal times. For each of the 1,012 interchanges remaining, it was necessary to estimate both the portion of the trip in the CBD, central city, and suburbs and the portion of the trip on arterials and freeways.

These estimates were made by using Spokane street maps. Consideration was given to Spokane's unique topography in which there is a limited number of river crossings. Consideration was also given to the location of freeway interchanges.

Friction factors for the gravity model were adapted from factors used by local agencies. Plots of travel time versus friction factors were made for each of three trip purposes, and smooth curves were drawn through the data points. The factors used for the LRT study were taken from the curves.

Trip length distributions for 1980 were not locally available, but 1980 census data included work trip information. Census records indicated that the 1980 home-to-work trip in the Spokane region averaged 18.4 min, whereas the QRS average home-to-work trip was 18.0 min. This was considered to be an acceptable match, given the difference in calculation methods.

Mode Choice

Three major data sets had to be prepared as input to the mode-choice model. The first data set was OD data for each of the 46 zones. The format of the resulting file is given in Table 1. A similar file

TABLE 1 Format of QRS Mode-Choice OD Data File

Zone	Origin Zone Data				Destination Zone Data				
	Automobile Occupancy	Income (\$000s)	Automobile Walk Time (min)	Transit Time (min)		Parking Cost (cents)	Automobile Walk Time (min)	Transit Walk Time (min)	
				Walk	Drive				
1	1.3	3.0	3	10	0	100	3	10	
2	1.3	3.0	3	10	0	100	3	10	
3	1.3	4.0	1	7	0	0	1	7	
4	1.3	5.0	1	10	0	0	1	10	
5	1.3	7.0	1	7	0	0	1	7	
6	1.3	8.0	1	7	0	0	1	7	
7	1.3	7.0	1	7	0	0	1	7	
8	1.3	6.0	1	10	0	0	1	10	
9	1.3	3.0	1	10	0	0	1	10	
10	1.3	5.0	1	10	0	0	1	10	

had to be created for each of the three trip purposes.

Transit walk times were estimated by measuring over-the-road distances on a base map, and the distances measured were from zone centroids to the nearest bus line. In very large zones, these transit walk times were increased to allow for the fact that a small portion of the zone's residents actually lived within practical walking distance of a bus line.

The second major data set required was a matrix of automobile travel times. The travel time matrix used in trip distribution was created based on certain assumed trip end conditions, including automobile access times.

The third major data set was one that described transit parameters for each interchange. Bus schedules and a route map from the Spokane Transit Authority (STA) were used to establish transit speed, transit circuitry, transit fare (\$0.50 for all interchanges), transit headway, and transfer time for each interchange in the 46-zone region.

Transit speeds were calculated for individual routes by measuring distances between time points on a transit route map and using route schedules to determine time between the points. These calculations showed an average system speed of 14 mph, which agreed with average speeds reported by STA (8). In the QRS application, routes with higher speeds were thus credited.

Transit headways were examined for individual routes during the morning peak period [for home-based work (HBW) trips] and during midday [for home-based nonwork (HBO) and non-home-based (NHB) trips]. It was determined that a 30-min headway was typical of the system as a whole.

A file of centroid coordinates was required as mode-choice input. Unfortunately, the coordinate file used in trip distribution could not be used for mode choice because mode-choice coordinates must be expressed in miles rather than in inches.

The final input to mode choice is a set of parameters used by QRS to convert time and cost to impedance units. These parameters, and the values used in the Spokane forecast, include the following:

- Weight for excess time, 2.50;
- Income to value-of-time factor, 0.33;
- Automobile operating cost, \$0.08 per mile (which represents a behavioral cost);
- Model exponent for HBW trips, 1.55;
- Model exponent for HBO trips, 2.40; and
- Model exponent for NHB trips, 2.15.

Calibration of the mode-choice model was achieved through successive iterations. Adjustments were made to the model exponents, transfer penalties, and

transit access times until the results were acceptably close to 1980 STA ridership figures. Two ridership measures were used to judge the QRS results:

- Total STA weekday ridership in 1980, which was 24,360; and
- Average 1980 weekday ridership on Valley routes, which was 3,450 (estimated as 97 percent of 1982 ridership, because 1980 daily ridership was 97 percent of that in 1982) (8).

The QRS mode-choice model was considered to be calibrated when the following results were achieved:

- Region weekday ridership equalled 24,400 (desired total, 24,360), and
- Valley route weekday ridership equalled 3,490 (desired total, 3,450).

#### Forecast

Future-year demographic forecasts were made available by local agencies. Year 2000 was the target for the LRT feasibility study; for each of the 286 zones, data on total households, total employment, and total group quarters population were available for the year 2000. These data were aggregated to correspond to the 46 zones used in the LRT study, just as had been done with 1980 data.

For the year 2000, total employment was split between retail and nonretail categories in the same proportion as had been observed in 1980. Exceptions were made for zones where total employment was forecast to change significantly. The zonal data were used in the calibrated trip generation model, and the output productions and attractions were entered into the calibrated gravity model.

Mode choice for the forecast year involved creating a rough design of the proposed LRT line with an attendant feeder bus service. A base map was prepared that included the LRT route as approved by the feasibility study steering committee. North-south bus routes in conceptual form were added in the Valley, but Valley bus routes with east-west orientation were assumed defunct except for one express route. Bus routes outside the Valley were assumed to be unchanged, both in coverage and in scheduling.

The same data files that had been prepared for mode-choice calibration had to be prepared for the 2000 forecast. Each of 1,012 interchanges was examined separately to identify the operating characteristics that were appropriate. Transit speed for each interchange was calculated by means of measuring distances on a base map and assuming transit speed to be a function of the share of the trip made by LRT versus the share made by bus. Determination

of the interchanges that could fairly be assigned to LRT was necessarily a matter of judgment.

In the final analysis, ridership forecast for the proposed LRT fell short of the minimum criterion of 900 passengers per peak hour and peak direction established by the feasibility study's steering committee. The forecast resulted in a figure of 6,579 daily LRT riders, which was converted to 610 peak-hour peak-direction passengers according to local transit information (12.3 percent of daily total trips = peak-hour total; 75 percent of peak-hour total = peak direction total) (8).

#### EVALUATION OF THE USE OF QRS

QRS is not, and was not intended to be, a scaled-down version of the Urban Transportation Planning System (UTPS). It was designed to be a computerized application of the techniques presented in NCHRP Report 187. Those techniques were established for manual travel demand forecasting; QRS has therefore inherited all the methodological shortcuts and shortcomings that were included in NCHRP Report 187. QRS was intended to allow the user to make a forecast faster than manual procedures would permit, but it was not intended that the QRS forecast would be better than a manual one. Therefore, it is not the authors' intention to criticize the inherent methodological structure of QRS. Instead, this paper concentrates on the authors' opinions about the QRS goal to be a "user-friendly" system with "ease of data entry" (7). However, some additional comments are provided.

The following criteria were applied in evaluating QRS:

- Is QRS user friendly?
- Does QRS incorporate ease of data entry?
- Is QRS quick?
- Is QRS responsive?
- When is QRS appropriate?

#### The User-Friendly System

All the programs within QRS are menu-driven. That is, the user is always presented with a list of numbered alternatives from which to choose. A single keystroke corresponds to each alternative, and QRS instructs the user to press the appropriate key. When the program begins (i.e., when the disk is "booted"), the QRS insignia appears along with a request to hit the ENTER key to proceed. Next appears a menu of all the QRS forecast modules: trip generation, trip distribution, and so on. The user (with a single keystroke) chooses a module, and a menu for that module appears. This menu contains a numbered list of the steps within the program.

Additional menus appear within each element of a program as data are required. The numbered options allow the user to recall previously saved files, to enter data directly, or to exit.

Finally, when a data file is being viewed, a menu of file management options appears. This menu provides single-keystroke options for editing, printing, saving, and scrolling. Many of the data files are structured so that a row of data corresponds to each analysis zone, and each row often has five or more entries. A convenient feature of QRS is the option to edit these files one entry at a time or a whole row at a time. Users may proceed more efficiently than if the option were not available.

A criticism of the QRS format relates to recall of previously saved files. The only ways that users can view a listing of files stored on the data disk

are to view them before booting QRS or to exit QRS and reenter the operating system. If users are unfortunate enough to forget the name of a file needed in the middle of a program run, the only way they can view the necessary file directory is to reboot the disk. This is annoying because booting with the UCSD p-system is incredibly slow. However, worse than losing time is the fact that any portions of the module already executed will be lost; booting requires that the whole process begin anew.

In general, QRS fulfills its promise to be user friendly. The only fault the authors find in this regard is the lack of a more convenient way to view file directories. In addition, although most of the QRS menus include HELP as an option, very few of the HELP message files can be found. Most requests for help remain unanswered.

#### Ease of Data Entry

In one sense, users will find data entry easy. At most points in the program where data must be supplied a menu directs users to create a new file or to recall a previously saved file. Usually, on-screen instructions are worded so that users will have no doubt about how to enter the required data. For example, within the mode-choice part of the program users will be required to create a file of OD data. QRS prompts will be the following:

- Enter zone number (enter 999 to exit),
- Input values for zone separated by spaces.

In cases where on-screen prompts are not clear, the user's manual (7) usually provides the necessary information. However, there are exceptions worth noting. First, in the mode-choice model, destination parking cost must be provided. The user should know from NCHRP Report 187 that one-half a trip's parking cost should be charged to each half of the trip. The user probably will not know, because neither the on-screen prompt nor the documentation explains, that the data will be divided by 2 when impedance is calculated.

Second, and also within the mode-choice module, a file on X-Y zonal centroid coordinates must be supplied. The documentation and the prompts do not point out that these coordinate measurements must be in miles, not inches. Users will be tempted to reuse the file of coordinates created for the trip distribution module, but that file is in inches and should not be used in mode choice (unless the base map's scale was 1 in. = 1 mi).

Third, within the trip distribution module, the user must supply intrazonal travel times. The on-screen prompt leads users to believe that these times must be directly entered each time the gravity model is run. If a file of travel times was created and saved during the first gravity model run, the intrazonal times were saved as a part of the same file. On subsequent gravity runs when users are asked to input intrazonal travel times, they should elect option 2 (direct input). QRS will retrieve and display the intrazonal times from the previously saved file.

Fourth, the user is never told that circuitry supplied as a transit parameter within mode choice will also be applied to the X-Y zonal coordinates for calculation of automobile travel times. This means that alteration of transit circuitry cannot be used as a means of testing improved transit service.

Most of the required data files may be saved and recalled as needed for iterative applications of QRS. This is essential because calibration of the models will no doubt require several, if not many,

trials, especially with the gravity model and the mode-choice model. It is extremely unfortunate that certain data files must be directly input for each iteration.

A minor example is the trip generation module, in which users must always enter the attraction equations, because QRS reverts to the default values when users exit the program. This does not constitute a significant problem, but users should be careful to keep records of the equations.

A more serious example is the mode-choice module, in which users must input for every interchange in the region five transit parameters: speed, circuitry, headway, transfer time, and fare. If users are working with a region that has uniform transit coverage and performance, they may enter these parameters once and they will be held constant for all interchanges. However, most likely a truer representation of the transit system will be achieved only if some of these parameters are varied for some of the interchanges. The designers of QRS realized that this would be the case and built in an option that allows the user to intervene in impedance calculations for any or all interchanges.

To intervene, users must first enter a list of all OD pairs requiring intervention. If users are working with a sizable number of zones, the list of interchanges requiring intervention may be long. The problem is that users cannot save this list; it must be entered every time. Furthermore, not only must users enter it for every iteration of the model, but for every trip purpose (HBW, HBO, and NHB trip tables are analyzed separately for mode choice).

After users supply this list of interchanges, QRS will calculate impedances for each interchange. QRS progresses in typical OD matrix order, beginning with 1-1, 1-2, 1-3, ..., 1-n and ending with ...n-n-1, n-n. Whenever QRS comes to one of the interchanges requiring intervention, it pauses and prompts users to enter the five transit parameters. These data also cannot be stored; users must enter them directly for each trip purpose and for each iteration.

The inability to save these data represents a serious flaw because mode-choice calibration will no doubt require several iterations, and the time required to directly enter the list of interchanges and transit parameters can be extensive. For the Spokane LRT forecast, 41 zones were accessible to transit, creating 1,681 interchanges (41 x 41). Of these 1,681, intervention was necessary for several hundred. A single run of the mode-choice model took 4 1/2 hr at the terminal (1 1/2 hr for each of three trip purposes).

In summary, QRS provides ease of data entry in most cases. The exceptions to the rule are not numerous, but they are significant.

#### Speed and Responsiveness

The QRS documentation states, "The basic approach to quick response does not rely on coded transportation networks . . . . Considerable time is saved by not coding networks" (7). QRS does not use coded networks because NCHRP Report 187 did not use them and the QRS designers merely programmed the manual techniques. This means that users will not necessarily save "considerable time." Assembling the necessary data for impedance and travel time calculation is an onerous burden requiring that each interchange be examined individually so that the parameters may be identified.

A fair estimation of the time required to make a forecast with QRS under normal circumstances is difficult. The authors' best estimate is that a person already familiar with QRS and general forecasting

procedures and with ready access to the required data could accomplish a regional or corridor analysis in 4 to 6 weeks.

An evaluation of QRS responsiveness is related to the other criteria: user friendliness, ease of data entry, and speed. QRS is responsive to users' needs if it rapidly evaluates alternative scenarios, and indeed once the QRS models are calibrated, they fairly rapidly examine forecast results on the basis of varying data. For instance, transit assignment resulting from a fare decrease could be calculated in just a few hours. However, more complex scenarios, perhaps involving major alterations in transit network structures, would require more time; determining impedance parameters would take several person days.

#### Appropriateness

Given the burden of continued entry and reentry of data and the nature of models that may rely on default values, the authors believe that QRS is most appropriate for local traffic studies. For example, a regional shopping center traffic study or major residential development could easily be handled with QRS. However, for regional or corridor studies with greater than 25 zones, a network-based system would be preferred.

The mode-choice model has no way to add a transit penalty separate from other parameters such as access time. This capability is needed for the calibration process. At last report, FHWA was developing a new mode-choice model, and until it is available the current one should not be used for transit patronage estimation because it is so difficult to calibrate.

#### SUMMARY

In general, the QRS designers have succeeded in producing software that computerizes the techniques presented in NCHRP Report 187. The program's most serious deficiencies involve its inability to save extensive files of data, so that a great deal of time is required to enter them. These deficiencies could be easily remedied, and it would also be easy to add a protocol to total trips in the mode-choice output matrices. Other elements of QRS that are perhaps undesirable concern the lengthy process of establishing parameters for transit impedance and travel time calculation. These elements cannot properly be considered flaws exclusive to QRS; they were inherited from the NCHRP Report 187.

QRS, in its present form, is a tool that can be useful for rapid calculation of zonal productions and attractions. If users already have access to appropriate travel times, as would be the case in any regional planning conference, the gravity model could also be quickly applied. However, the authors believe that the mode-choice model, in its present form, is not a particularly useful tool. It is cumbersome and may require that input be less than ideally logical. Personnel at the Transportation Systems Center are reportedly planning to incorporate a different mode-choice model in the future.

In summary, the authors established four criteria with which to judge application of QRS. The results of this evaluation are as follows:

1. Is QRS user friendly? Yes. With few exceptions, users will have no trouble understanding and applying the software.
2. Does QRS incorporate ease of data entry? Sometimes. Users are generally well-informed about

the actual procedures to follow during data entry, but the fact that some lengthy files cannot be saved and reused is a significant failing.

3. Is QRS quick? Yes and no. The authors believe that users could complete a regionwide forecast in 20 to 30 person days, given readily available data and prior knowledge of QRS. Hence, QRS is faster than a mainframe UTPS-type forecast. On the other hand, estimating some of the QRS input parameters requires days of person effort, and trip matrices must be manually summed. In general, QRS is quick, but not as quick as it should be.

4. Is QRS responsive? Sometimes. A calibrated QRS can respond quickly (in hours) to some program or policy data changes. Examination of other alternatives might require days or weeks of effort.

Potential users of QRS should be familiar with the techniques presented in NCHRP Report 187 before deciding to use QRS for a travel demand forecast. The short-cut methods contained therein--and in QRS--are not applicable to all situations.

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