Comprehensive Approach to In-Vehicle Route Guidance Using Q-Route

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The Q-Route route guidance concept was developed with the objective of providing drivers with comprehensive and traffic-responsive route guidance to address-specific network destinations within a large urban area. The traffic-responsive aspect of Q-Route is implemented using a macro level routing, which can consider historic and/or real-time traffic volume and capacity estimates on all roads in the control area. In the autonomous mode, macro routings, which reflect recurring congestion, are implemented on a time-of-day basis. However, a communication link is required to have real-time routings that respond to nonrecurring congestion. The driver is delivered to address-specific network destinations using a micro level routing, which considers only the local streets within the immediate vicinity of the driver's final destination and is invoked automatically once the driver's destination zone is reached. The combined macro/micro routing procedure is transparent to the user/driver. The prime objective of this paper is to describe the Q-Route route guidance concept and to indicate how the system can be integrated with traffic control models to provide consistent routing information through several compatible driver information subsystems. In addition, the paper illustrates the prototype implementation of the in-vehicle subsystem of the Q-Route prototype, which was tested in Kingston, Ontario, Canada.

For the design of Q-Route, it was considered that drivers within most urban traffic networks belong to one of three subsets of drivers, each of which could benefit significantly from improved route guidance (*1*).

The first group consists of those drivers who are unfamiliar with the city's road network structure and are unaware of either the exact location of their destination or the optimum route toward that destination. Second, there are drivers who have a general awareness of the road network structure, as indicated on a standard city map, but who are unfamiliar with the relative amounts of traffic congestion on alternative routes at various times of the day. Finally, there are drivers who are familiar with both the network structure and recurring traffic congestion patterns, but who are unaware of any nonrecurring traffic congestion that is unique to that particular time or day.

The ultimate objective of Q-Route is simultaneously to provide improved routing information that can satisfy the needs of drivers belonging to any of the aforementioned subgroups. Such a system would reduce excess travel distance/time, decrease the extent of recurring congestion, and minimize the impact of nonrecurring traffic congestion. Consequently, the emphasis of the Q-Route system is on determining the optimum traffic routings within a traffic network and on effectively communicating this routing information to the drivers. This focus is distinctly different from that of similar systems that attempt to establish/trace accurately a vehicle's location and only passively display the amount of traffic congestion on various links throughout the network. Within this paper, the former Q-Route activity is referred to as routing, and the latter is referred to as navigation. It is the opinion of the authors that although navigation may prevent drivers from getting lost, only routing can achieve the aforementioned travel distance and time savings.

Whereas some of the attributes of Q-Route are similar to those of ALI-SCOUT (*2*), AUTOGUIDE (*3*), and CACS (*4*), as all of these systems are ultimately attempting to provide a similar type of service to the driver, the Q-Route concept is seen to be unique for three main reasons. First, Q-Route is intended to disseminate routing information that can be generated using a variety of different traffic control and simulation models. Second, the in-vehicle component of Q-Route is intended to be functional in either an autonomous mode—using historical traffic flow patterns—or in a nonautonomous, quasi-real-time mode—using real-time traffic flow data that are periodically downloaded to the in-vehicle unit to update the default historical routings.

Finally, the Q-Route concept is intended to be comprehensive in that it can immediately provide networkwide routing coverage in an urban area and can provide consistent routing information using either its In-Vehicle, Changeable Message Sign (CMS) or Pre-Trip Planner subsystem. Because overviews of Q-Route's CMS and Pre-Trip Planner subsystems were presented earlier, however, this paper focuses in detail on primarily the core structure of Q-Route's in-vehicle aspect.

Q-ROUTE: A COMPREHENSIVE DRIVER INFORMATION SYSTEM

The Q-Route Driver Information System was first described by Van Aerde and Blum (*5*) as a single system that could address the route guidance needs of an urban area. This is accomplished through the joint control of three compatible subsystems:

1. Pre-Trip Route Planners,
2. Changeable Message Signs, and
3. On-Board Route Guidance Systems.

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These three subsystems are all designed to be simple variations of the same basic Driver Information System, as shown in Figure 1. This is true both conceptually and physically, as consistent route guidance information needs to be assembled and disseminated, and as the same algorithms, hardware, routing vectors, and data base structures can be relied upon.

Routing Vector Concept

The entire Q-Route route guidance concept is developed around the use and sharing of a central set of route guidance vectors (*5,6*) by all routing subsystems. These vectors are also standardized with respect to the central traffic control models, which are used to generate the traffic-responsive routings. As illustrated in Figure 2, the routing vectors indicate the shortest or quickest route from any point in the network (origin node) to any specific network destination (destination node). Specifically, the vectors indicate, for any network node, the next street to follow to get closer to one's destination. At the end of this street, one can iteratively reuse the vector to proceed incrementally toward the desired ultimate destination.

The routing vectors are stored for use in Q-Route in a standard tabular format, which allows the use of a variety of different procedures to generate these vectors and allows each of the three Q-Route subsystems to derive its "optimum" routings using these same routing vectors. For example, as illustrated in Figure 3 (for the sample network in Figure 2a), the Pre-Trip Planner can trace all the links along the intended path and can list both the turning movements and the distances to them. Similarly, the in-vehicle unit can display "bird's eye view" maps of each intersection en route and indicate the optimum turning movement as indicated by the corresponding routing vector entry. Even the CMS Controller can use them to select the appropriate freeway exit for a given destination. This shared use of a common routing data base is intended to provide more consistent and less expensive routing services within an urban area.

Quality of Routing Services

The quality of the route guidance information depends not only on the quality of the traffic model that determines the actual routing vectors but also on the extent to which this routing vector generator has considered the feedback impact of driver responses to the recommended routings or reroutings. Therefore, Q-Route was designed to be compatible with a variety of different traffic models, including the INTEGRATION (*7–11*) model. This traffic model determines traffic-responsive routings through congested traffic networks in response to any incidents, queuing, and changes in the prevailing network controls. In addition, the model can consider the feedback impact on the city's traffic pattern of different percentages of drivers who use in-vehicle route guidance units.

Prototype Testing in Kingston

A typical Q-Route application involves the sequential or concurrent execution of the routing vector generator and a Q-Route routing information dissemination subsystem.

Fully autonomous route guidance is provided by pregenerating sets of routing vectors off-line and preprogramming these data into the in-vehicle unit. An appropriate set can be selected from this library on a time-of-day or day-of-the-week basis. This type of preprogrammed routing is very similar to fixed-time control of traffic signals, with a similar economy of operation and level of effectiveness.

If a communication link exists, routing vectors can be disseminated on request in real time using approaches parallel to those taken to provide real-time traffic signal control. When the routing vectors are calculated on-line, fully traffic-responsive routing can be implemented. At a lower cost, this same objective can be achieved through a dynamic selection of routings from a library of precalculated routing patterns. In either case, the operation of the Q-Route in-vehicle control logic is virtually identical.

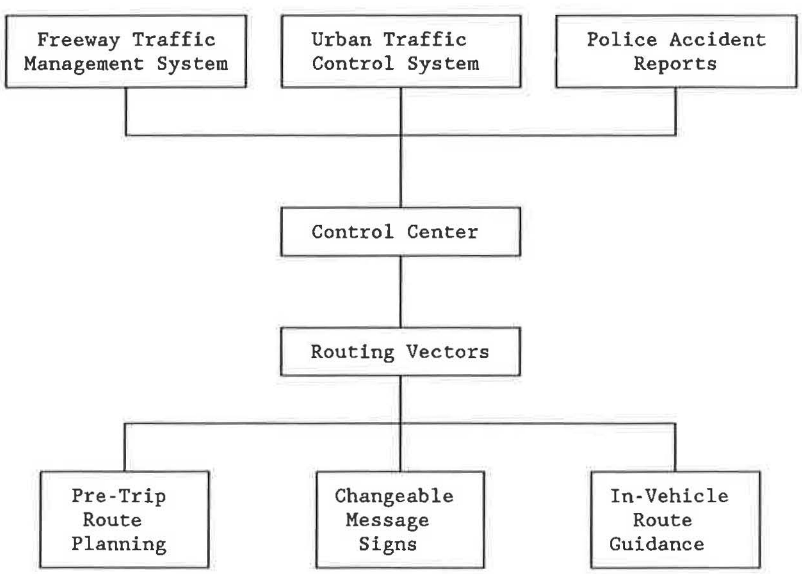
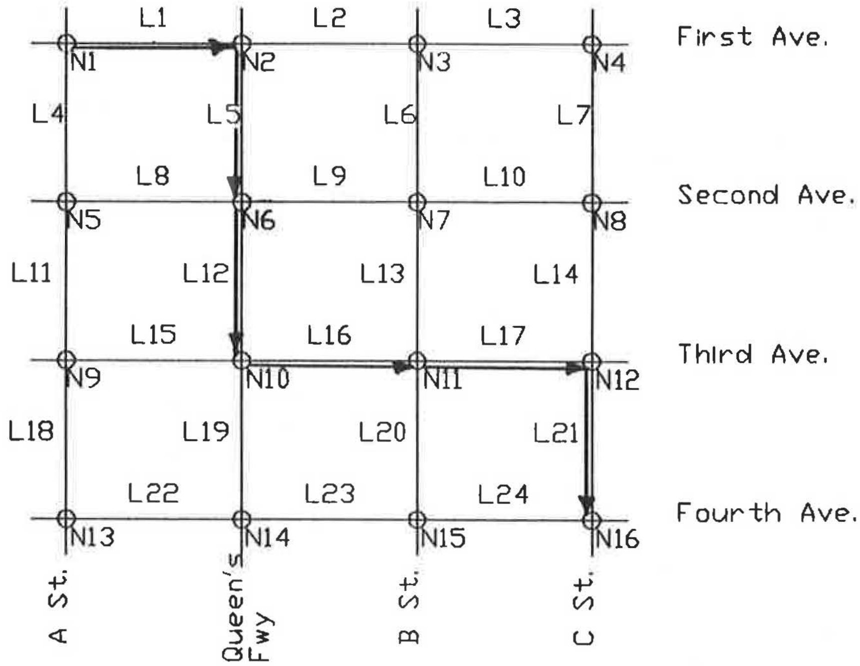


FIGURE 1 Overview of Q-Route route guidance subsystems.

(a)



(b)

Routing Vector Corresponding to Dest. N16

Node From	Number of Next Link	Start/End Node of Next Link
N1	L1	N1 -> N2
N2	L5	N2 -> N6
N3	Lx	
N4	Lx	
N5	Lx	
N6	L12	N6 -> N10
N7	Lx	
N8	Lx	
N9	Lx	
N10	L16	N10 -> N11
N11	L17	N11 -> N12
N12	L21	N12 -> N16
N13	Lx	
N14	Lx	
N15	Lx	
N16	0	Destination

Lx - other link number, not relevant to this route.

FIGURE 2 Minimum path route of hypothetical network: a, sample; b, routing vector representation.

(a)

<u>Queen's Route Planner</u>

Current Location: A St. /First Ave. (N1)

Destination: C St. /Fourth Ave. (N16)

Take First Ave. (L1)
at 1000 meters Turn RIGHT onto Queen's Fwy (L5)

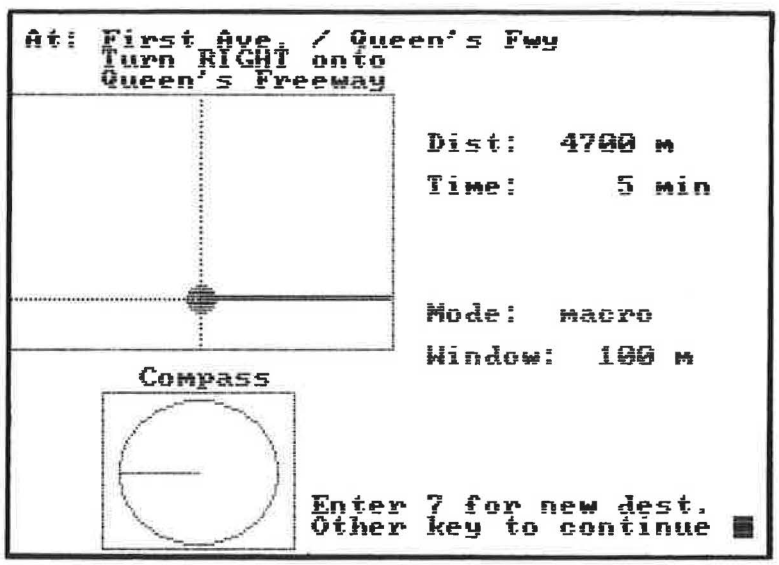
Queen's Fwy
at 1900 meters Go STRAIGHT through Queen's Fwy /Second Ave. (N6)
at 2800 meters Turn LEFT onto Third Ave. (L16)

Third Ave.
at 3800 meters Go STRAIGHT through B St. /Third Ave. (N11)
at 4800 meters Turn RIGHT onto C St. (L21)

drive another 900 meters to your destination.

Total Trip Length: 5700 meters.
Estimated Time: 5.9 min.

(b)



(c)

<u>CMS Located at Node N6:</u>

Dest. N16: USE EXIT N10

FIGURE 3 Q-Route use of routing vectors: a, Pre-Trip Planner Subsystem; b, In-Vehicle Subsystem; c, CMS Subsystem.

During the 1988 Q-Route prototype testing in Kingston, the autonomous mode was evaluated most extensively. The use of a communication link, based on a cellular car telephone, was also tested. The configuration of the Q-Route prototype during this testing is illustrated in Figures 4a and 4b, which show the linkages to the computer voice routines (TEXT TALKER) and the trip origin-destination selection menu (NODEID), as well as to the main data inputs.

MACRO/MICRO ROUTING CONCEPT

The data management problems associated with providing the "best" traffic-responsive routing within large metropolitan areas are addressed in Q-Route by selecting a driver's trip path based on a sequential macro/micro routing process.

Combined Macro/Micro Routing

The macro routing considers only major freeways, arteries, and collectors and provides the driver with a traffic-responsive routing to the edge of the zone of the intended destination. Usually, only the freeways and major streets are considered, as interzonal trip makers should be discouraged from traveling along local streets. In addition, these macro network links are likely the only ones to be sufficiently detectorized to support traffic-responsive routing. Furthermore, by limiting the initial macro destination choices and restricting the routing choice set to only those links that represent major streets, the macro routing calculation is significantly simplified.

Prototype Testing in Kingston

Figure 5a illustrates the macro network that was used during the Kingston route guidance experiment, whereas Figure 5b illustrates the micro network that was employed to provide a sample micro routing within Macro Zone 39, which contains the Queen's University campus. During the tests, micro routings to various macro destination zones within the downtown area were also tested. Typically, each of the micro networks contained approximately the same number of links/nodes as the initial macro network for the entire study area.

Once Q-Route detects that the driver has reached the periphery of the macro destination zone, a second micro routing is automatically invoked. It guides the driver from the zone's periphery to the final micro destination by finding the quickest path from the macro/micro transition node to a specific landmark. The micro routing is necessary because the macro network usually contains neither the local destination street nor the local streets that lead to the final micro destination. A lack of guidance to the exact destination would limit the system's potential usefulness to drivers who are unfamiliar with the ultimate trip destination.

As the local street links contained within the micro network are usually not detectorized, the final micro routing is usually performed using preprogrammed link speeds and link lengths. Only when the final micro network is for a congested downtown area would the routing vectors be generated on the basis of a more detailed local analysis.

Switching Between Modes

Within the current version of the Q-Route system, the routing starts with the macro mode and switches automatically to the micro mode if a micro network is available. The actual macro/micro switch is performed at one of many possible destination-specific transition nodes, which indicate to the macro routing system that the micro routing network has been reached and that the micro routing can take over. As there are a number of different transition nodes designated along each macro zone boundary, the transition can take place at a number of different locations, depending upon which direction the driver arrives from. In any case, the macro-to-micro transition is transparent to the user.

Super Macro Mode

It is anticipated that a super macro mode will later be added that will contain all the major roads within a province or state. In this fashion, a super macro routing would first guide the driver to the metropolitan area of interest. Subsequently, the normal macro mode would guide the driver from the boundary of the metropolitan area to the neighborhood of interest, before the micro routing would guide the driver to the ultimate street address within the desired neighborhood.

Advantages of Mixed Macro/Micro Routing

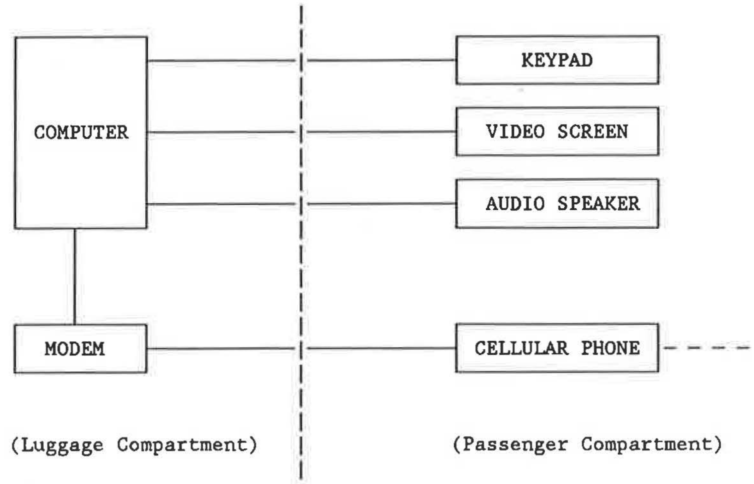
The main advantage of the mixed routing approach arises from the fact that a data base containing all macro network links within a city remains relatively small. A concurrent, rather than sequential, analysis of both the macro and micro networks would likely cause several problems in terms of memory space requirements and execution time for both the on-board unit and the central routing control facility. The macro/micro network partitioning also allows the system operator to provide only macro routing coverage at the outset, whereas micro networks for critical destination zones can be added as resources permit. Alternatively, even the ultimate configuration may provide strictly macro level coverage in the suburbs and may concentrate the micro routing services in the downtown areas.

The use of a macro network en route avoids the cumbersome reference to local street details during cross-city trips on main freeways or arteries. The reduced information load along the route will allow the drivers to concentrate better on the display when they reach their destination zone and the micro routing is invoked.

GENERATION OF ROUTING VECTORS

In contrast to the micro routing, which is usually derived from strictly static travel time estimates, the macro routing vectors can be made traffic-responsive if an appropriate data input source is available. Of course, if the more sophisticated, real-time, traffic-responsive data are not available, or if the vehicle is not equipped with a communication link, the macro routing mode can always default to the use of static routings. The traffic-responsive potential of Q-Route's macro routing derives from its compatibility in structure and concept with different

(a)



COMPUTER - IBM compatible Personal Computer, 640 Kbytes memory

KEYPAD - 6.5 X 5 inch, 23 keys

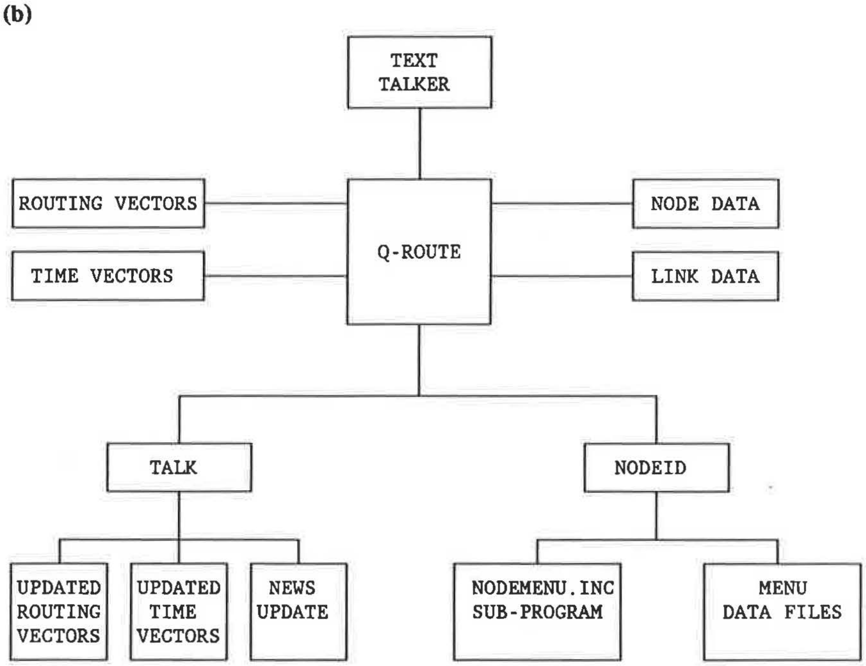
VIDEO SCREEN - 8 inch monochrome graphics screen, 23 rows X 40 col.

AUDIO SPEAKER - with volume control

CELLULAR PHONE - standard portable cellular phone

MODEM - 1200 baud

(b)



Q-ROUTE - Route Guidance Program

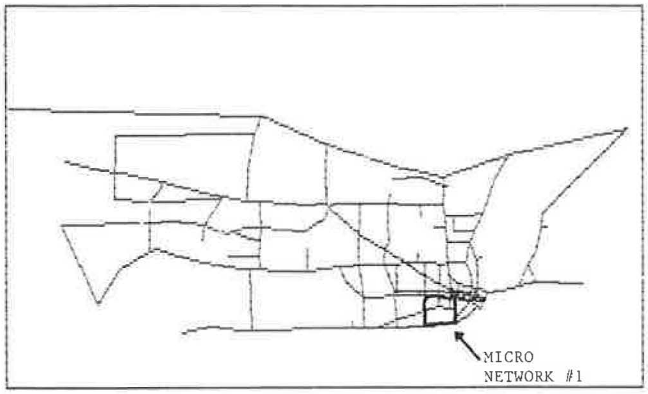
TEXT TALKER - Synthetic Speech Software

TALK - Communications Software (used with cellular phone + modem)

NODEID - Menu Program (for easy selection of origin/destination)

FIGURE 4 Q-Route prototype during field tests in Kingston: a, hardware; b, software.

(a)



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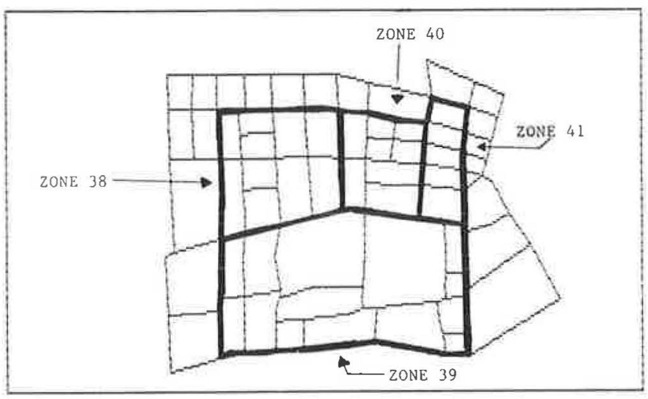

FIGURE 5 Typical network representations: a, greater Kingston area; b, Micro Network # 1.

types of related traffic models. This compatibility includes common link and node files that describe the network topography and common routing vectors that are the key to the exchange of traffic-responsive routing information, as described next.

Generation of Routing Vectors Using an Off-Line Model

The simplest way of generating Q-Route's macro routing vectors involves the use of an off-line transportation planning model or a freeway corridor control model. Relatively large networks can be handled in this fashion, and often such networks have already been coded for other traffic studies of the same area. In addition, these models can easily be used off-line to pretest different routing scenarios, and routing vectors for different traffic flow scenarios can be simulated using different origin-destination (O-D) demands for different times of the day. In each case, the routings can be pregenerated, checked, and stored in the form of a library, using either disks, tapes, or EPROMS, from which they can be selected on a time-of-day or day-of-the-week basis. This approach can deal only with recurring or predictable congestion, however.

Hybrid traffic operations/transportation planning models, such as CONTRAM (*12*), SATURN (*13*), or INTEGRATION (*7–11*), may be of assistance in preparing these off-line routings, as they provide a traffic assignment capability in a traffic management context that reflects local congestion, queuing, and signal timings. They may be used in conjunction with either a part of the macro network or for an entire micro network that includes a troublesome traffic generator.

Generation of Routing Vectors Using On-Line Data

The ideal operation of the Q-Route system would provide routings that respond to nonrecurring as well as recurring congestion in real time. The initial step toward traffic-responsive route guidance would involve the use of on-line traffic flow measurements and incident data to compute the optimum routings through the network in real time. At this time, the main obstacle to this type of on-line generation of routing data is the difficulty of pooling the traffic data for an entire urban area from the numerous traffic authorities that may be responsible for different parts of the traffic network.

The ultimate objective of an on-line Route Guidance System would involve the use of real-time O-D counts, rather than simple real-time link counts (*10,11*). These data, in conjunction with an on-line control model, could predetermine the expected diversion impact for a given rerouting instruction and establish whether the impact of the re-routing could be accommodated by the system. Not only could these vectors be purely reactive in the sense that they respond to existing traffic problems, but they could also become preemptive by responding to expected traffic problems before they actually occur (*1*).

Prototype Testing in Kingston

The initial Q-Route prototype was tested using preprogrammed routing vectors that were based on a transportation planning type of analysis of peak and off-peak traffic conditions during a typical day. These routings were then selected in the autonomous mode based on the time of day. All routings for a given O-D were all or nothing, on the basis of travel times and a traffic assignment for a network that was already in equilibrium. Because the number of routing participants initially is relatively small, these all-or-nothing routings are not likely to disturb the existing equilibrium assignment.

As no computerized traffic control center is now in operation in Kingston, it was impossible to test properly the on-line capabilities of Q-Route. The general capability, however, was tested by uploading to the mainframe a series of different routing vectors, which were downloaded to the in-vehicle unit through the cellular car phone and a modem. This allowed the testing of both the communication software and the automated data-manipulation procedures. It was found that even when no on-line traffic source is available, the communication link may advise drivers of road conditions and reroute them around construction. Although a separate cellular phone number may need to be set up for approximately every 100 participants in the traffic-responsive mode, this cost should be compared with that of installing beacons throughout an entire urban area.

ROUTING INFORMATION DISSEMINATION

Q-Route's initial field testing identified a number of issues related to the dissemination of real-time route guidance data.

On the basis of an analysis of these issues, the two main types of communication hierarchies, which are illustrated in Figures 6a or 6b, appeared to provide feasible implementation approaches.

Alternative Communication Hierarchies

Figure 6a shows the first hierarchy in which the Q-Route central control facility could process the traffic and routing information and produce the macro routing vectors for each macro destination. In addition, any descriptive messages regarding significant traffic incidents within the system would be generated. These vectors would then be downloaded to the roadside units at each major intersection at prespecified time intervals. Any vehicle that then passes the roadside unit would be provided with the routing vector for the driver's specific destination on request. As the roadside unit could also communicate its location ID, this roadside-to-vehicle link would therefore also support a form of vehicle navigation.

Within the second Q-Route hierarchy, which is shown in Figure 6b, a central control facility could communicate directly with the in-vehicle units through a cellular telephone or another type of radio communication. With this type of communication system, new routings and descriptive messages could be downloaded to the vehicle, but the unit would need to identify its current network location without any external assistance. This is not a problem if the driver follows the recommended route but may cause problems if an incorrect turning movement is made. In this case, navigation techniques, such as dead reckoning plus a ground- or satellite-based radio frequency method, may be required to reestablish the vehicle's

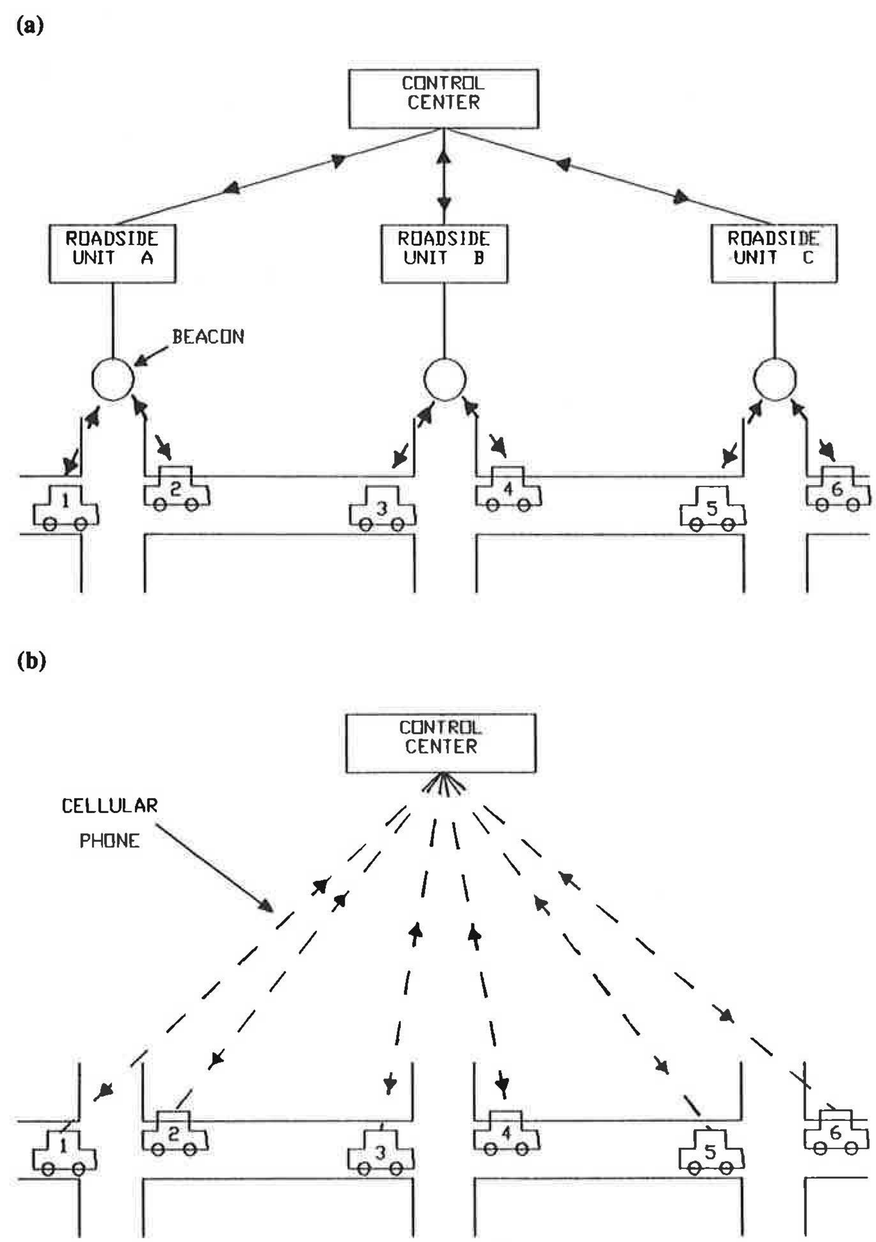

FIGURE 6 Communication hierarchies: a, Version I; b, Version II.

network position so that Q-Route can provide a new routing from the new network location onward.

Communication Links

For the system configuration in Figure 6a, two major communication links must be present. The first link primarily supports the downloading of the routing vectors from the control center to each roadside unit. Reverse communications from the roadside unit to the central computer would allow the roadside unit to send statistics on the number of user queries back to the control center. These statistics on the number and types of destinations queried by the users could provide a real-time update of the prevailing O-D patterns. This communication would likely share existing traffic control communication links to each intersection.

The second link is a two-way communication link between the roadside unit and the in-vehicle computer. It allows the driver to request and receive the routing vector for his or her specific destination and to perform emergency calls and incident reports. In addition, the roadside unit's ID allows the vehicle to reestablish its network location if the driver has not followed the recommended route. Q-Route could be implemented using either infrared beacons or inductive loops to support this two-way exchange of data.

DISTRIBUTION OF DATA AND INTELLIGENCE

The type and extent of communications that need to be provided within a Route Guidance System are intimately related to the distribution of data and intelligence within the system and to the level of routing sophistication that is desired. For a given level of sophistication, increased communications can often be substituted for decreased intelligence, and vice versa, as shown next.

Extremes in Data/Intelligence Distribution

On one extreme, the central computer could only download updates of link travel times and therefore required the on-board unit to compute the new routings on its own. This would demand considerable on-board computational power and require that the on-board unit store internally the entire network data base. The amount of data to be transmitted to the drivers would be proportional to the number of links in the network, however, and this data stream would be common to all drivers, regardless of their origin or destination. Consequently, a general citywide broadcast system would be sufficient, and no communication link from the driver to the central computer would be required.

On the other hand, the central computer could perform all computations and only forward information about the next turning movement to the on-board unit for display. The reduction in computations and data storage would allow for a less expensive on-board unit. This would require more extensive deployment of roadside hardware, however, as dedicated communication services would need to be provided at each intersection. In addition, two-way communications would be required for the roadside unit to send the appropriate routing instructions.

Prototype Testing in Kingston

Q-Route experiments to date have compromised by computing routings centrally and by storing the network data base on-board. At the start of the trip, the user can either retrieve a routing from the on-board library or request a new vector for the destination through the cellular phone link. In the latter case, the routing vector for the intended destination is downloaded by phone to the on-board unit, and both systems operate identically from this point on.

During long trips, the routing vector can be updated by request, so that the best new route from the vehicle's current location onward will be selected. Any diversion options that have already been passed, however, will obviously no longer be considered. This flexibility in downloading frequency allows one to trade off the communication costs involved in each update against the expected benefits.

DESIGN OF USER INTERFACE

Critical to the success of any Route Guidance System are the details of the final user interface design. This section provides the types of user interface formats that have been considered for use with Q-Route, and discusses the consequent trade-offs involved.

Alternative Modes for Presenting the Routing Data

In the ideal Q-Route system configuration, the user would have a color graphics screen display available for presenting the routing information. This represents the user interface that has been used in laboratory experiments to date; virtually all other types of interface are subsets of this ideal.

At the start of the trip, Q-Route provides the driver with a plot of the entire network, with the recommended route highlighted in a different color. This allows verification of the trip's origin and destination and provides a general indication of the intended routing for the trip. Upon the start of the trip, a sequence of timed intersection map snapshots and turning movement instructions are shown for each major intersection along the route. Each such snapshot screen includes

1. A graphics representation of the turns at each intersection,
2. A supporting verbal description of the recommended turn movement,
3. A positive identification of the name of the intersection,
4. The name of the street or road to be taken or followed,
5. The remaining distance to the ultimate destination,
6. The estimated time to the ultimate destination, and
7. Warning messages dealing with incidents or weather conditions.

In more economical system configurations, the in-vehicle units consist only of simple LED/LCD character displays of the required turning movement messages at each intersection. Alternatively, a directional turning movement indicator can replace the turning messages and can be used in conjunction with another message that identifies the intersection. Each of these alternatives requires a lower cost to the in-vehicle unit but also only provides a more limited route guidance message.

Prototype Testing in Kingston

During the Q-Route in-vehicle field tests in Kingston, a monochrome composite video monitor in 40-column mode was used to display graphics and text simultaneously. In addition, a synthetic voice was included to provide an audio equivalent of the messages provided on the screen. This option was found useful during heavy traffic conditions, but problems remained in terms of the quality of the computer voice and its ability to pronounce irregular street names. Before commencing the trip, the aforementioned video screen and computer voice were also used to provide the driver with a series of hierarchical menus to assist in the selection of his trip destination. This menu program could be accessed by street name or number, by street intersection, by city landmark, or through a directory of services, such as hotels, restaurants, banks, shops, and tourist attractions.

Selecting the Appropriate Display Medium

Even for the ultimate user interface, which included a color graphics screen, finding the right balance between sufficient and excessive information proves to be no simple task. On one hand, there is a tendency to provide the driver with all the information that is known to the central system and that could be of possible interest to the most sophisticated user. On the other hand, however, this ideal amount of information for the sophisticated driver also turns out to be too much information for the less sophisticated driver. Such a driver either becomes lost in the wealth of information provided or becomes distracted enough to present a safety hazard to others as well as to himself.

The cost of the display is intimately related to its resolution and quality. Experiments to date have shown that multicolor displays are clearly the most attractive and interesting but that, in routine application of the unit, those benefits may not warrant their extra cost. Even for a given display hardware configuration, considerable flexibility remains in the actual format of the display. Consequently, three types of display formats are undergoing user testing. All of these directional displays conspicuously indicate to the user the recommended turning movement at each intersection.

Alternative Screen Messages

The simplest version of the display is illustrated in Figure 7a and consists of a directional arrow on the screen. This is a very simple display as it illuminates one out of eight arrows, which indicates the recommended turning movement to within a 22.5-degree angle. This display can also be implemented without a video screen, but then additional hardware is needed for the accompanying messages to be displayed.

Improved routing information is provided using an intersection display that provides an abstract bird's eye view of all the streets that meet at the current intersection, as illustrated in Figure 7b. In this case, the turning movement direction is superimposed on the shape of the intersection, which provides the driver with the relative angle of the recommended road relative to the other roads at the intersection. This mode requires either a low- or medium-resolution graphics display, and it was used most extensively during the Kingston experiments.

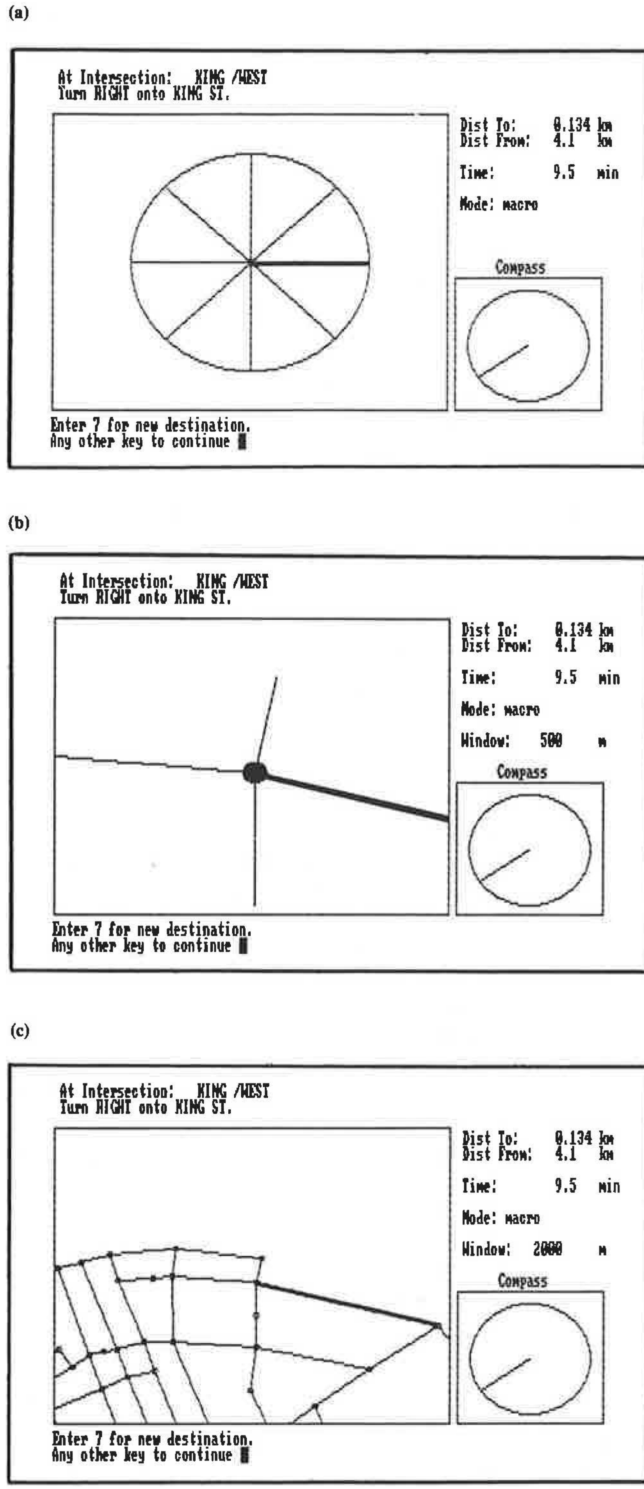

FIGURE 7 Alternative user interface display formats: a, arrow display; b, intersection display; c, graphics display.

The highest-quality message is produced using a full graphics display, as shown in Figure 7c. In this case, the driver is presented with a localized electronic map that is centered at the next intersection and is rotated to show the crossing roads and any nearby streets in the same orientation as they are seen from the car. A zoom capability has been added to provide both small- and large-scale views of the area on the graphics screen. The computations involved in this display are much more complex than in either of the preceding displays and, while useful in the lab, this display was found impractical in the vehicle.

Drivers interact with the aforementioned display using a simple keypad. The arrow keys are used during the O-D selection process, and the function keys can retrieve special weather and news information.

SUMMARY AND CONCLUSIONS

This paper discusses the development and prototype testing in Kingston of the Q-Route route guidance approach to collecting, processing, distributing, and presenting traffic-responsive route guidance information.

At this stage, the routing vectors provide all-or-nothing assignments to the Q-Route users, and it is assumed that their routings do not influence the network's traffic assignment equilibrium. As a larger fraction of the drivers become Q-Route users, however, it will be necessary to provide multipath routings that explicitly take into account the impact of the Q-Route routing vectors on network equilibrium. Ultimately, the routing vectors may be generated in such a fashion as to permit preemptive routing strategies, which prevent anticipated traffic congestion rather than strictly respond or react to traffic congestion that has already materialized.

The combined macro/micro routing concept permits fully traffic-responsive route guidance within large urban areas using a macro network of all freeways and major arteries and collectors. Ultimately, a super macro network may be available for the entire province, state, or country, which automatically switches to the available macro and micro networks for each city as the vehicle is detected on the periphery of the latter networks.

Critical to the successful implementation of a driver information system such as Q-Route is the availability of comprehensive traffic data for all parts of an urban area, regardless of who has legal jurisdiction in each subnetwork. In addition to the administrative obstacles, the technical aspects of such data integration in an off-line or on-line mode may impose some other difficulties. These technical and administrative difficulties are by no means unique to Q-Route.

In addition, standards need to be established for the development of route guidance data bases, communication protocols, and hardware and software. Without such standards, it appears unlikely that drivers would purchase systems that they could not use in other cities, towns, or states/provinces within the same country. As in any emerging technology, however, standards may negatively affect the application of new technology as it becomes available and may result in standardization based on an obsolete technology.

Q-Route's current prototype implementation only assists in selecting the most efficient route from a known location to either a known or unknown destination, and it assumes that drivers follow this route at all times. Before a more comprehensive experiment can take place, an affiliated navigation system may need to be incorporated to deal with drivers who fail to follow the recommended route and get lost. At this time, the system is capable of providing new routings when a driver gets lost, but it is unable to establish on its own that the driver has drifted from the recommended path.

At present, current route guidance research is concentrated on more extensive field testing of Q-Route in the Greater Toronto Area, on the evaluation of the benefits of route guidance during different types of recurring and nonrecurring traffic congestion, and on the opportunities for providing micro route guidance on freeways with core and collector lanes, such as Highway 401 in Toronto, Ontario (*9–11*).

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