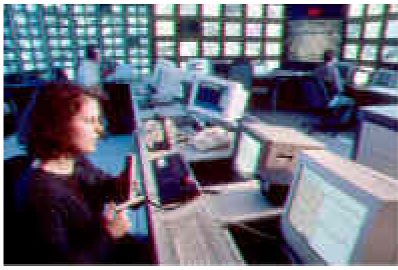
Introduction Page 1



Advanced Traffic and Management Systems (ATMIS) are systems designed to foster real-time sensing, communication, and control of urban networks. One of the primary objectives for ATMIS is reducing congestion effects. Encouraging more optimal routing of vehicles over time and space is a primary goal. ATMIS coordinates detection of recurring and non-recurring congestion and initiate changes in traffic flow through adaptive signal control, incident response management, and provision of traffic advisories and/or route guidance information with dynamic message signs (DMS) and highway advisory radio (HAR). DMS and HAR broadcast traffic advisory information to the general driver population. Their purpose is to inform travelers of congestion in the network. DMS are used to disseminate congestion advisories on a specific part of a roadway or over one section of the network. Alternatively, HAR can provide network-wide traffic advisories. DMS and HAR are limited in their use as traveler information systems. They cannot provide navigational or travel planning guidance. Drivers have little control over when they can acquire this information. While DMS and HAR can manage traffic diversions around localized congestion they cannot be used for network-wide reallocation of trips. Last, credibility and compliance are major issues with DMS and HAR systems. It is well documented that not every traveler pays attention to these broadcasts. Of those who do, many cannot comprehend or internalize the information and many choose not to comply with the advice. Furthermore, if drivers perceive that the information is imperfect information in the past are less likely to believe these systems in the future.

Introduction (cont'd) Page 2

Dynamic traffic assignment systems are suites of models and algorithms that seek to address supply-side network performance objectives by making real-time adjustments to supply-side control devices based on best predictions of traffic flow, over time and space. They collect information and disseminate travel advisories in real-time through VMS and HAR placed strategically around the network.

Dynamic traffic assignment systems | IRANS

Dynamic Route Guidance and In-Vehicle Systems

Introduction (cont'd) Page 2

IRANS provide drivers with information specific to their trip. Their purpose is to aid drivers and seek to satisfy the routing needs and preferences of the individual driver. Linkages with network information providers can supply real-time data to the IRANS and thus enable these devices to offer more "intelligent" navigation and en-route decision-making assistance.

Dynamic traffic assignment systems | IRANS

Terminology Primer Page 3

The next few pages present essential terminology and definitions for this module.

Traveler Information System: A system used to acquire, process, transfer, and present information to travelers for purposes of aiding decision-making.

In-vehicle system: A device designed to be used within the vehicle. Generally refers to systems that are built into the vehicle and not portable.

Roadside Information System: A device located within the roadway network to provide drivers with information.

Terminology Primer (cont'd) Page 4

Format of Information:

- **Prescriptive:** Route guidance systems are prescriptive in that the system provides drivers with directions leading them from their current position to a desired destination. The advantages to using route guidance systems is that drivers do not need to be familiar with the network layout or travel conditions. They can rely on the routing system to provide an efficient path through the network. A potential disadvantage is if the driver does not comply with the information given.

- **Descriptive (normative):** Traffic advisory systems are descriptive in nature, used to inform drivers of prevailing travel conditions. Drivers are required to process the information and to develop their own routing strategies. Drivers with a high degree of network spatial knowledge benefit most from descriptive systems. These drivers are capable of identifying paths through the network. The availability of traffic advisories aids in making better travel decisions.
- **Static Information:** Information that was determined at one point in time and is not updated. For example, most PC-based mapping and routing software use average speed or average travel time to find shortest routes.
- **Dynamic (Real-time) Information:** Information that is frequently updated and provides an accurate snapshot of prevailing conditions in the network. For example, loop detectors provide real-time information on queue lengths and vehicle presence; vehicles used as probes can provide real-time information on current travel speeds and times on a link.
- **Anticipatory or Predictive Information:** Information related to forecasted or estimated network condition.

Terminology Primer (cont'd) Page 5

Terminology Related to Spatial Behavior:

- **Spatial Knowledge:** Knowledge related to spatial networks.
- **Cognitive Map:** Internal mental representation of a spatial system (such as a transportation network). It is developed through experience and acquisition of spatial data.
- **Wayfinding:** A term that encapsulates the process of forming a cognitive map, planning a route, navigation
- **Navigation:** The task of directing a vehicle along a course.

Terminology Primer (cont'd) Page 6

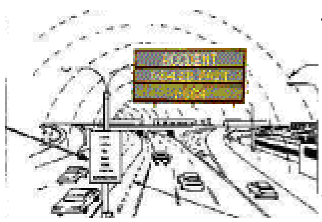
Types of Information:

- **Route Guidance:** Specific information related to the "best route" from an origin to a given destination. May be based on current and/or historical information.
- **Dynamic Route Guidance:** Route guidance based on real-time and/or anticipatory information.
- **Traffic Advisory:** Information regarding network congestion. Drivers are advised of network problems but retain route choice.
- **Yellow Pages:** Refers to information along the lines of a yellow pages directory. That is, information regarding addresses, location, and phone numbers of key businesses and attractions across an urban area.
- **Congestion information** advises drivers of congestion ahead on the current roadway or on other roadways that are in the network in the vicinity of the sign.
- **Diversion information** provides drivers with information on alternate routes

through the network or to bypass a highly congested part of the network

- **Directional Guidance** including directions to parking lots, special event sites
- **General Information** can provide drivers with ways to obtain additional information through other means (e.g., via radio or by phone)
- **Roadway Work Information** to warn drivers of construction and maintenance zones
- **Roadway status information** to warn drivers of wet or icy pavement surface, reduced visibility due to snow or fog.
- **Operational information** that specifies special conditions on the roadway such as HOV lanes or reversible lanes.

Historical View: 1st Generation Systems Page 7



The era of development of traveler information systems can be grouped into two distinct classifications. 1st generation systems, which we refer to as traveler information systems, arose from the emergence of computer technologies and traffic surveillance and control systems in the late 1960's and early 1970's. They represented an initial attempt to use communication technologies for information dissemination. In many cases, these systems were designed to improve flow at localized points in a network, such as a heavily congested freeway-to-freeway interchange, or to make travelers aware of non-recurring congestion, such as special events or incidents. Dynamic message signs (DMS) and highway advisory radio (HAR) are representative 1st generation systems. DMS and HAR are useful technologies for disseminating information to a wide audience. However, they are not well suited for forcing optimal route assignments.

Historical View: 1st Generation Systems (cont'd) Page 8

The leap from 1st generation to 2nd generation information systems represented a significant change in philosophy over what traveler information is and how it is presented. DMS and HAR are one-way communication systems which are used to convey general traveler information to vehicles and the responsibility fell upon the user to sift through the information to determine what, if any, part of the broadcast applies. 2nd generation systems attempt to personalize the provision of travel assistance.

The advances in communication, mapping, and multimedia technologies have led to systems which can provide a specific traveler with routing, wayfinding, or yellow pages assistance. 2nd generation systems eliminate data sifting by reducing the amount of information provided to the traveler and focusing on the specific needs of that user. Characteristic 2nd Generation communication devices include IVRGS, cellular telephone, cable television, information kiosks, and the Internet.

Historical View: 2nd Generation Systems Page 9

We are currently experiencing the growth and maturity of 2nd generation systems, or Advanced Traveler Information Systems (ATIS). Today's ATIS encompass a wide range of new technologies and are being designed to provide travelers with dynamic route guidance, real-time traffic condition information and traveler services information. Metropolitan areas are looking toward regional multimodal traveler information systems to enable the traveling public to make more informed mode and route choices. Second generation systems are capable of more direct broadcast of information to users by incorporating one or more of the following "advanced" technologies and features:

Interactive User Interface: ATIS provide an opportunity for quasi two-way communication as users can request specific information from the system. For example, in-vehicle systems allow drivers to specify a destination and the system can compute a shortest path route for the driver. This interaction between user and machine may be facilitated through multilingual and menu-driven interfaces and multimedia presentation consisting of both visual and auditory exchanges.

Vehicle Location and Intelligent Mapping: Many ATIS integrate highly defined mapping with Global Positioning Systems (GPS) to enable real-time vehicle tracking and navigational mapping. These systems are capable of positioning the vehicle, determining if the vehicle is on or off course, and making appropriate adjustments to routing strategies to help the traveler navigate through the network to the intended destination.

Advanced Path Search Routines: Several routing systems allow users to select from one of several travel objectives used to direct the path search. Typical options include minimizing travel time, minimizing travel distance, and maximizing use of freeways links.

Yellow Pages Directory: Some ATIS come with pre-programmed directories of major attractors, retail stores, restaurants, hotels, and other destinations that drivers might want to locate. These systems can help travelers select a destination in conjunction with routing options. For example, users could query the system to locate the nearest movie theater or to find a certain type of restaurant within a 15 minute travel time radius.

Multimodal Information: Smart information kiosks have begun to incorporate information from both highway and transit systems to provide comprehensive travel planning including mode, departure time, and route choice.

Dynamic Route Guidance (DRG): Dynamic route guidance systems are being designed to provide route recommendations based on actual or predicted traffic conditions based on data gathered from an equipped network.

Dynamic Route Guidance and In-Vehicle Systems

Self-Review Exercise #1 Page 10

Exercise	Answers

Done? Now check your answers by clicking on the appropriate buttons.

Click the buttons to see the answer to the question.

1. Describe how routing is a central element within ATMIS.

Having automobiles select inefficient routes is one of the causes of congestion. A key objective of ATMIS is to promote more efficient route choice over space and time.

Close Window

Dynamic Route Guidance and In-Vehicle Systems

Self-Review Exercise #1 Page 10

Exercise	Answers

Done? Now check your answers by clicking on the appropriate buttons.

Click the buttons to see the answer to the question.

1. Describe how routing is a central element within ATMIS.

2. Define the term "first-generation" information systems. Identify two first- generation information systems and explain their role within ATMIS.

First-generation ATIS represent technologies that transmit information in simplex mode. That is, broadcasts of traveler information provided to the general traveling public. DMS and HAR are the two best examples of first generation traveler information systems.

Close Window

Self-Review Exercise #1 Page 10

Exercise | **Answers**

Done? Now check your answers by clicking on the appropriate buttons.

Click the buttons to see the answer to the question.

1. Describe how routing is a central element within ATMIS.

2. Define the term "first-generation" information systems. Identify two first- generation information systems and explain their role within ATMIS.

3. List three ways in which Traveler Information Systems have advanced in recent years

Here are five examples of recent advances: (1) Regional information/ yellow page directories; (2) integration of information across several modes; (3) more personalized information such as provision via kiosk or in-vehicle; (4) flexibility to use multiple criteria path search; (5) dynamic information when combined with GPS/vehicle location

Close Window

Dynamic Route Guidance and In-Vehicle Systems

Self-Review Exercise #1 Page 10

Exercise | **Answers**

Done? Now check your answers by clicking on the appropriate buttons.

Click the buttons to see the answer to the question.

"Route guidance" refers to any information intended to help guide a traveler along a prescribed route. Static route guidance means that the information provider bases the set of instructions on network orientation without accounting for real-time traffic congestion. Dynamic route guidance refers to turn-by-turn instructions on a route computed with real-time traffic congestion information. Dynamic route guidance also refers to the ability to change paths while en-route in response to real-time changes in network performance.

Close Window

4. What is the difference between "route guidance" and "dynamic route guidance"?

Route Choice Behavior, Wayfinding & Navigation **Page 11**

Working toward a more optimal distribution of demand over time and space is important within ATMIS. Understanding travel choice behavior, especially route choice, is a fundamental prerequisite to discussing DTA and IRANS. This section provides an overview of theories and models of route choice behavior.

Driver Tasks

In the context of trip making, a driver is responsible for several tasks:

1. **Pre-trip Planning:** Decision-making process that occurs before the trip to determine activity, destination, departure time, mode, and initial route.
2. **Navigation:** En-route process of traversing a network, typically following a chosen path.
3. **En-route decision making:** Decisions considered while traveling, such as changing paths, altering activity (making an extra stop or deciding on a new destination), and seeking information.
4. **Driving Task:** Activities associated with handling the vehicle. Includes steering, lane changing, decisions regarding speed, acceleration, and braking, interactions with other vehicles, recognizing and responding to traffic signals and signage.

In-vehicle driver information systems can play an important role in carrying out these driving tasks. This module will focus primarily on navigation and en-route decision-making behaviors.

Framework for Route Choice Behavior **Page 12**

Spatial Behavior and Spatial Knowledge

Bovy and Stern (1990) explain that route choice is one part of the broader area of *travel behavior*, which in turn, is one element of *spatial behavior*. Spatial behavior focuses on the study of people and their behavior within their environment. It is a direct function of the extent of learning about the environment.

Spatial learning can be facilitated by direct experience, the process of making several trips through a network, having access to maps, or receiving verbal or written instructions. As individuals learn, they form a mental image of the network environment in their mind. This mental image, commonly called a *cognitive map*, is essential for supporting spatial behavior.

Dynamic Route Guidance and In-Vehicle Systems

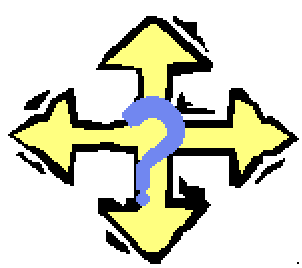
Framework for Route Choice Behavior (cont'd) Page 13

Spatial knowledge in Route Choice is made up of this set of knowledge:

- **Landmark Knowledge** — Ability to recognize certain features, but no knowledge of their locations or relationships between them.
- **Procedural Knowledge** — Knowledge of certain routes, and the procedures necessary to navigate from one end to the other.
- **Topological Knowledge** — Knowledge of how the known routes intersect and form a network - ability to combine parts of known routes into new routes.
- **Metric Knowledge** — Ability to recall metric relations between locations - distances, angles - this level of knowledge is needed to reason about previously untraveled routes and shortcuts.

Framework for Route Choice Behavior (cont'd) Page 14

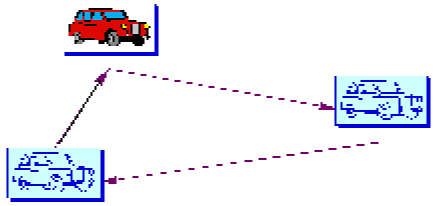
The increase in spatial knowledge leads to the evolution of cognitive maps, that in turn, increase drivers' abilities to make spatial decisions. In turn, people are able to perform high level tasks including conceiving of paths between points in the network, receiving and providing navigation instructions, and linking parts of the network to important landmarks.



Imagine you and your family are planning a car trip to the country to view the fall foliage. You should use this story to continue through the lessons to understand the navigation concepts you are learning about and help you construct a cognitive map of the decisions you will be faced with. Which route should you take? What will help you decide?

Wayfinding Page 15

Wayfinding refers to the process of finding an efficient path between two points in a network and making the trip. There are five components to wayfinding



1. **Orientation:** Maintaining full awareness of one's position within the spatial environment.
2. **Route Choice:** Selecting a route from the origin to the destination.
3. **Navigation:** The action of maneuvering or directing a vehicle along its course.
4. **Route Monitoring:** En-route assessment where one analyzes his current position within the route to make sure that (1) he is on the correct route and (2) the route will lead to the destination.
5. **Destination Recognition:** Being cognizant of being at the destination or in its vicinity.

Some suggest that the process of forming a cognitive map is also part of wayfinding.

Navigation and Spatial Ability Page 16

Navigating a vehicle within a roadway network requires the ability to read maps, recognize terrain, be aware of one's direction, and recall details from previous trips across the network. Drivers with poor navigational skills may be more likely to commit navigational errors. It is believed that as much as 6 percent to 9 percent of all travel time has been attributed to driver navigational errors, resulting in wasted fuel, increased congestion, traffic delays, and higher risk of accidents.

Spatial ability is a central element of navigational skill. Spatial ability refers to the ability to process information about the relationships among objects in space and time. As a result, individuals with high spatial ability are likely to have good navigational skills, while individuals with low spatial ability are more likely to become confused and lost. Age-related declines in spatial ability suggest that older drivers may have diminished navigational skills. Older drivers may have an increased likelihood of getting lost and may have a particular need for navigational assistance.

Pre-Trip (Activity) Planning **Page 17**

Trip planning refers to the decision process of deciding "where to travel". How would you plan your trip to the country? What pre-trip activities do you engage in while planning the trip? Often travelers face one of two activity planning issues. The first case is knowing the activity but being uncertain of the location within the area. For example, one may want to go to see a movie but does not know where the movie theater is located. The second case is when a person has not yet selected an activity and would like information on events of interest in the area. This is typical of tourists who are unfamiliar with an area and would like to know about interesting events.

Trip planning information can be provided by several devices, including kiosks, internet, phone, and in-vehicle system. For many areas, especially urban areas, ATIS that can aid in trip planning are vital for encouraging tourism.

- Roadway touting between an origin and a destination for a trip to begin at a user specified time and date. The user may also request one or more intermediate points be included in the route.
- A list of travel services available within a specified geographic area during a specified period of time.
- A list of events of interest within a specified geographic area during a specified period of time.
- The weather in a specified geographic area and during a specified period of time.

Pre-Trip Route Choice **Page 18**

Pre-trip route choice involves the generation of a choice set and selection of the "best" route. Defining a set of route choice is influenced by several factors:

Spatial Knowledge: In the context of route choice, spatial knowledge has two important layers: (1) knowledge regarding the layout and orientation of the network and (2) knowledge of the distribution of traffic congestion across the network over time and space.

System Constraints: Certain links or roadways in the network specifically prohibit certain vehicles. For example, some highways do not allow heavy vehicles to traverse; others are off-limits for vehicles hauling hazardous materials.

Route Attributes: Routes can be characterized by several factors such as: travel time, distance, reliability, number of turns, number of traffic signals, scenic, perceived safety, among others. The significance of these attributes on route choice depends on the preferences of the driver and the trip purpose.

Driver Preferences: Each driver has strong preferences for route choice. For example some prefer the "fastest route" other may prefer a route that is both "fast and direct".

Trip Purpose: Variations in preference over trip purposes is common. For example, a driver may see the fastest route for a commuting trip but the most scenic route while vacationing.

The cognitive map has direct bearing on driver's route choice behavior. Drivers who have a greater familiarity with network conditions and network layout should be expected to make more efficient pre-trip route choices as well as be able to better adjust their travel pattern en-route in the presence of severe congestion.

En-route Route Choice Behavior Page 19

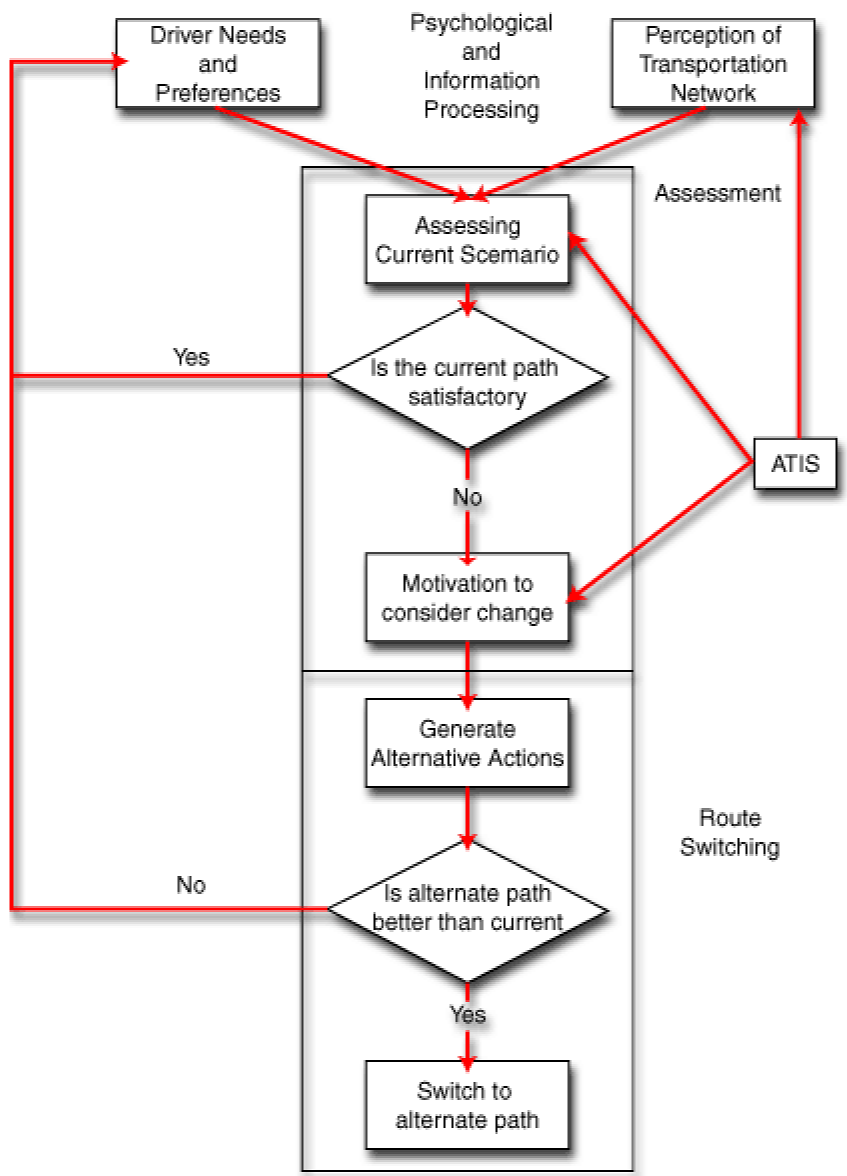
The en-route decision making process framework has two components:

Assessment: Analyzing the current route and determining if the current route will best satisfy the travel needs and preference. If the current path is perceived to be ineffective, a decision as to whether the driver should change the trip itinerary (new route, new destination, new activity, alter objectives) is required.

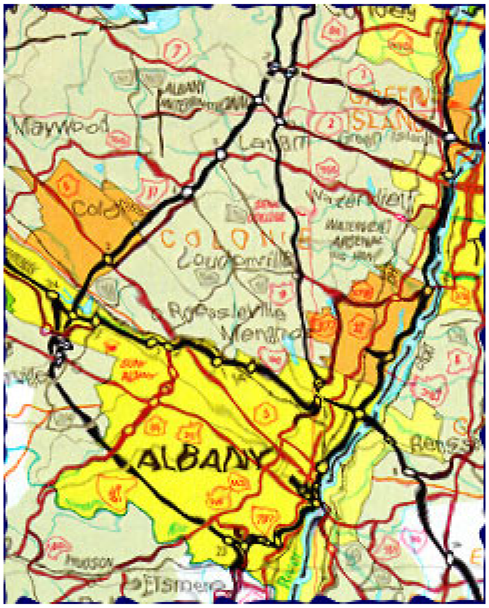
Route Switching: This involves comparing the expected performance of the current route to the expected performance of an alternative route. In pre-trip the best route from a choice set is selected, regardless of the perceived difference in value between the two best routes. For en-route decision-making, switching from one route to another requires one to consider the relative performance, namely how much better would the alternate route be. Drivers tend not to switch routes for small perceived improvements. There needs to be evidence of "significant improvement" to motivate route switching.

This framework is shown next in a schematic diagram.

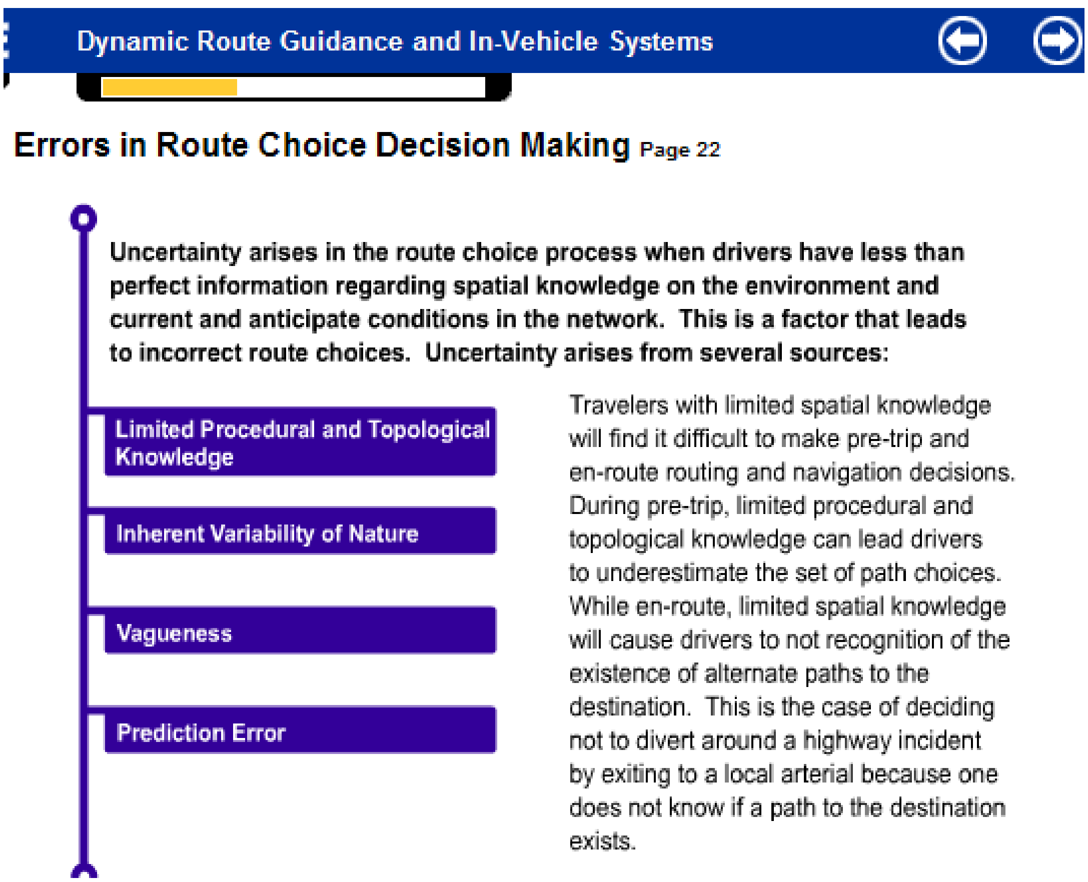
En-route Route Choice Behavior (cont'd) **Page 20**

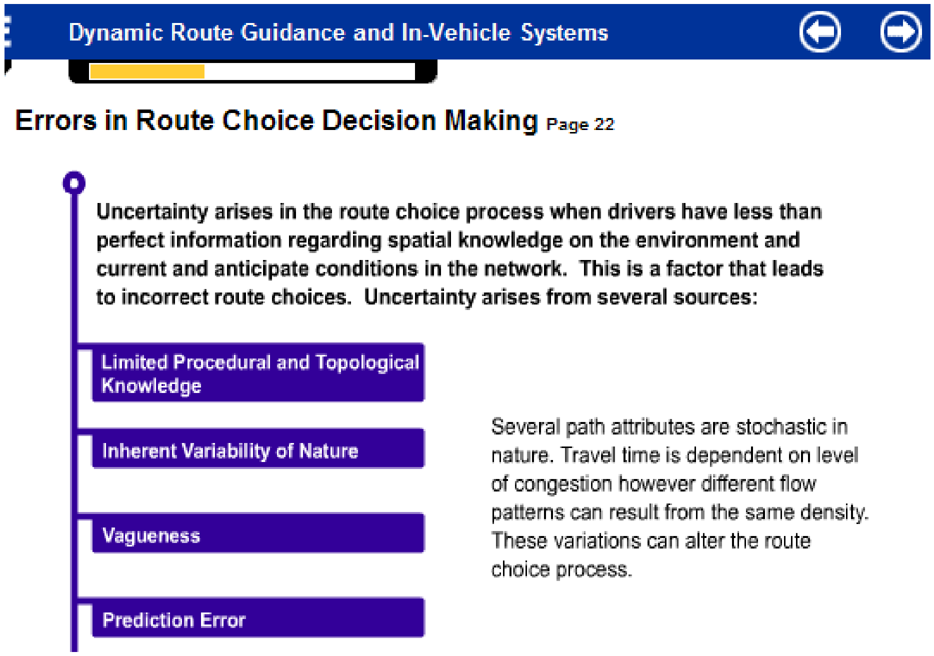


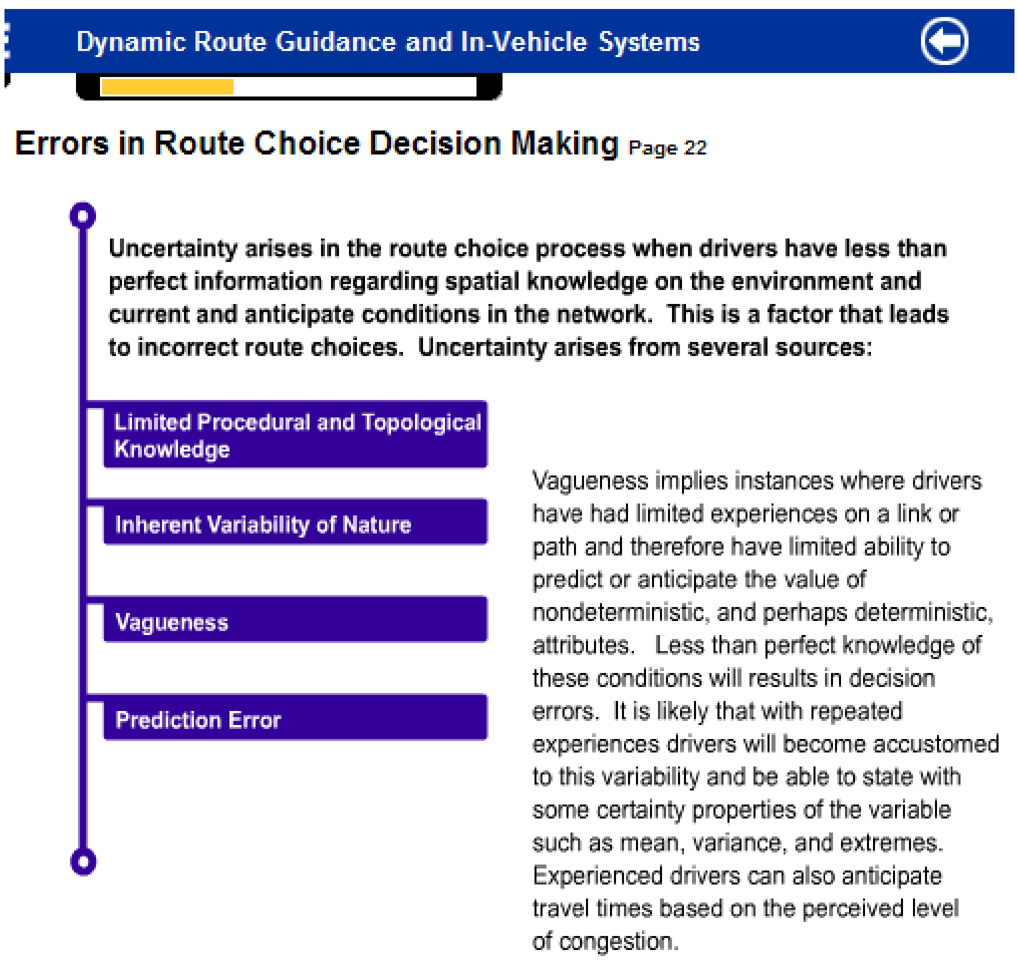
Information and Route Choice Behavior **Page 21**



In the context of **ATMIS**, we are concerned with the prospects of drivers making efficient pre-trip and en-route choices. Information is of great value to drivers to aid in route choice. This section describes the type of errors that can be made by drivers within the context of pre-trip and en-route decision-making. Think about the kinds of mistakes you might make on your trip to the country and the type of help you might like to have to evade route errors.




Dynamic Route Guidance and In-Vehicle Systems
Errors in Route Choice Decision Making Page 22
Uncertainty arises in the route choice process when drivers have less than perfect information regarding spatial knowledge on the environment and current and anticipate conditions in the network. This is a factor that leads to incorrect route choices. Uncertainty arises from several sources:
Limited Procedural and Topological Knowledge
Inherent Variability of Nature
Vagueness
Prediction Error
Several path attributes are stochastic in nature. Travel time is dependent on level of congestion however different flow patterns can result from the same density. These variations can alter the route choice process.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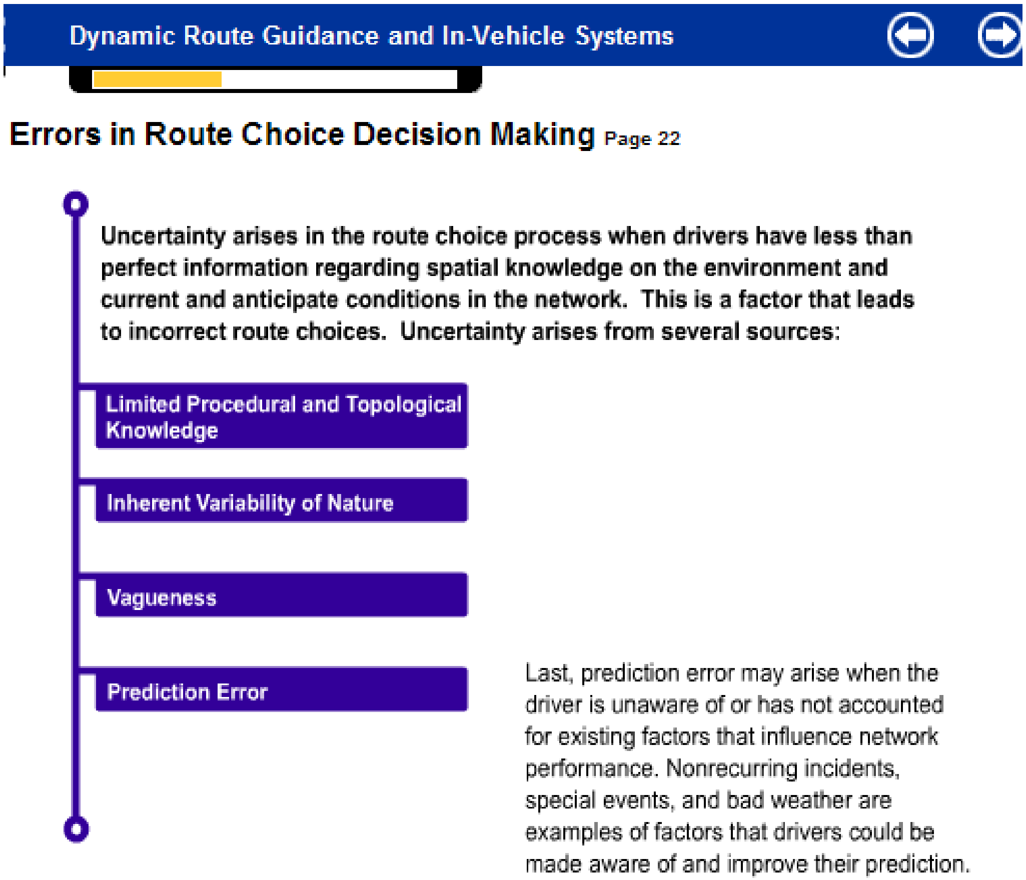
Limited Procedural and Topological Knowledge
Inherent Variability of Nature
Vagueness
Prediction Error
Vagueness implies instances where drivers have had limited experiences on a link or path and therefore have limited ability to predict or anticipate the value of nondeterministic, and perhaps deterministic, attributes. Less than perfect knowledge of these conditions will results in decision errors. It is likely that with repeated experiences drivers will become accustomed to this variability and be able to state with some certainty properties of the variable such as mean, variance, and extremes. Experienced drivers can also anticipate travel times based on the perceived level of congestion.



Impacts on Pre-trip Route Choice Behavior Page 23

Uncertainty or limited knowledge can result in two types of errors in pre-trip route choice:

1. **Errors in defining the set of route choices:** Though limited topological knowledge a driver may overestimate or underestimate the available choice set. Underestimation results from forming routes from an incomplete knowledge base. Overestimation may result from making incorrect inferences on this incomplete topological knowledge base.

2. **Estimation errors:** The driver can form the set of available routes but has erred in measuring the attributes accurately resulting in a suboptimal route selection.

Impacts on Pre-trip Route Choice Behavior (cont'd) Page 24

As a result of less than perfect information and imperfect judgment, three classes of errors may arise:

1. **Misdiagnose congestion on the current route:** When the driver has imperfect knowledge of the congestion on the current path, it becomes difficult to make correct diversion assessments:
   a. *Overestimating the problem with the current path:* A driver may overestimate the congestion on the current path and switch routes. While the best alternate path may be satisfactory, it would not be preferred to the current path under normative conditions.
   b. *Underestimating the problem with the current path:* It is possible to underestimate the congestion on the current path and fail to take advantage of available better alternatives.

Incorrectly identifying possible diversion routes: With limited spatial knowledge and information on network congestion a driver may err in identifying alternate paths:

. *Not identifying an alternative path:* Limited spatial knowledge may lead a driver to ignore potential alternative paths or detour routes.

a. *Selecting the wrong path as the "Best Alternative Path":* A driver may identify several possible diversion routes but incorrectly determine which is best. The resulting decision process to assess the best alternate path versus the current path may yield a suboptimal choice.

Misdiagnose congestion on the best alternate route: A driver may recognize that an alternate route exists but has limited knowledge of the current and/or anticipated congestion on that path.

. *Overestimating the advantage of the best alternate path:* Uncertainty regarding the alternate path may lead the driver to incorrectly decide to switch paths rather than remaining on the current route.

a. *Underestimating the advantage of the best alternate path:* Underestimating congestion on the best alternate path may lead the driver to forego switching paths when, in reality, it would be advantageous.

Behavioral Conditions leading to Inefficient Route Page 25

Beyond the decision-making errors due to incomplete knowledge, inefficient choices may be made as a result of behaviors related to the psychology of driving and navigating. Wayfinding can make people tense. Drivers can be frustrated about sitting in congestion, anxious about getting to their destination on time, and fearful of driving through unfamiliar neighborhoods. As a result, they may make inefficient route choices.

Deriving Benefits from Information Systems Page 26

Driver information systems, whether providing traffic advisories or route guidance, can reduce errors in judgement and alleviate psychological effects. Real-time traffic advisories help people better comprehend the congestion on the network and aid in making more informed path switching decisions. Confidence in route guidance systems will enable people to have a better handle on navigation, allow for greater and more confident exploration of networks, and encourage following detour routes that require travel through unfamiliar neighborhoods. In general, people are fearful of the unknown and having a source of information that is reliable and trustworthy will ease these fears.

Self-Review Exercise #2: Check Your Answers Page 28

1. Define wayfinding and describe why it is important within the context of route guidance?

Solution: Wayfinding refers to the process of finding an efficient path between two points in a network and making the trip. When travelers have low wayfinding capabilities, such as within a network that they are unfamiliar with, traveler information can help them compensate for their lack of knowledge. In particular, route guidance can be helpful for planning and making trips within that network.

2. What is spatial knowledge? What types of knowledge does it consist of?

Solution: Spatial knowledge refers to knowledge acquired by a person on a spatial environment. Researchers differ as to what the primary components of spatial knowledge are. It is generally agreed that spatial knowledge can include:

- knowledge on the layout and orientation of streets and highways in the network,
- key intersections and interchanges that describe how streets are connected,
- information on roadway lengths, and
- perhaps familiarity with some landmarks that can help identify certain parts of the network.

3. What is a cognitive map and what role does it play in travel choice behavior?

Solution: A cognitive map is a mental image of a network that is generated by the traveler. Acquisition of spatial knowledge forms and shapes a person's cognitive map of a network. Cognitive maps are thought to be one of the most critical pieces of information used by travelers to plan routes.

4. Describe the tasks that occur pre-trip and those that take place en-route.

Solution: Pre-trip: activity, destination, mode, route, departure time choices and some statement of travel objectives. En-route: wayfinding and navigation along the current path, assessment of travel conditions on the path, decisions regarding diversion.

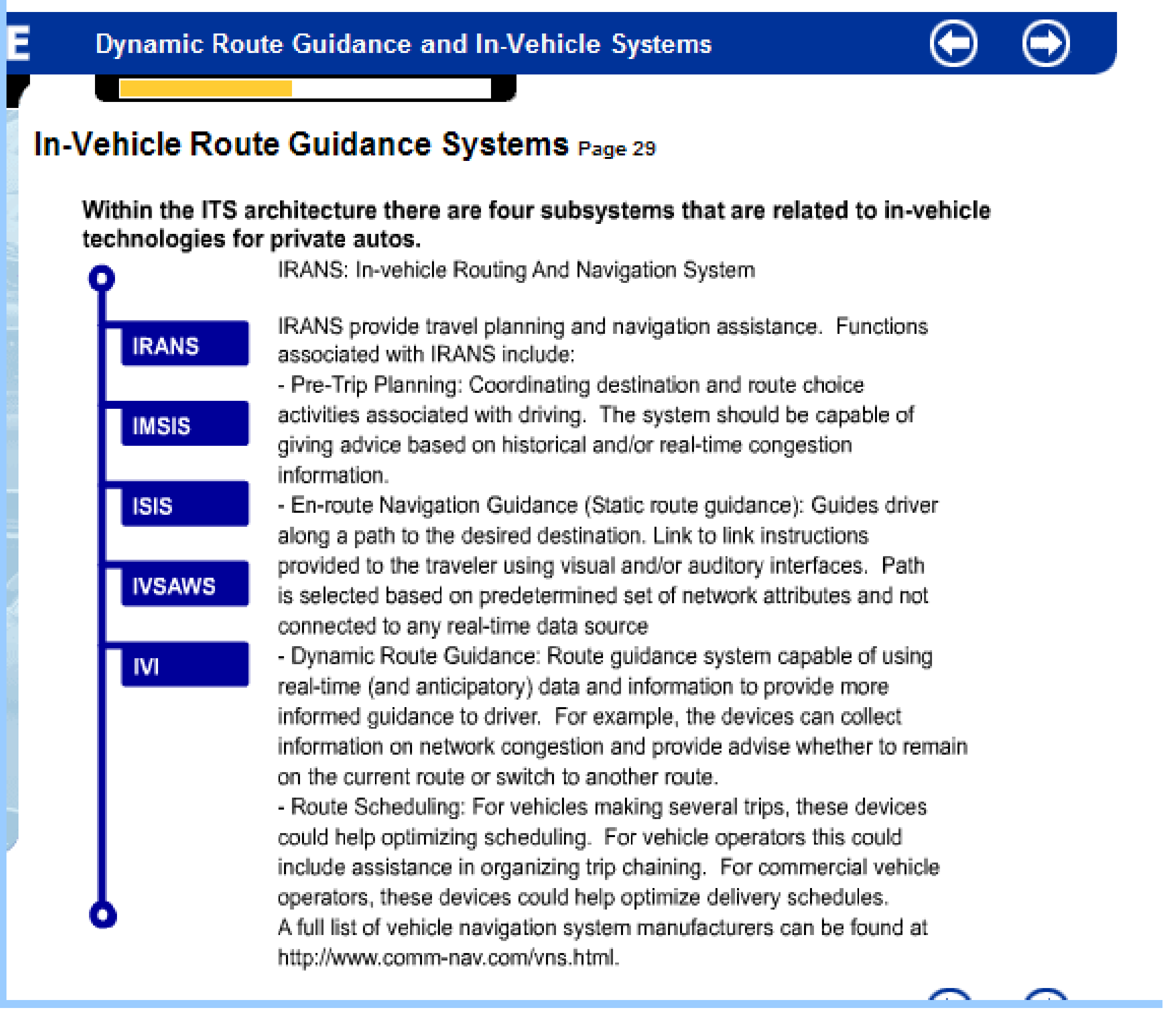
5. List three types of route choice errors that can occur and state how traveler information systems can be used to make route choice behavior more efficient?

Solution:

a) Misdiagnose congestion on the current route: When the driver has imperfect knowledge of the congestion on the current path, it becomes difficult to make correct diversion assessments: Traffic advisories can help drivers better comprehend the congestion on the current route

b) Incorrectly identifying possible diversion routes: With limited spatial knowledge and information on network congestion a driver may error in identifying alternate paths: Traveler information can make the driver more aware of the network and viable diversion alternatives

c) Misdiagnose congestion on the best alternate route: A driver may recognize that an alternate route exists but has limited knowledge on the current and/or anticipated congestion on that path. Similar to (a) in that traveler information systems can help drivers better comprehend the congestion on the current route



In-Vehicle Route Guidance Systems Page 29

Within the ITS architecture there are four subsystems that are related to in-vehicle technologies for private autos.

- IRANS
- IMSIS
- ISIS
- IVSAWS
- IVI

IMSIS: In-vehicle Motorist Information System

Beyond route guidance, there are several classes of information that are useful in the context of trip planning.
- Yellow Pages Directories: The device can serve as a database of transportation related information as is found in a "yellow pages directory". The system enables drivers to query the database for information for a host of information such as nearest gas stations, destination options, business phone numbers, etc.
- Destination Coordination: The device can facilitate real-time information transmission between the vehicle and an outside station. For example, a driver could lookup a restaurant in the yellow pages directory and use the device to phone ahead and make a reservation.

Dynamic Route Guidance and In-Vehicle Systems

In-Vehicle Route Guidance Systems Page 29

Within the ITS architecture there are four subsystems that are related to in-vehicle technologies for private autos.

- IRANS
- IMSIS
- ISIS
- IVSAWS
- IVI

ISIS: In-vehicle Signing Information Systems

These systems will be linked to external roadside signage and have the capability of displaying the information to the driver inside the vehicle:

- Roadway Markings: Displaying signage that is used to identify the roadway geometry, includes: street signs, mileposts, interchange signs, and the like.
- Roadway System Control Signage: Includes information contained on signs that help control traffic, including: speed limits, stop signs, yield signs, traffic signals
- Roadway Notification Signage: Display signs that are used to notify drivers of special conditions, such as: reduced speeds in work zones, reduction in lanes, weather-related information, and road construction/maintenance-related information.

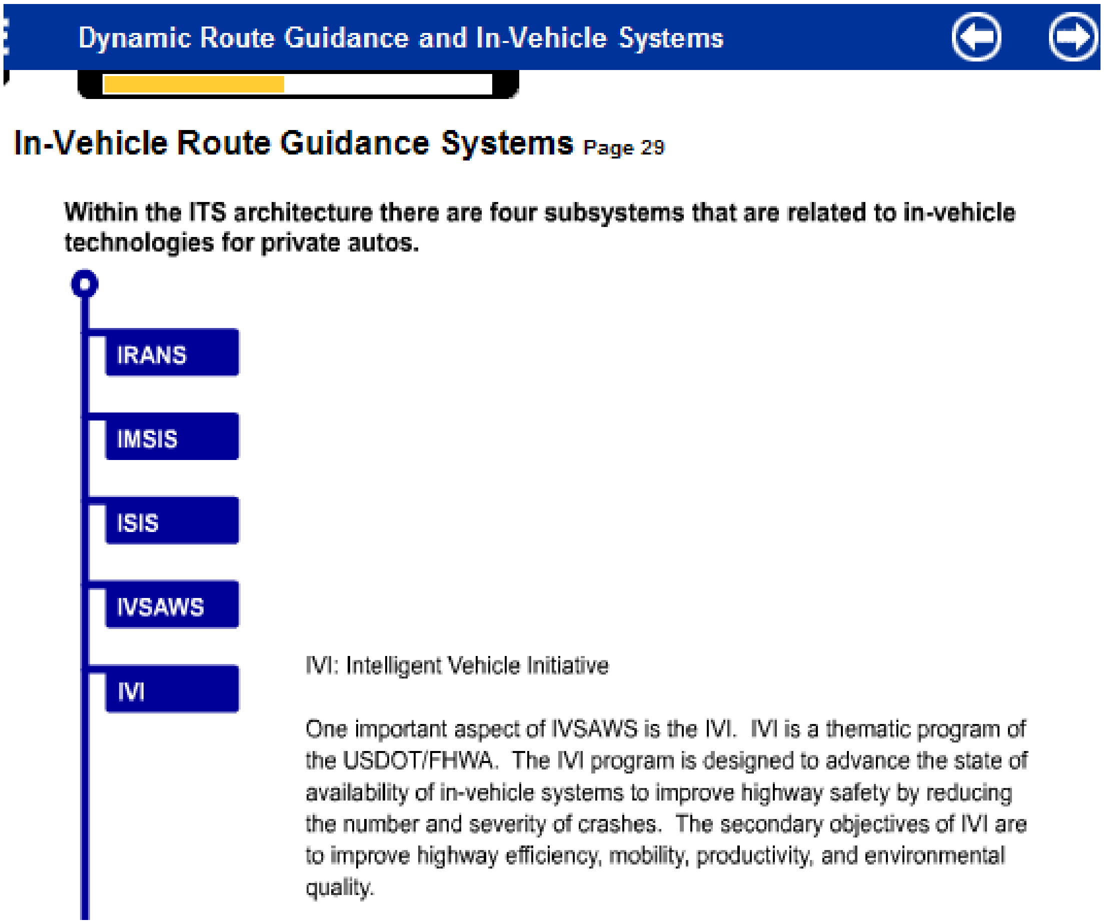
In-Vehicle Route Guidance Systems Page 29

Within the ITS architecture there are four subsystems that are related to in-vehicle technologies for private autos.

- IRANS
- IMSIS
- ISIS
- IVSAWS
- IVI

IVSAWS: In-Vehicle Safety And Warning System

The broadcast of information that warns drivers of potential safety hazards. Included are:
- Roadway Condition Information: Changes in roadway or driving conditions due to bad weather (e.g., icy pavement, reduced vision.).
- Automatic Aid Request (Mayday Signal): Vehicle emits a signal requesting emergency assistance.
- Vehicle Condition Monitoring: Links to the vehicle's engine and systems to help inform the driver as to changes in the vehicle's condition. It could warn drivers on impending problems, such as being low on fuel or that service is needed.



Intelligent Vehicle Initiative Objectives Page 30

1. To evaluate the performance of proposed advanced safety systems and provide a means of informing transportation decision-makers and the general public of potential opportunities for improved safety. This evaluation shall be based on thorough testing in a real operational environment of the performance of systems including sensors, processing algorithms, and driver-vehicle interfaces, especially the driver's ability to easily understand and effectively use the proposed safety systems.

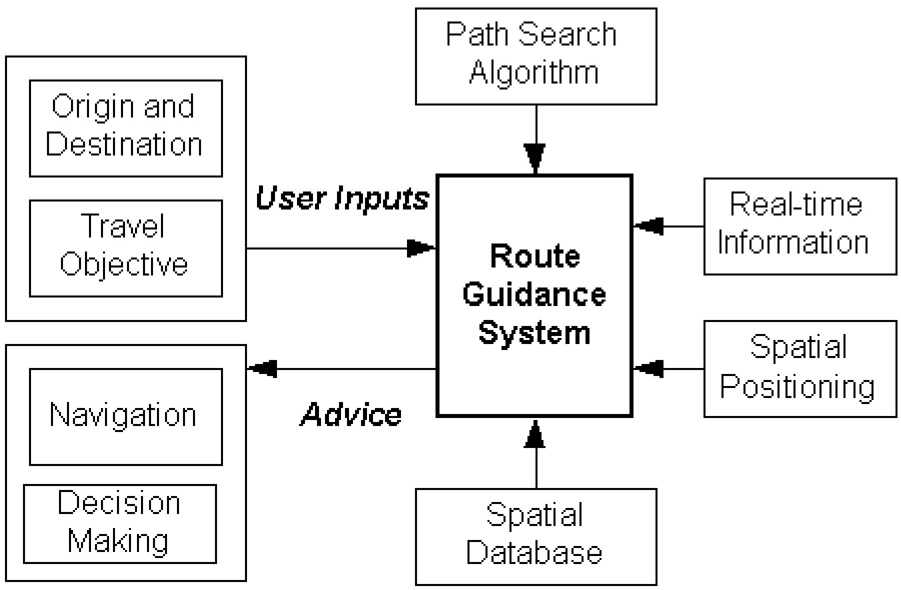
2. To accelerate deployment of advanced technologies which enhance safety by providing a substantial level of understanding of risks of all types including, but not

limited to, marketing, operating, crash, and liability risks, thus reducing deployment risks.

3. To help forge additional strategic partnerships with transportation stakeholders as an effective model of public-private cooperation for the development of advanced safety systems.

4. To apply and assess the state-of-the-art in benefits analysis for advanced, vehicle-integrated crash avoidance systems.

Fundamentals of Route Guidance Systems **Page 31**



Spatial Database **Page 32**

All in-vehicle systems require a spatial database that contains information about the roadway network. Most systems today are designed to accommodate a database that is stored on a CD and provided by a mapping company.

Navigation Technologies is the largest vendor of spatial information systems. They claim that "Every in-vehicle navigation product in North America and the majority of products in Europe that offer turn-by-turn route guidance uses a NAVTECH database." The NAVTECH database is a detailed, digital representation of the road network that provides the depth, accuracy and coverage needed to enable turn-by-turn, door-to-door route guidance. Every road segment can have up to 150 attributes (pieces of information) attached to it, including information such as street names, address ranges and turn restrictions. In addition, the database contains hundreds of thousands of Points of Interest information in more than 40 categories, including restaurants, petrol/gas stations, police stations and hospitals.

ETAK is another well-known company involved with spatial databases and navigation systems. Their databases are used within web-based and PC-based applications. They also provide development support for PDA's, notebook computers, and cellular phones.

Vehicle Location System **Page 33**

To relate the key trip parameters (current location, destination, and route) to the spatial database, in-vehicle systems require three additional components:

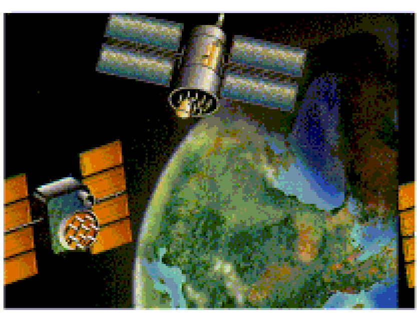
1. **A Global Positioning System (GPS)** - A GPS involves a receiver (typically mounted to a vehicle or a device) that is sent data transmitted from satellites in orbit around the earth. The message being sent contains the real-time position of the vehicle (longitude, latitude).

2. **Dead Reckoning System** - This component relates the vehicle's current position to the spatial database.

3. **Mapping Algorithms** - These procedures are used to adjust the measurements of the dead-reckoning system and help display the current position of the vehicle within the map display.

How They Work

Vehicle Location System (cont'd) **Page 34**



Global Positioning System (GPS) satellites are used to pinpoint your vehicle's location. There are a total of 24 satellites circling the planet; three satellite signals allow for a positional accuracy of about 100 meters. In addition to GPS, most navigation systems also use "dead reckoning" to pinpoint your location. A built in sensor measures the car's movement and records driver distance. An electronic signal from the speedometer, a gyroscope that measures turns, and software in the car translates the location information into maps and routes. With these additional inputs, the navigational accuracy is less than 15 meters. A key component to a navigation system's reliability is the navigable map database, which usually comes on CD-ROM. The database has to be accurate and up-to-date for a system to work properly.

Path Search Routines Page 35

A path (route) is a set of links that can be followed from the current location of the vehicle to the intended destination. There can be several viable paths that connect any two nodes in the network. The objective is to identify an optimal path -- one that best satisfies the needs and preferences of the driver. Identifying optimal paths through a network requires two elements: (1) eliciting path preferences from the driver and (2) applying a path search algorithm to identify the optimal path.

People make route choices based on factors that are perceived to be important. There are several route attributes that influence choice behavior:

- Travel time (mean and variance)
- Number of stop lights and/or signalized intersections
- Percent of trip on freeway
- Route length
- Road quality
- Familiarity with route
- Number of road changes required
- Scenic

IVNS - Example Technology Page 36

Many of today's navigation systems allow drivers to select an option from a set of pre-programmed objectives. For example, the Alpine NVA-N751AS In-Vehicle Computer provides drivers with the following set of objectives:

- Shortest Route
- Minimize Turns
- Minimize Freeways

- Minimize Toll Roads
- Auto Re-Route
- Accident/Avoid Road

IVNS - Example Technology (cont'd) Page 37

There are several ways to get access to IVNS:

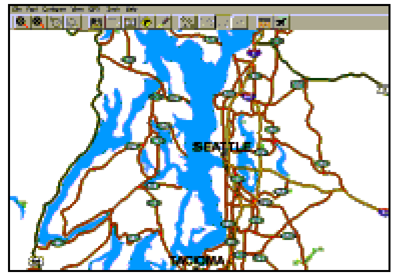
Vehicle-Based, Factory or dealer installed - This refers to the purchase of a car that comes equipped with a navigation system or is installed at the dealership. Car companies that provide this option include: Acura, BMW, Land Rover, Lexus, Mercedes Benz, Volvo, Oldsmobile.

Aftermarket - Several companies offer systems that can be installed in any automobile. Alpine and Magellan are examples of such companies. This refers to the purchase of a car that comes equipped with a navigation system or is installed at the dealership. Car companies that provide this option include: Acura, BMW, Land Rover, Lexus, Mercedes Benz, Oldsmobile.

Rental Cars - The rental car market is viewed as one of the ripest markets for making in-vehicle route guidance systems available. Having access to these navigation systems are viewed as valuable tools by tourist and business travelers who must rent a vehicle to drive through unfamiliar areas.

Route Guidance and Notebook Computer Page 38

Route guidance is not limited to in-vehicle devices. There are several map navigational systems designed to work with a notebook computer in-vehicle.



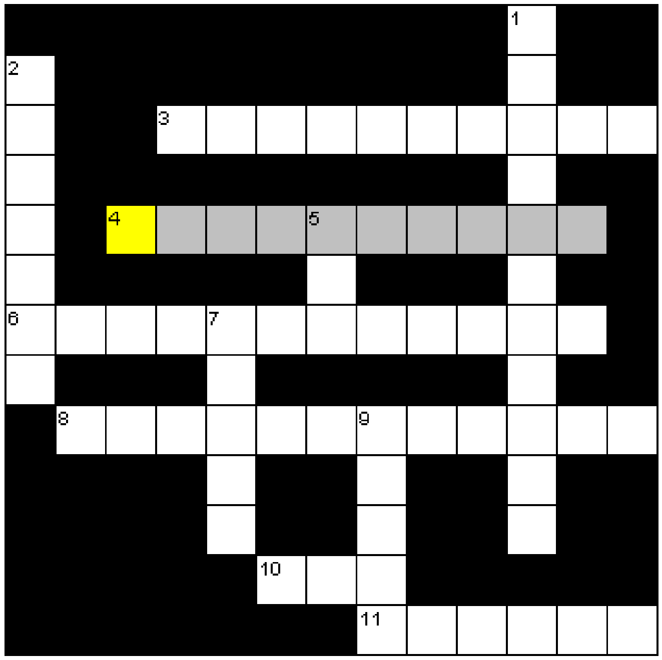
SkyMap Pro provides easy-to-read, detailed maps of all 50 states and major metropolitan areas, over 700,000 searchable business listings and a powerful Address Book.

SkyMap, developed by Sony and using TeleAtlas maps, provides pre-trip planning and route guidance assistance via a lap top computer. For less than $300, you can lease for your automobile a 12 channel GPS receiver linked to a notebook computer via a PCMCIA card.

Route Guidance and Notebook Computer (cont'd) Page 39

Several commercially developed systems can be purchased off-the-shelf for less than $100. Streetfinder, developed by RandMcNally, is one of the most popular systems. The company's GPS unit automatically shows the driver's course and real-time position on StreetFinder's highly detailed street maps, which have a large, user-friendly format that is easy to read while traveling in the car. Drivers can find and mark their destination on the map, and visually follow their course as they drive to it. The screen also shows the destination address, distance from destination and compass bearing at all times. In addition to its mapping functions, StreetFinder offers a number of trip-planning tools, such as a trip organizer, an address book, expense report tracking, concierge recommendations, and the Mobil Travel Guide® database for restaurants and lodging.

Crossword Puzzle Page 40



Across

3. This car manufacturer markets IVNS-equipped cars.

4. The process of finding an efficient path between two points, and making the trip

6. Internal mental representation of a spatial system.

8. A property of route guidance systems.

Down

1. One of the four components of Wayfinding.

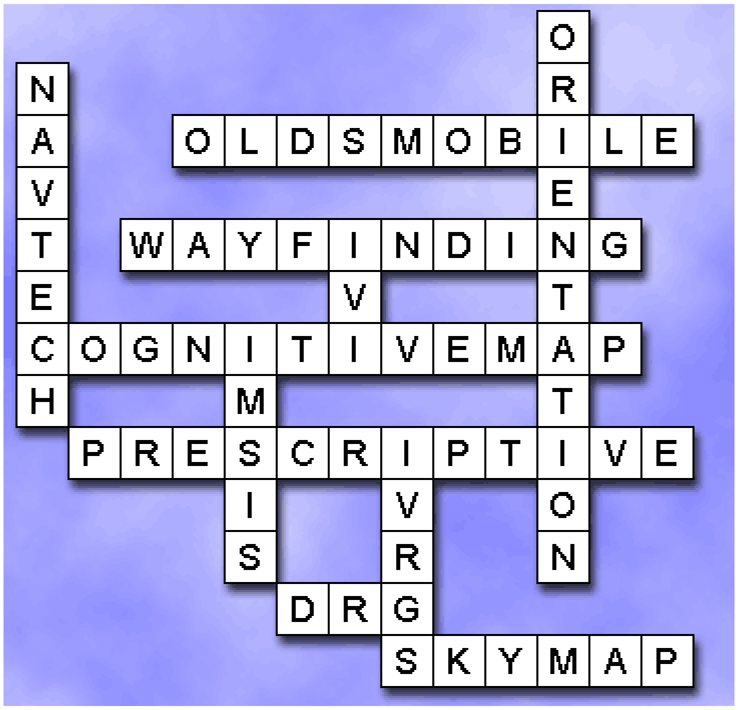
2. The largest vendor of spatial information systems.

5. Program of the USDOT/FHWA designed to increase the availability of in-vehicle systems.

7. One of the four subsystems associated with in-vehicle technology ...

Crossword Compiler Software © A. Lewis 1999

Crossword Puzzle Solution Page 41



Implementation Guidelines Page 42

There are several important issues that have a direct impact on drivers considering the purchase of in-vehicle devices:

Do Drivers Really Want In-Vehicle Information? Several studies have tried to answer this question. There have been a variety of responses given. Some drivers are satisfied with current information being provided by radio reports. Others say that they never change their route, even in response to unexpected congestion. There are those who do not believe that they should pay for something that is being received currently for free. Some are willing to pay a modest fee for an in-vehicle navigation device. As this market matures there are several areas to keep a watchful eye on:

Control over the Route Planning A focus group participating in the ADVANCE ITS demonstration project in Chicago discussed the importance of 19 features of a real-time in-vehicle DRG tested in the project. The test drivers wished to have more control over the route planning and to set their own criteria. The drivers suggested that computer learning of their route selection criteria or of their favorite routes would be desirable.

Cost Traveler information systems are being developed as services to travelers and the users are expected to pay for the service (either by purchasing an in-vehicle system or subscribing to a regional information provider). Currently the cost of in-vehicle devices is high and relatively few drivers have opted to purchase these devices. In addition, there are few opportunities for devices to link with information providers in order to provide dynamic route guidance and real-time advisories.

Trust and Compliance Page 43

When it comes to traveler information, whether it involves in-vehicle or roadside devices, maintaining a high degree of trust with drivers is essential. Once drivers' confidence is lost, they are more likely to ignore the travel advice. This is an important issue as it relates to route guidance. Within the context of ATIS there are two extremes: the driver retains ultimate route choice decision-making and uses ATIS for advice or the driver places full trust in the device and follows the device blindly.

Compliance refers to whether drivers follow the advice being provided via ATIS. Drivers who believe that the information being provided is not accurate, misleading, or not useful would be less likely to comply with the system. In the longer run, if driver confidence in these systems fails, then fewer people will purchase these systems and the expected benefits will not be realized.

Oversaturation Several studies have indicated that as the number of vehicles equipped with in-vehicle route guidance systems increases, the marginal benefit to the network diminishes. Some have shown that maximum system benefit is achieved if only a small portion of drivers (up to about 25%) is equipped. Mahmassani and Chen (1991) assert that ultimately, the decision for a traveler to invest in ATIS will be based on the trade-off between system cost and perceived benefits. If the system experiences diminished value from ATIS as market penetration increases, then fewer travelers may be tempted to invest in these systems.

Driver Comfort Drivers will be more apt at investing in in-car systems if the interface and operation are easy to handle. In addition, drivers seek systems that respond in a manner consistent with the driver's behavior, but sooner, smoother, and in a more reliable manner. It is suggested that comfort and trust in the system's ability to complement driver behavior is an essential criteria for older drivers whom may consider investing in these systems.

Short vs Long-Term Effects on Route Choice Behavior Page 44

Over the past few years there has been much research focusing on the effects of ATIS on short-term route choice behavior. It is known that that driver familiarity with network orientation and travel conditions influence how drivers make route choices and use ATIS. On a given day it may be expected that drivers who are more familiar with network conditions and layout should be able to make more efficient pre-trip initial route choices as well as be able to better adjust their travel pattern en-route in the presence of severe congestion. Alternatively, drivers with limited experience should, on average, perform worse than experienced drivers. They should be expected to select initial route choices that are inferior and while en-route be less equipped to make adjustments in response to major congestion.

One issue that is not well understood is the long-term effect of ATIS on spatial knowledge and driver's attitudes and preferences toward route selection. Of particular interest is whether drivers who own or have access to ATIS will be enabled to accelerate their spatial learning and expand their cognitive maps. Some suggest that the use of ATIS will enhance spatial knowledge; others argue that information gathered via ATIS may in fact hinder the development of driver's cognitive representations of their spatial environment

Competing Architectures: Centralized vs. Decentralized Page 45

When it comes to deploying in-vehicle systems there are various strategies that aim to optimize the performance of these systems. Two issues are most prevalent: (1) how much power to put onboard (2) how much control over routing is provided to the system.

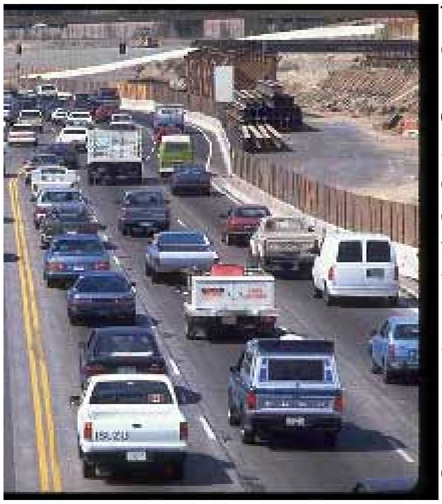
There are two competing architecture for in-vehicle devices:

Active Terminal:

The first approach is to place much of the analysis and path search intelligence within the device inside the vehicle. In other words, the device is equipped with the mapping, positioning, and path search capabilities. All routing guidance computations are made within the vehicle. To accommodate dynamic route guidance, the device may communicate with outside sources of information.

Passive Terminal: The second approach is to use the in-vehicle device as conduits for communicating with ISP (information service providers). When information is requested, the device communicates with a network information provider through a wireless network. For example, the driver wants to travel between points a and b. The device transmits a message to the service provider who then computes the best path and relays the signal to the in-vehicle device. The information is processed and provided to the driver.

Who Controls Routing? Page 46



There are two ends of the spectrum: fully centralized and fully distributed assignment.

Centralized Assignment: Centralized assignment refers to architectures in which the calculation of optimum routes, according to traffic conditions, is carried out by a central computer which takes into account route requests from all vehicles using the infrastructure and which determines the optimum routes for all vehicles at a given time. In principle, such systems will be of interest to infrastructure managers whose networks are saturated and who therefore require a means of improving their modal distribution. Centralized systems require very powerful computers (the only functions that in-vehicle equipment would need to provide are reception and temporary data storage) and can be adversely affected by overloads (insufficient computing capacity when the system most needs it). Under-optimization based on zone ranking can undoubtedly improve the robustness of such systems. Centralized systems are also referred to as infrastructure-based systems.

Decentralized systems: Decentralized (or autonomous) systems are systems in which all drivers receive information on traffic conditions through in-vehicle terminals and then choose their routes, or mode of guidance, according to their own personal criteria. Such systems require powerful on-board computing capacity as well as large flows of data to the vehicle to allow real-time updating of on-board databases. Such systems are also referred as vehicle-based systems.

Market Penetration and System Performance Page 47

From a systems perspective the most benefit to be gained is by effecting more efficient (i.e. lower travel time) route choice behavior across the driver population. There is an interest to determine the extent of improvement in system-wide performance should a significant number of vehicles be equipped to receive shortest time path guidance. Simulation experiments have been conducted to study the effect of increased market penetration on trip lengths and network performance. It has been reported that the use of in-vehicle routing systems will reduce the level of inefficient route choices and decrease the sum total of travel times. However, they have also indicated that as market penetration rate increases, beyond some threshold (estimated to be 30-40%) the marginal improvement decreases and the net benefit in travel time savings is diminished significantly.

This loss in performance benefits is based on myopic decision making. If all of the drivers traveling between the same node pair utilize the identical in-vehicle route guidance system, they will be given the same advice and likely suffer the same consequences. It is evident that these systems need to be more informed about real-time traffic conditions. Lee (1994) argues that when market penetration of IRANS is high under a centralized traffic control system, providing dynamic minimum time path route guidance will have an adverse impact on network performance, as too many vehicles will be routed onto the same shortest path. He advocates the use of a multiple-path routing strategy whereby the k-minimum time path is solved and vehicles are randomly provided with route guidance for one of the 'k' best paths.

Estimating Benefits and the Future Page 48

In-vehicle systems will contribute to reducing system-wide transportation impacts. However, it is also important to realize that there are several benefits to be derived by individual drivers who own and use IRANS. By focusing only on the supply-side impacts of IRANS there is a potential to overlook or underestimate the real benefits. For example, one might argue that the ability of IRANS to reduce stress and anxiety by helping drivers make path choices is a real benefit to the consumer. Private developers of IRANS systems clearly recognize that the market is consumer driven and many of the IRANS currently available for purchase include provisions for drivers to select one of several criteria for path guidance.

Many believe that IRANS are an intermediate, and likely to be short-lived, step toward an in-vehicle personal computer. Microsoft and Intel, along with many car manufacturers and computer firms, are working on next generation in-vehicle computer systems that will provide drivers and passengers many of the same conveniences found in today's laptop computers and PDAs.

Several projects to develop these next generation in-vehicle computer systems are underway, including:

- **The Auto PC**, powered by Microsoft Windows CE is expected to become a major force over the next few years
- **ICES**, an in-vehicle computer system developed by Visteon Automotive Systems (A unit of Ford Motor Company)
- **Network Vehicle**, developed by IBM, Delphi Delco, Netscape Communications, and Sun Microsystems

Self-Review Exercise #3: Check Your Answers Page 50

1. What are the four major classes of in-vehicle systems? Which are directly relevant to ATMIS?

Solution: IRANS, ISIS, IMSIS, IVSAWS, Application to ATMIS

- IRANS - Provides drivers with pre-trip planning and en-route navigation. Can result in more drivers making more efficient route choice
- ISIS - Help drivers to see roadway signage which could improve safety and reduce incidents
- IVSAWS - Also improve safety and emergency response.

2. Describe how in-vehicle navigation systems work.

Solution: IVNS integrate real-time congestion information, spatial reasoning, vehicle location (through GPS) to help guide a driver to an intended destination via a path that satisfies his travel objectives. {* specific details in text *)

3. List and explain four factors that should influence development and deployment of in-vehicle systems.

Solution:

a) Cost: System and information must be affordable to drivers

b) *Control Over Route Planning:* System should be able to respond to different route choice criteria

c) *Comfort:* The device must be easily accessible and user friendly

d) *Compliance:* The information must be presented in a manner that is easily comprehended by the driver. The information must also be perceived by users as being correct so that the driver will comply.

e) *Oversaturation:* As market penetration rates of these devices increases, it is important to study how network performance will change.

4. Compare and contrast a centralized information architecture versus one that is distributed. What are the advantages and disadvantages of each?

Solution:

- *Centralized systems:* Centralized assignment refers to architectures in which the calculation of optimum routes, according to traffic conditions, is carried out by a central computer which takes into account route requests from all vehicles using the infrastructure and which determines the optimum routes for all vehicles at a given time. In principle, such systems will be of interest to infrastructure managers whose networks are saturated and who therefore require a means of improving their modal distribution. Centralized systems require very powerful computers (the only functions that in-vehicle equipment would need to provide are reception and temporary data storage) and can be adversely affected by overloads (insufficient computing capacity when the system most needs it). Under-optimization based on zone ranking can undoubtedly improve the robustness of such systems. Centralized systems are also referred to as infrastructure-based systems.

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Dynamic Traffic Assignment (DTA) Page 51

DTA systems are suites of software tools designed to support traffic management systems. Using current and historical data, DTA systems estimate traffic congestion and determine appropriate traffic control and route guidance strategies. Today's DTA systems are used for off-line planning but it is likely that they will have on-line capabilities in the not too distant future.

Background The problem of dynamic traffic assignment can be described as follows. First, as time unfolds, there are people wishing to make trips across the network; they have origins, destinations, desired departure and arrival times and implicit preferences for mode and route. Second, a multi-modal network exists by which these trips can be accommodated. However, there is a reasonable probability that at some point within the current horizon, demand will exceed supply. As people's travel desires manifest themselves, a juncture will arise when it is necessary to take systematic system-wide control actions that bring demand in line with supply. That is, a need will arise to reallocate trips either 1) among modes, 2) in time, or 3) between facilities. In effect, the spatial and temporal pattern of trip-making will need to be adjusted so that the resulting flows fit within the scope of the capacity available.

DTA Background Page 52

The redistribution of trips among paths tends to be a real-time decision making problem. As the pattern of flows unfolds, instances arise when the anticipated level of traffic on a given facility in a given time period (or time slice) exceeds the capacity available, or delays are produced that are unacceptable. This may happen because of unexpected events, such as incidents, bridge openings, or bad weather. Or it may occur because the level of demand across a short time frame exceeds the system's absorption capacity. Such is the case when a sports event ends, a factory lets out, or weekend vacation traffic is getting underway. In such situations, the challenge is to make the best possible use of the network-wide capacity available, distributing trips in an "optimal" way so that the quality of service delivered to the users is as high as possible given the loading conditions.

To a certain degree, reallocation of trips in time can help alleviate overloads. Trips can be redistributed among paths so that delays are reduced but arrival times are postponed. The challenge is to do so without seriously violating any individual user's preferences for routing and/or arrival time, capitalizing on those people who do not have strident requirements for either or both. In situations where these types of users do not exist, the only choice is to manage the traffic as effectively as possible given the options for action that exist.

DTA Background (cont'd) Page 53

The conclusion we draw from this discussion is that dynamic traffic assignment has two components. The first is the act of "planning ahead:" developing "the best possible" trip-making strategy before the trip commences, given the information for each individual about what conditions will arise across the network as the trip proceeds. The second is to gain maximum performance from the system given whatever users are present.

The first of these tasks has the property that near-optimal decision-making can in theory be achieved. If enough is known about future conditions in the network, optimal departure time-mode choice-path assignment decisions can be made. In the latter, the more likely scenario is that informed "judgmental" decisions will attempt to maximize the system's performance given whatever real-time events unfold.

In both instances, pro-active decision-making has value. In the first, the goal is to be as "smart as possible" about future conditions and make decisions that minimize the probability that a bad situation will develop. In the second, it is to make path choices (or path reassignments) that provide the highest system performance possible while not unnecessarily restricting the spectrum of future "capacity relieving options" that can be exercised. This means that in pre-trip decision-making, the task is to make highest and best use of 1) historical information and 2) off-line analyses to identify mode-departure time-path choices that have a high probability of delivering the quality of trip-making being advertised to the user.

Once trips are underway, the real-time decision-making process involves shifting path assignments for individual vehicles from one path to another, thereby "optimally" assigning capacity between and among the vehicle trips taking place. This allows current performance to be maximized subject to a "downstream requirement" that future performance is not adversely affected by inappropriately committing scarce resources that will be of critical value in the future time intervals.

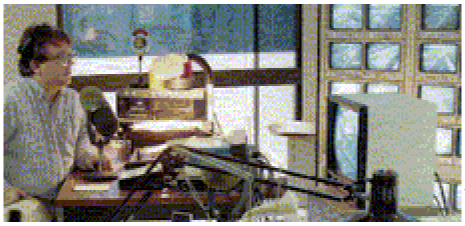
Technical Review Page 54

Dynamic Traffic Assignment (DTA) modeling may be viewed as an extension of static traffic assignment (STA) models that have been used in transportation planning studies for many years. STA models attempt to find an optimal solution to the problem of assigning drivers to network links according to an objective function that defines the goal of the problem. There are two well-recognized goals - User Equilibrium (UE) and System Optimal (SO) solutions. These were identified and defined by Wardrop in the following ways:

- **User Equilibrium:** Under equilibrium conditions traffic arranges itself in such a way that no individual trip maker can reduce his path by switching routes. Also, under equilibrium conditions traffic arranges itself in congested networks such that all routes between any Origin-Destination (O-D) pair have equal and minimum costs while all unused routes have have greater or equal costs.
- **System Optimal:** Under system optimal conditions traffic should be arranged in congested networks in such a way that the average (or total) travel cost is minimized.

The UE and SO solutions may be identical when demand is low and there is no significant congestion. As congestion increases the UE and SO assignment rules will find different solutions. The UE solution finds best routes for the drivers between any O-D pair regardless of congestion effects caused by and to drivers between other O-D pairs. The SO solution finds best routes for all drivers acting collectively, regardless of the fact that some drivers will get shorter routes at the expense of others. With respect to ITS, the UE solution may be considered demand-based and the SO solution may be considered supply-based. Thus, users or drivers tend to follow UE paths and TMCs tend to recommend SO paths. Appropriately trading off these opposing worldviews is part of the job of ATMIS-based flow and network management.

Technical Review - STA Models Page 55



STA models use an O-D matrix of trips, or trip table that is a snapshot of demand over a single time period. Usually, in a planning study, this trip table is derived from earlier trip generation, trip distribution, and modal split steps in a 4-step model. The O-D matrix is loaded onto the network, assigned to appropriate links. The model uses an impedance function to estimate link travel times and uses the link travel times to determine if the objective function, UE or SO, has been met. Most STA models use an algorithm with iterative approach to reach convergence of the solution. As the error in the assignment reaches a small value, the algorithm terminates its search for a perfect assignment.

Generally, as has been discussed, trip time optimization (either UE or SO) has been nearly exclusively used in STA modeling. STA UE and SO solutions have been extended to include multiple-objectives such as travel time, out-of-pocket cost, tolls, and so forth. Such multiple-objective STA algorithms are useful in studies of tolls, transit, and parking policy.

Technical Review - DTA Modeling Page 56

DTA modeling has been approached by many techniques in order to reduce the STA problem extended over the time domain to a computationally approachable problem and to take advantage of the repetitive aspects of finding solutions over the same network over time. The time-extension problem of DTA has been approached in various ways, particularly (a) discrete time and (b) continuous time methods. In discrete time models, the objective function is solved in sequential equal (discrete) time steps. There is no agreed upon time step size; smaller time steps may give greater accuracy, but drive up the computational cost of solving the problem. Continuous time models treat time as an uninterrupted flow. Each type of approach to time in DTA has its advantages that network modelers attempt to use and disadvantages that they try to reduce or eliminate.

Another aspect of time that is important to DTA modeling is the past, present, and future state of the network as well as the day-to-day evolution of demand over the network. One of the critical problems in DTA modeling is finding an appropriate dynamic O-D matrix. Ben-Akiva () and Cascetta () have been active pioneers in deriving O-Ds from flows that are by far the most common form of traffic data available. Time-based flow data collection is done either with electronic counters or with pneumatic tubes placed across the roadway for a few days to get a representative sample. Assuming dynamic O-D data is available over the network, one could see a day-to-day pattern and use this information with present sate information to anticipate traffic over the next few minutes. This adds an anticipatory element to the use of time in DTA that both enhances its power and complicates the formulation of solution algorithms

Technical Review - DTA Modeling (cont'd) Page 57

Also, in using time various mathematical and computer-based methods are suitable. Thus, one sees in the literature a number of approaches including mathematical programming, simulation, analytical methods, automatic control theory, Lagrangian methods, artificial intelligence, and so forth. It is beyond the scope of this session to go into all those approaches in detail, which would be a course in itself, but two projects are discussed below. There is a growing body of network modeling articles in the transportation journals, and a lot left to do in practice.

Two major projects in DTA development and off-line testing have been funded by USDOT: DynaMIT (Massachusetts Institute of Technology) and DYNASMART (University of Texas at Austin). Both models use a rolling horizon approach in predicting future traffic and driver response to information. In a rolling horizon, during the update period (say, 5 minutes) the model calculates the anticipated traffic demand and response to information that must be consistent for the look-ahead period (say, 30 minutes). At the end of the update period, the current time is updated to the end of the update period. The process then repeats itself. In this way the roll period looks ahead at dynamic conditions.

DynaMIT uses a microsimulator, termed MITSIM, to move vehicles across the freeway network. MITSIM has been used to study the effects of various designs on traffic flows on the Boston Central Artery and Third Harbor Tunnel network. DynaMIT has several modules that estimate driver movements and driver acceptance of information. DynaMIT has been used to study the effects of ITS on flows as part of the Boston Central Artery Tunnel project.

Technical Review - DYNASMART Page 58

DTA modeling has been approached by many techniques in order to reduce the STA problem extended over the time domain to a computationally approachable problem and to take advantage of the repetitive aspects of finding solutions over the same network over time. The time-extension problem of DTA has been approached in various ways, particularly (a) discrete time and (b) continuous time methods. In discrete time models, the objective function is solved in sequential equal (discrete) time steps. There is no agreed upon time step size; smaller time steps may give greater accuracy, but drive up the computational cost of solving the problem. Continuous time models treat time as an uninterrupted flow. Each type of approach to time in DTA has its advantages that network modelers attempt to use and disadvantages that they try to reduce or eliminate.

DYNASMART is based on mesoscopic flow model. DYNASMART has been used to estimate the effects of market penetration using a bounded rationality approach to route change. Bounded rationality assumes that drivers will not change routes unless a previously set condition is met for making a change, such as a 10 percent improvement in trip time. Also DYNASMART has been used to compare dynamic UE and SO solutions. Findings showed that there were significant differences between the solutions and that the improvements from ITS would come at medium to high densities.

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The near-term use of DTA models is as design tools to better deploy ATIS equipment and understand the effects of ITS. The end goal of these approaches with respect to ITS is to solve the DTA problem for realistically large networks in real-time, so that they might be deployed in Transportation Management Centers. In a TMC the adaptive response to evolving traffic conditions advanced by the DTA model would be used to modulate the use of VMS, HAR, and IVRGS information to motorists to attain a better network loading. So far, these DTA models have primarily been used off-line to study the effects of congestion and incidents. After considerable development and verification these DTA models will be soon be ready for use in what can be envisioned as a three-step process:

1. Offline location of ATIS equipment and development of incident response strategies

2. Offline assistant to real-time operation in a TMC by operations personnel

3. Online operation of TMC-based field equipment

Self-Review Exercise #4: Check Your Answers Page 61

1. How does Dynamic Traffic Assignment differ from static assignment? Explain how DTA is related to ATMIS.

Solution: Static traffic assignment is a process that takes an O-D table as input and assigns the demand to paths in the network in a manner that the resulting path and arc flows satisfy some equilibrium condition (typically user equilibrium).

DTA is a real-time realization of static assignment that takes projected time-varying O-D demands and attempts to find a solution for the time varying assignment that satisfies equilibrium conditions.

2. What is the difference between online and offline processing?

Solution: On-line refers to a process that is integrated within a real-time system. For example, signal actuation is an on-line process by which traffic signals are adjusted in real-time based on prevailing and anticipated demands. Off-line refers to the execution of a process not connected to a real-time system. Off-line processes often are simulations of real-time systems that aid in systems planning and analysis.

3. What is an O-D matrix and why is it important for DTA systems?

Solution: An O-D (origin destination) matrix is a data set that specifies the estimated demand for travel between an origin zone and destination zone across a transportation network. OD matrices can reflect total trips during a specified duration (e.g., AM Peak) or can be time-varying and represent demand over small time intervals or correspond to day-to-day changes in demand.

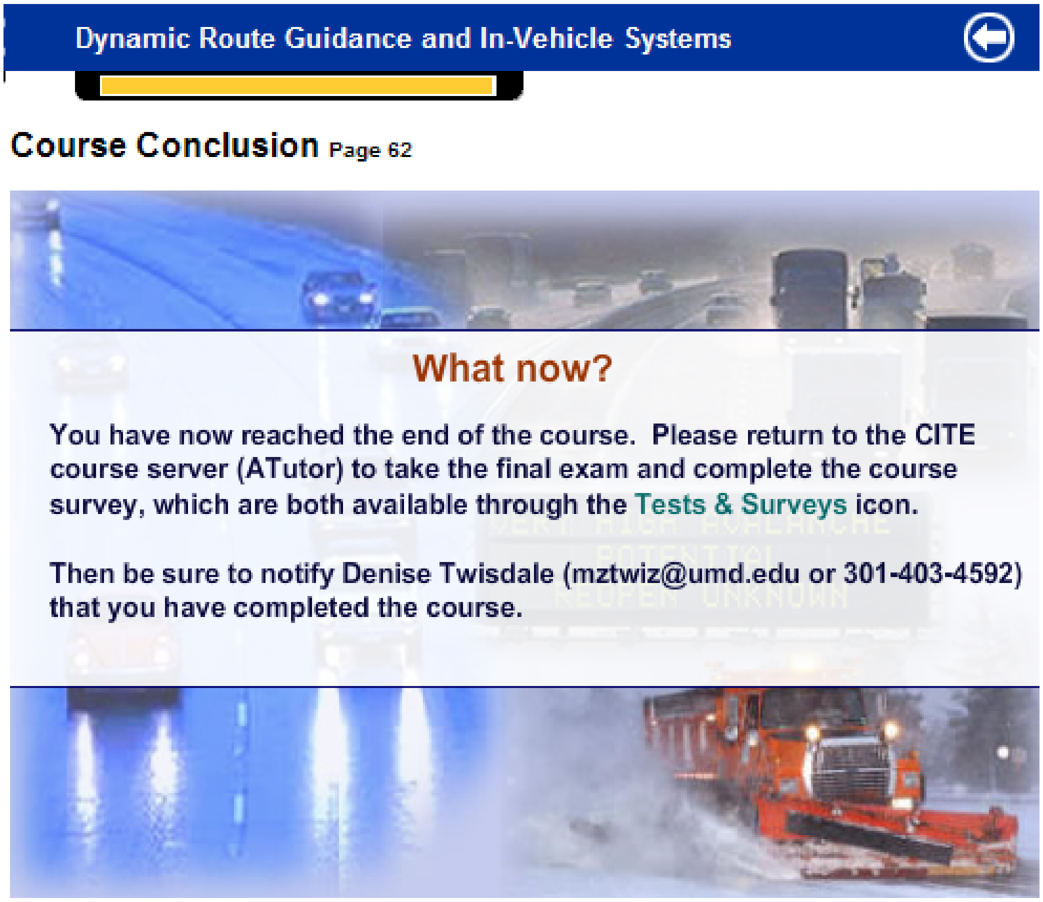
4. Explain the terms User Equilibrium and System Optimal.

Solution: UE: Under equilibrium conditions traffic arranges itself in such a way that no individual trip maker can reduce his path by switching routes. Also, under equilibrium conditions traffic arranges itself in congested networks such that all routes between any Origin-Destination (O-D) pair have equal and minimum costs while all unused routes have have greater or equal costs.

SO: Under system optimal conditions traffic should be arranged in congested networks in such a way that the average (or total) travel cost is minimized.

5. What are the information requirements for a DTA system?

Solution: DTA systems need to have real-time information on current volumes across the network (to assess congestion and travel times), information on control systems in the network, estimates of time-varying OD demands, and information regarding IVRGS and path choice behaviors of drivers.


Dynamic Route Guidance and In-Vehicle Systems
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What now?
You have now reached the end of the course. Please return to the CITE course server (ATutor) to take the final exam and complete the course survey, which are both available through the Tests & Surveys icon.
Then be sure to notify Denise Twisdale (mztwiz@umd.edu or 301-403-4592) that you have completed the course.