CACS—Urban traffic control system featuring computer control

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INTRODUCTION

In Japan, the number of automobiles has exceeded thirty million and the number of driver’s license holders reached thirty-five million (approximately thirty-five percent of the total population) at the end of 1976. Automobile traffic in many cities has been increasing rapidly year by year. Automobiles and trucks, at present in Japan, perform the most important part of a means for transporting passengers and goods. In fact, for seven years, the amount of transportation by automobiles exceeded that by railways in Japan.

Increased use of automobiles in cities, on the other hand, has caused many serious problems: traffic congestion, traffic accidents, air pollution from exhaust gas etc. For example, more than thirty persons are killed by automobile accidents every day. These problems impose great losses and strains on city dwellers. The city traffic problem has become one of the most important social problems in Japan.

To solve this traffic problem, many means and systems have been considered and applied to the cities. Area traffic signal control systems have been installed in the major cities of Japan. Many big cities have also been equipped with air pollution surveillance systems. Enforcing traffic regulations, extending safety facilities, developing new city transportation systems and many other means have been tried.

It cannot be said, however, that the situation has changed for the better. Both time involved and area covered by traffic congestion in the city are still increasing. As a result even with an increase in the number of vehicles, the transporting capacity of automobiles in the city is decreasing.

In order to solve the city traffic problem, it is basically necessary, in addition to the above, to consider a means for increasing efficient utility of the road network in a city. For this purpose, Comprehensive Automobile Control System (CACS) project, which is introduced in this paper, was established and is continuing. The purpose of the CACS project is to develop an effective means and system for controlling the city automobile traffic comprehensively and efficiently. Technically, this project aims to develop a total information processing system for the automobile traffic by combining car electronic device, car-ground communication, computer control and network technologies. This system will be used in coordination with the existing traffic control system mentioned above.

The CACS project is financed by the Agency of Industrial Science and Technology, Ministry of International Trade and Industry. The project started in 1973 and is planned to continue six years. More than twenty million dollars have been invested up to now. Organizations involved in this project are the Research Association for Comprehensive Automobile Control Technology, Toyota Motor Co., Ltd., Nippon Denso Co., Ltd., Sumitomo Electric Industries, Ltd., Nippon Electric Co., Ltd., Hitachi, Ltd. and others.

SYSTEM OBJECTIVES AND FUNCTIONS

In the CACS project, for analysis of city automobile traffic problems, the following four system objectives have been adopted:

1. Relieve vehicle traffic congestion.
2. Reduce exhaust pollution that accompanies traffic congestion
3. Prevent automobile accidents
4. Increase public and social applicability of automobile use.

In order to achieve these objectives, the following four functions have been set up as technology development target functions:

1. Provide optimal route guidance to moving vehicles while preventing congestion and resultant exhaust pollution during the traffic congestion period
2. Provide travel priority to emergency and public service vehicles
3. Provide drivers with driving information pertinent to safe driving
4. Provide drivers with other advance information on for example, the state of traffic emergency in a specific area.

In the actual CACS project development phase, these
Target functions are realized through the development of five subsystems shown below:

1. Route guidance subsystem—A system which guides drivers to their destinations via optimal routes according to traffic conditions by displaying guidance information visually inside vehicles.
2. Route display board subsystem—A system which gives drivers the information on road congestion status and recommends routes by outside visual displays.
3. Driving information subsystem—A system which brings to drivers attention information on traffic regulations and driving warnings by inside indications.
4. Traffic incident information subsystem—A system which transmits accident information and the like to drivers for the area through which they are driving by car radios enforced to receive concerned signals.
5. Public service vehicle priority subsystem—A system which allows public service vehicles, such as ambulances, fire engines and repair trucks pass through with priority. This system is to operate in conjunction with signal control systems.

These five subsystems constitute Comprehensive Automobile Control System. Figure 1 shows a conceptual configuration of the CAC system. Figure 1 also shows potential relationships in the future between CAC system and representative external systems, such as area traffic signal control system, expressway surveillance system and others. Traffic administration and road administration also have important relations to the CAC system operation.

PILOT SYSTEM TEST

A pilot system test was conducted in the CACS project for a year beginning in October of 1977. Purposes of this pilot system test are to:

1. Evaluate the effectiveness of developed technologies in city streets
2. Collect traffic data for future system design
3. Evaluate social acceptability of this system.

The pilot test area is a 28-square kilometer area in the southwestern section of Tokyo (see Figure 2). This pilot area contains a road network representative of the road network of the entire city; 89 main intersections in this area (including 15 expressway ramps) have been chosen as guidance intersections for route guidance. Three hundred thirty test vehicles, which are equipped with full sets of vehicle units, and 1,000 data collecting vehicles, which are equipped with transmitting parts of vehicle units only, are planned to be used in the pilot test.

PILOT SYSTEM FEATURES

The pilot system is composed of the following five subsystems:
- Route guidance subsystem (RGS)
- Driving information subsystem (DIS)
- Traffic incident information subsystem (TIS)
- Route display board subsystem (RDB)
- Public service vehicle priority subsystem (PVP)
Figure 8 shows the system configuration which realizes functions of these five subsystems.

Main features of the pilot system configuration are as follows:

1. The route guidance subsystem forms the central part of the pilot system. The realtime data on traffic conditions are collected by the route guidance subsystem and are used by other subsystems. The guidance indication is fed to test vehicles only in the pilot area but any point in 23 wards of Tokyo can be designated as the destination.
2. The driving information subsystem mostly shares the same equipment with the route guidance subsystem.
3. The traffic incident information subsystem and route display board subsystem also utilize the equipment, especially computers, of the route guidance subsystem.
4. For the public service vehicle priority subsystem, only the function of identifying public service vehicles and their locations is realized.

ROUTE GUIDANCE SUBSYSTEM

Destination code

A driver who wants route guidance subsystem service determines a destination code number corresponding to his desired destination by looking at the guidance road network map of the pilot system. The destination code is represented by a seven digit number. The first two digits represent a region whose area is approximately equal to that of prefecture (2,000km²~14,000km²). A section (whose area is, as in the case of Tokyo, about 30km²) in the region is represented by the first four digits. Each section is divided into less than seven zones (the fifth digit) and the zone includes less than sixty-three points (destinations) (the last two digits). Each point (destination) corresponds to individual sides of the road between intersections.

Vehicle unit and roadside unit

Each test vehicle is equipped with a vehicle unit. The vehicle unit consists of a destination encoder, display unit, vehicle loop antenna and control unit (see Figure 3). The driver, at the start of his trip, sets the recognized destination code number on the destination encoder. The driver can also select the use of an expressway by pushing an expressway option button. When the vehicle passes over a road loop antenna buried near a roadside unit before entering a major intersection, the destination code number and expressway option information are transmitted to the roadside unit through the vehicle antenna, along with other information, such as vehicle unit number and vehicle class code. A roadside unit is installed near each one of major intersections in the pilot test area. The roadside unit consists of a roadside control unit and a set of road loop antennas laid under the road in each arm of the intersection. Each roadside unit is connected to a computer center with a communication line (see Figures 3 and 5).

Guidance indication

The information from the vehicle unit is fed into the roadside control unit with the information identifying the road from which the vehicle is entering into the intersection. Using the destination code number, expressway option information, vehicle class code and entering link number as key words, the roadside control unit searches a guide table stored in the unit and keys guidance information corresponding to the request. The guidance information is sent back to the vehicle unit through antennas and is indicated on the display unit attached to the dashboard. The indicated information includes the following (see Figure 4):

a. Intersection shape (intersection indicator emblem in Figure 4)
b. Turning direction (indicated with one of seven arrows; the case in Figure 4 indicates a turn to the right)
c. Lane selection before entering intersection
d. Lane selection after passing intersection
e. Slope (UP: uphill, DOWN: downhill)
f. Entrance to expressway
g. Exit from expressway
h. Emergency guidance (detouring instruction)
i. Destination arrival (indicated by flashing arrow).
Driving in accordance with the guidance indication of this subsystem from the start point to the destination enables the driver to reach the destination in the minimum amount of time even though he is unfamiliar with the place. This guidance indication is automatically updated every fifteen minutes according to changes in present and predicted future traffic conditions.

System configuration

Figure 5 illustrates the route guidance subsystem configuration. One hundred and three roadside units installed at major intersections in the pilot test area are connected to a communication control computer in a control center with 1200 bps speed data communication lines. Six computers are installed in the control center: a communication control computer, central computer, operation control computer, traffic network controller and two route search computers. A traffic network simulator performs a substitute for the route search computers. One hundred and eighty two conventional traffic flow detectors are connected to the system in order to measure the vehicle flow rate and road occupancy.

System operation cycle

General guidance information fed to drivers is automatically updated every fifteen minutes. Every processing required for its renewal, such as traffic data processing, traveling time estimation (arc costs), optimal route computation, guide table formation and so on is consequently carried out in fifteen minute cycles. Some other processings, for example diagnoses of roadside unit efficiency, are also executed every fifteen minutes. The data on traffic flow and road occupancy are collected from detectors at five minute intervals. The information from vehicle units is gathered at one minute intervals. Lengths of these cycles can be changed by commands from an operating console.

The basic operation of this subsystem consists of a sequence of the following three cycle operations. The data on traffic flow, density and running test vehicles are collected in the first fifteen minute cycle. Upon these data, the optimal paths are computed and the guide tables are made in the second fifteen minute cycle. In the third cycle, the guidance for the vehicle is performed according to these guide tables. Therefore, the vehicles are eventually guided on the basis of data for two cycles before.

Information flow and processing

Figure 6 shows an outline of the information flow and processing in this subsystem. The communication control
computer collects data on points and times of communications between roadside units and equipped vehicles from roadside units and sends the data to the central computer. The data on traffic flow rates and traffic densities, detected by the detectors, are also collected from the roadside units and a traffic data processing unit and sent to the central computer.

In the central computer, an arc cost for each segment of the road network is estimated and predicted on these collected data. Here, the "arc cost" represents the length of time required to traverse the distance from one communication point to the next communication point beyond the intersection. These arc cost data are sent to the route search computers or to the traffic network simulator.

The route search computers compute optimal paths using the arc cost data, pertinent area traffic regulation data and other network data. The computation of optimal route search is performed at each intersection. Time-minimal paths from each intersection (origin) to every point (destination) in the network are computed. The network structure is expressed most precisely near the starting point (origin) and its expression becomes less precise as the field goes away from the starting point.

Computation results are condensed into a guide table from every guidance intersection. The guide table is expressed in a combination of list and table structures. The maximum size of the table is less than two kilowords (one word is sixteen bits). The guide table thus formed is transmitted to each roadside unit through the 1200 bps speed data communication line. The use of the guide table at the roadside unit was previously mentioned.

OTHER SUBSYSTEMS

Driving information subsystem

The driving information subsystem gives the driver information helpful to safe driving by inside display and audible signal. When a vehicle equipped with the vehicle unit passes by a buried loop antenna connected to a roadside unit, pertinent area traffic regulations and other information on the road the vehicle is traversing is transmitted to the vehicle unit and any pertinent warning information is shown on the display unit. The warning information is expressed in one of the following messages (see Figure 4):

1. Pedestrian crossing (① in Figure 4)
2. Go slow
3. Change in lane condition
4. Stop
5. Change in width of road
6. Road under construction.

The information on the posted speed transmitted from the roadside unit is stored in the vehicle unit, which checks the vehicle's cruising speed. When the vehicle speed exceeds posted speed limit, an audible warning signal is emitted.

The contents of this driving information, stored in the roadside unit, is updated by the master information in the central file at every system cycle. The contents can also be changed by intervention command from the control room.

Traffic incident information subsystem

The traffic incident information subsystem informs a driver about information on emergencies which affect traffic flow by means of area-limited broadcasting. The broadcast information includes the news on traffic accidents, fire, sudden traffic jam and the like. It also contains advice for the driver such as recommended route, foreseen trip time etc.

In an emergency, the above information, a part of which is made up of arc cost data from the route guidance subsystem, is immediately transmitted from the control center to pertinent TIS roadside units. Each TIS roadside unit broadcasts the information to vehicles through the leaky coaxial cable antennas (LCX). When a vehicle having a car radio equipped with TIS radio adapter enters into LCX range, the vehicle receives the announcements. These announcements interrupt regular radio broadcasts and are received even though the radio is switched off.

Route display board subsystem

The route display board subsystem furnishes data concerning traffic conditions to all drivers of vehicles which are...
not equipped with vehicle units. The information includes data on traffic congestion, accidents and/or recommended routes. This data is indicated on route display boards installed along the road. The names of a number of neighboring intersections and arrows connecting them are illustrated on the board (see Figure 7). The traffic conditions on the route between two intersections connected by an arrow are indicated by the colors of the arrow:

1. Red: heavy congestion
2. Yellow: slight congestion
3. White: no information
4. Green: recommended route to a major intersection

The congestion information and recommended routes result from arc cost data calculated in the route guidance subsystem. They are sent from the central computer system to the route display boards through off-line operator handling.

Public service vehicle priority subsystem

The function of this subsystem is not realized in the present pilot system. Only the capabilities of detecting and tracking the equipped public service vehicles on the central wall type display are checked.

CONTROL ROOM

Figure 8 is a sketch showing total CACS pilot system configuration. A control center is located nearly at the center of the pilot test area. One large-scale computer (NEAC 2200/375), five minicomputers (four NEAC 3200/70 and a HIDIC 350), one special-purpose computer and four specific use processors are installed in the control center.

A control room is included in the control center in order to control and manage operation of the overall system and to supervise pilot test execution. The major devices installed in the control room are a supervisory operating console, four subsystem operating consoles and a wall display (see Figure 9). The wall display includes a central screen display (2.0m × 1.5m) with a projector in the rear, color character CRT display, lamp panel and a few indicators.

With the aid of these devices, the following operations are performed in the control room:

1. Initial system set up
2. Starting and stopping the overall operation or partial function of the system
3. System function intervention after an accident, in an emergency situation etc.
4. Recording system operating data
5. Roadside unit status diagnosis
6. Changing system parameters, configuration etc.

Figure 8—Pilot system configuration
7. Monitoring traffic conditions
8. Monitoring system and device status

The congestion degree on each road in the pilot test area, public service vehicle location, optimal route and like data are indicated by colors on the map projected on the central screen of the wall display. Information pertinent to tracking a designated vehicle can also be illustrated there. Roadside unit and detectors status data are indicated on the character CRT display. In addition, the computer system’s status, test conditions, data and time are shown on the wall display. Most of these figures can also be seen on the color graphic display mounted on the operating console.

CONCLUSION

The Comprehensive Automobile Control System has been described. Essentially, the description has concentrated on its pilot system. It is expected that the CAC System will produce many beneficial effects on individual drivers and society to:

1. Lighten the driving effort of a driver who is unfamiliar with an area by guiding him on the optimal route to his destination
2. Reduce the time required for traveling from the start point to a specific destination
3. Relieve local traffic congestion in a city
4. Decrease traffic accidents due to careless driving
5. Eliminate the gasoline waste caused by engine idling in traffic congestion
6. Reduce air pollution due to exhaust gas.

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