THE APPLICATION OF ELECTRONICS IN TRAFFIC RISK CONTROL

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SUMMARY

The introduction of electronic aids in traffic offers special opportunities for alleviating tasks of both public bodies and individual road users. However, the introduction is often problematical too. In this context potential and existing applications are discussed in a functional classification, based on the traffic safety process. Perception, decision-making and action are dealt with for each phase of the process. The discussion gives rise to conclusions, relating to respectively the stimulation of new developments, applied research, broader application, and optimization. Finally, demands prior to instrumentation and implementation of electronics in traffic are considered, among them possibilities and restrictions related to electronics themselves, aspects of information transfer to and information processing by road users, and the impact on traffic task performance.

1. INTRODUCTION

The use of electronic aids is currently growing rapidly in practically every area of our lives, by no means least in the area of transport and traffic. This is due mainly to the advent of integrated electronics, or micro-electronics, which has increased the possible applications considerably, while at the same time miniaturization and the drop in prices have removed practical and economic obstacles. Particularly interesting in this connection are the developments in the field of digital micro-electronics: with its great processing capacity, flexible programmability, precision and reliability it is now in principle able to tackle functions which until now have been the exclusive province of human operators. Ideas on the incorporation of electronics in our daily lives, however, have remained way behind technological developments. The availability of electronic aids is often sufficient reason for their introduction. Furthermore, the society - and the authorities, acting on its behalf - lack effective means of guiding the introduction of electronics. This paper attempts to give a systematic account of the possible applications of electronic aids in road traffic, the current applications and the gaps or areas where improvements could be made. The emphasis will be on the role electronics can play in improving road safety. The problem has accordingly been approached by way of a functional classification based on the accident process, seen from the point of view of both road users and the authorities. Finally, we shall look at the preconditions for the introduction of electronics in road and traffic systems.

2. FUNCTIONAL CLASSIFICATION

The processes which take place in traffic can be classified by their interrelations, the order in which they occur and the time they take. Traffic is a result of people's need to take part in social, cultural and economic activities; we shall not discuss the influence of electronics on travel needs. The starting point for our considerations is travel behaviour, which comprises a number of planning processes: the choice of destination, the transport mode, the route, and the timetable.

The actual performance of a planned journey involves participation in traffic. The processes which take place here can be subdivided into two levels of performance, a 'scenario level' and a 'script level'. The scenario level covers the processes associated with following a route, plotting a course and choosing a position on the road. These activities we call traffic behaviour. The script level covers activities such as braking and steering as a result of encounters with other road users, discontinuities in the road course, etc. - manoeuvring behaviour.

In the phases of the traffic process we have discussed so far the road user can still act effectively to prevent an accident. In the crash phase itself the road user's activities play hardly any part; for the most part he is dependent on the course of events. Electronic aids can however still play a part in reducing the amount of damage. In the post-crash phase electronics can be used in assisting the victims and removing the obstacle to the traffic process.

To function in the traffic process road users must perceive, make decisions and take actions, accepting a certain degree of risk, themselves taking certain risks and dealing with risks which materialize. Risk control is thus an integral part of their functioning. Electronic aids can make perception, decision-making and action in the various phases of the accident process easier for road users; they can even take over certain tasks entirely. What has just been said about individual road users also applies broadly to the authorities, who also have to perceive, make decisions and take actions to enable traffic to flow as smoothly as possible with a minimum of harmful effects (accidents, air pollution, noise etc.). In the ensuing chapters we shall consider what part electronics can play in each phase of the accident process to alleviate the tasks of road users and the authorities.

3. TRAVEL BEHAVIOUR

3.1. Possible applications

To begin with, electronic aids can be used to collect up-to-date information on traffic as a whole - census data on the amount of traffic and the modal split at a given moment and on traffic movements. The authorities need data of this kind in order to make sound large-scale policy decisions on, say, the infrastructure or mobility. Electronic computing equipment, with the associated software, is needed to analyse large quantities of data, and decision-aid software can assist with decision-making.

In order to balance the various interests within the traffic process (safety, flow, comfort) against one another and to balance the interests of traffic against interests in other fields for which the government is responsible, the traffic census data can be linked with accident data or data banks of other national monitoring networks, e.g. environmental measurements. This fulfills an important information need on the part of the authorities. The monitoring equipment could in theory also be used to identify objects, although there would have to be safeguards to ensure that there will be no interference with road users' privacy.

The picture of traffic which the government can obtain using electronic aids for detection, data processing and analysis covers a wider area than the individual's field of vision. By passing on this information to road users, with or without recommendations or instructions as to behaviour, the authorities can make road users' job of perception easier and directly influence their decisions and actions. Thus, temporary problems in particular, with the associated risks, can be prevented or solved.

Electronic aids can intensify communication between the authorities and road users and enable the information to be made more and more specific.

3.2. Existing applications

Data collection and processing

All the industrialized countries have set up computerized monitoring systems to collect traffic data on a continuous basis (1). These networks are generally sparse and usually measure only the numbers of road users, providing only a rough idea of the major national traffic movements. In addition, mobile or temporary monitoring systems are installed to supplement the aforementioned data on the main road network: these systems provide information on specific locations, for example, or the secondary road network. Monitoring systems, which play a part in traffic control systems, are also occasionally added to national networks. Examples of the parameters measured are vehicle speeds, distances between vehicles, traffic density and the traffic mix (derived from distances between axles or axle loads).

Automatic equipment to collect data of this kind has been available for some time and there is a relatively large quantity of literature on sensors and detectors, their installation, the appropriate hardware and data-processing software (2,3,4,5,6,7,8,9,10).

Data on destination, trip motive, mode of transport, route, trip duration and length, time and so on are generally obtained from periodic surveys among samples of the population, sometimes supplemented by data from toll systems.

Various countries are planning to make their monitoring networks denser and collect more data automatically as a matter of course, in particular the data mentioned above which at the moment are collected only from time to time (1).

In all the countries where automatic traffic censuses are carried out nationally the results are compared with accident statistics and often with data on recreation, air pollution, etc.

Information transfer

In all the Western countries the authorities, and sometimes private organizations as well, provide road users with information on special situations concerning the roads, traffic and conditions. The factual information is often combined with prognoses, recommendations or instructions. Particularly interesting are the developments in information transfer by way of radio and viewdata.

Traffic information by radio usually operates as a self-contained system: data obtained automatically or otherwise are collected and evaluated centrally and broadcast via radio stations. The information is generally broadcast periodically or at regular times on a certain station; in urgent cases news flashes may be broadcast. So far it has been mainly reports of national importance which have been broadcast. A number of European countries, however, also broadcast regional traffic information modeled on the West German 'Autofahrer Rundfunk Information' system, or intend to do so in the near future. This enables reports to be broadcast more quickly and selectively. In the German system FM frequencies are assigned to sections of the road network and indicated alongside the road. Road users can tune to the particular frequency manually, or there are receivers which will tune to it automatically, awake from a 'sleep state', or override other stations. Developments are also taking place in the field of local radio traffic information services, but these will be dealt with in the next chapter, on traffic behaviour. Another development in traffic information by radio is digital broadcasting of information, which can be stored in the memory of a special receiver. This enables the transmission time to be reduced considerably: a 90-second report, for instance, takes only 1 or 2 seconds to transmit. Road users can then selectively call up that information, which is relevant to their routes. Various sources describe radio traffic information systems in detail (11, 12,13,14,15,16). These authors discuss such things as: the reliability, accuracy and form of the information; restrictions on receiving; linking possibilities with other sources of information; and effects on road users' behaviour.

Experiments are taking place with viewdata in Great Britain and the Netherlands. Subscribers can request recent information on the quickest, shortest or most interesting route to a destination on a screen. Additional information can be provided on journey times, landmarks on the way, etc. At the moment a road user wishing to use the information en route has to remember it or record it on a photograph, but experiments are in progress with tape-recorded information which can be shown again en route.

Also worth mentioning, lastly, is an advanced electronic toll collection system developed for Hong Kong, which should be operational in 1987 (17). Vehicles entering the toll area are automatically identified with the aid of detectors in the road and electronically readable number plates, and recorded at monitoring stations. The toll charges are determined centrally depending on the place and time of entry into the toll area, the route taken and the destination. The charges are deducted from road users' accounts automatically at regular intervals. This system is meant to control traffic in the city centre, by means of economic pressure. Certain elements of this system involve an encroachment on road users' privacy.

3.3. Recommendations

The current trend in the collection of information on traffic movements would seem to be mainly towards making the monitoring networks which are already operational denser, and increasing the amount of data being recorded on a permanent basis. It is well worth asking, however, whether this is the most efficient way of meeting the information needs of policy-makers and researchers in the field of traffic and road safety. To answer this question properly these needs would first have to be carefully surveyed. Even at this stage the likelihood is that it would be better to collect only a limited quantity of absolutely necessary basic data permanently. The other data could be collected ad hoc from samples; the samples should however be drawn systematically. A method of this kind, which is increasingly being used to replace population censuses, would make a considerable increase in ways of meeting information needs including those in areas of government responsibility other than traffic, and it would make for more dynamic thinking. All this could be achieved at relatively low cost and with relatively little effort.
The best way of passing on information at present would seem to be the radio traffic information service, especially considering the improvements in methods, usefulness and user-friendliness which it seems could be achieved in the near future. Its use nationally is subject to various limitations relating to information content, viz. the specific nature, detail and selectivity of the messages. Regional radio traffic information services are much less subject to these restrictions: the general information can be supplemented with specific information on smaller areas. Particular attention should be given to the development of a system that broadcasts messages in compressed form which are subsequently translated into intelligible texts by the on-board radio. This obviates the need for long interruptions of programmes even if the number or length of the messages increases.
It would also be possible to prefix a message with a regional code so that messages could be received selectively and the number of transmit-

ters could remain small. In this way the information package could continue to be enlarged, both in the field of travel behaviour and in that of local traffic behaviour. This development would require more extra-vehicular equipment, i.e. the systems for collecting, processing and passing on the information. Few modifications would be required of the receiving equipment, however, which has definite practical advantages. There has been no systematic study as yet of the ways of building up extensive radio traffic information systems and the compatibility requirements, although it is clear that the acquisition and processing of the information would require great efforts on the part of the central bodies.

Electronic vehicle identification offers ways of directly influencing travel behaviour. Certain categories of vehicle or owner could for example be denied access to certain areas (e.g. city centres) at certain times. The identification would not have to be so detailed as in the toll system in Hong Kong mentioned above; this would considerably reduce the problems associated with privacy. A limited form of identification could furthermore make it easier to obtain information on traffic. The literature examined did not in fact mention any practical applications of restricted identification systems of this kind.

4. TRAFFIC BEHAVIOUR

4.1. Possible applications

At the level of traffic behaviour, electronics could help the authorities to distribute traffic over the road network, guide traffic flows and detect hazards; in short to control traffic. From a static local activity, traffic control could develop into a dynamic integrated system for guiding traffic over an entire road network. With the aid of electronics time and place-determined behaviour could be detected, processed and taken into account in traffic control, albeit this would place considerable demands on the software. Integrated control could avoid problems instead of solving them.
The information the government collects for traffic control could also be used to help individual road users to function, providing information on routes, recommended speeds, the state of the road surface and so on. This information could be passed on in the form of factual announcements, recommendations or instructions; it would even be possibe to intervene in the control of vehicles. Lastly, electronic aids could provide drivers with independent information storage and data processing facilities to ease their task of navigation. These systems could be designed so that they can be influenced from outside.

4.2. Existing applications

Traffic control

The current applications of electronic aids in traffic control include both detection of hazards (due to weather conditions, incidents or traffic density) and guiding traffic flows on roads or over road networks. Fog, ice and strong winds can be detected automatically (18,19,20,21,22, 23,24,25).
Incidents cause road users to execute emergency manoeuvres - braking, suddenly changing lane, etc. At a certain traffic density, manoeuvres of this kind are reproduced upstream, whereas downstream the traffic density reduces and speeds increase. Automatic electronic incident detection systems measure and analyse behaviour of this kind and are thus able to determine the place and time of an incident. It is known that the traffic

density on certain roads reaches almost maximum capacity during rush hours. The greater chance of congestion increases the chance of incidents. Consequently, systems of this kind may also be designed not only to detect incidents but also to detect or even predict saturation of road capacity. Often additional facilities are incorporated to establish the causes of incidents, e.g. television surveillance (26,27,28,29,30,31). The principles of incident detection systems are increasingly being incorporated in other traffic control systems; some examples are given below.

Ramp control

The traffic flow on a main artery can be improved by controlling traffic on approach roads. Advanced systems are able to judge the amount of traffic to be admitted a good distance upstream.

Queue warning

Systems of this kind make traffic approaching a queue reduce speed gradually and in good time. The more advanced systems determine speeds and traffic densities on a section of road permanently. As soon as a queue forms somewhere, upstream road users see illuminated signs with reducing recommended speeds.

Homogenization of the traffic flow

Where necessary, recommended speeds are indicated and overtaking is prohibited on the basis of measurements of traffic density, speeds, weather and light conditions, and traffic mix.

Comprehensive traffic control systems

The function of these systems is to permit traffic control in an area under varying conditions, to achieve the greatest safety and the smoothest flow of traffic. They comprise various subsystems: incident and queue detection, homogenization, ramp control, indication of poor weather conditions and alternative routes. Some of them are linked to urban traffic control systems. The subsystem which detects the worst condition overrides the others. In addition to indicating recommended speeds and lanes, the system can also provide information on the nature of a problem. Subsystems to detect poor weather conditions are not yet completely reliable; the warning signs still have to be switched on by human operators, as they do in the case of roadworks.

Assisting road users

In theory electronic information and communications aids to assist road users can be divided into traffic information (including hazard warning), route information and modification, and emergency message systems. In practice, however, these systems are combined in various ways.

Locally relevant information collected centrally and kept up-to-date can be provided by way of on-board radio. 'Local cellular radio', as it is known, is used in various countries in various forms, most of them experimental.

Route information systems can be divided according to design into two-way and one-way (or semi-one-way) communications systems, and independent systems (32,33,34,35,36). A two-way system consists of a transceiver, a destination keyboard and a display in the vehicle, a transceiver with the corresponding hardware in or alongside the road, and a central computer. The driver feeds his destination into the central computer through the keyboard. The computer determines the best route, which is then shown on the display. The system takes account of current traffic and weather conditions and other route requests. It can also give information on suitable driving behaviour. Systems of this kind have been tried in the United States, Germany and Japan (37).

A one-way or semi-one-way system consists of the components mentioned above plus an on-board computer in the vehicle. Traffic approaching a congestion can be distributed over alternative routes by having the central computer send different information to the on-board computers in turn. A system working on this principle has been designed in the Netherlands (38).

In the case of independent route guidance systems most of the system is in the vehicle. Alongside the road beacons can be stationed which transmit location data to the vehicle. Before starting his journey the driver feeds his starting point and destination into the system. A map stored in the vehicle in digital form can be shown on a display. The system determines the route and indicates the direction to take at each point where a choice has to be made. Systems of this kind are being developed in various countries, most of them still at an early experimental stage.

Lastly it should be noted that two advanced emergency communications systems have been developed in Germany. One is a mobile telephone system which uses coaxial cable antennae and relay stations. The other provides two-way radio communication between vehicles and a central control room, and automatic location of vehicles.

4.3. Recommendations

Hardly any evaluation of the effects of traffic control systems, particularly on road safety, has been carried out yet. Consequently it is often unclear how well they perform, whether particular designs have advantages, where improvements could and should be made, and so on. Information on these matters could guide development research into practical applications and encourage more widespread use. Little is known yet about the cost-benefit ratio, although considerable investments are required to install the more advanced systems.

As regards comprehensive control systems, a strategy should be devised by which they can be built up from subsystems and the linking facilities should be standardized. The system can then be extended gradually with the addition of subsystems which have proved their worth.

The various electronic systems to assist road users differ considerably in their aims, the way they present information, the location of data processing, and the form of communication. Examples of functions are route information, route guidance, hazard warning, traffic control and combinations of these. The single-function systems are limited in their usefulness, but most are potentially capable of performing more functions. The systems enable central authorities to take over decisions from road users and prescribe their behaviour. The majority of these systems are still at the experimental stage. Experiments involving transmission of information as part of traffic control are few and far between since the extravehicular equipment forms part of comprehensive control systems, most of which are themselves still at the development stage. The information can be given in visual or auditory form: both systems would seem to be applicable, but more information is needed on the advantages and disadvantages of each. The information can be collected and processed centrally and then passed on; all the road user needs is communication equipment. If on-board computers process the information, the central authorities have fewer ways of influencing road users and there is less flexibility.

As regards one-way and two-way communications, two-way systems provide more scope for individualization, but this has not yet been fully explored. Special attention should be given to the possibility of localizing vehicles sending out emergency calls.

5. MANOEUVRING BEHAVIOUR

5.1. Possible applications

In theory central authorities can assist road users to regulate their speeds, follow the road and avoid undesired encounters with the aid of electronic systems; they can even take over certain tasks from road users entirely. The government will probably not be able to introduce systems other than those which are independent and vehicle-linked until comprehensive control systems have been introduced on a large scale.

5.2. Existing applications

The existing applications are:
- cruise control;
- lateral position control;
- longitudinal guidance;
- collision avoidance systems;
- anti-locking systems;
- steering wheel movement control;
- general vehicle monitoring and warning systems.

Cruise control systems enable a predetermined speed to be maintained. They are particularly useful on long-distance routes where there is a speed limit in force (39,49,41).

A number of systems have been developed to help drivers maintain lateral position on the road or take over the task from them. They are still at the experimental stage. A sensor on the vehicle detects markers in or alongside the road; the information thus obtained is passed on to the driver or to an automatic control system.

Longitudinal guidance and car-following systems work on two different principles: central control and control from the vehicle. Combinations are also possible. In centrally controlled systems each vehicle is followed from a control centre and its position set. This system requires an extensive infrastructure in the form of detectors and communications facilities, whereas the equipment on the vehicle can be relatively simple. In-vehicle control systems require advanced sensors and computing equipment to determine and control the vehicle's position in relation to the road and other road users. In the combined forms, sensors on the vehicle pass on information to a control centre; on the basis of this information and information from its own position sensors the control centre assigns each vehicle a target position (set point control). The equipment in the vehicle uses its own strategy to direct the vehicle to the target position (36,42,43,44).

Collision avoidance systems reduce the risk of collision by warning the driver in good time or automatically applying the brakes and slowing the engine. Most of the systems, which are still experimental, use radar on the front of the vehicle (45).

Anti-locking systems are already being used on a fairly large scale. They ensure that the wheels keep turning during braking, making for a shorter braking distance and better directional stability. Magnetic induction sensors measure the speed of revolution of each wheel being braked; if a wheel locks or slips too much the braking power on it is automatically reduced. The system is also very useful for increasing the stability of articulated vehicles and preventing jack-knifing (46,47,48,49).

Steering-wheel movement control operates on a speed-related basis; it prevents a deflection from being made which is larger than the stability of the vehicle permits. The effect can to some extent be compared with that of modern power-assisted steering systems, whereby the higher the speed the lesser the power assistance.

General monitoring and warning systems keep the driver informed of the way essential vehicle components are functioning. Systems of this kind usually recognize different levels of urgency and adapt their warnings accordingly.

5.3. Recommendations

Various electronic aids to manoeuvring have been developed to the point that they could be installed as standard features: anti-locking systems, steering-wheel movement deflection controllers and general monitoring equipment. The first two systems in particular are useful on roads which carry mixed traffic and would indirectly benefit the safety of non-motorized traffic considerably. The systems which aim to provide one form or another of vehicle guidance are still for the most part at the experimental stage; we have not come across practical trials on a significant scale. Nor does the literature contain detailed ideas on incorporating them in traffic control systems, although this is possible in theory. Apart from anti-collision systems, guidance systems restrict themselves to assisting drivers. The possibilities of taking over drivers' tasks should be researched further. Special attention should be paid to possible risk compensating behaviour, and the possibilities of correcting malfunctions. Where the final decisions are taken is also a matter of importance: if the decisions are taken centrally, the authorities have more control over traffic than if the on-board equipment or the driver makes the decisions. In critical situations, however, the correctness of the decision must meet extremely high standards; this aspect requires more study.

6. EVENTS DURING AND AFTER AN ACCIDENT

As soon as an accident is inevitable electronic aids can activate mechanisms to protect the vehicle occupants. Applications include the airbag (50) and a device that pulls safety belts tight. Both devices are activated on the basis of measurements of vehicle deceleration.
Experiments are taking place in Great Britain with a device for catching pedestrians so that they are not thrown out in the event of a collision.
In the post-crash phase electronic aids can be used for communication; in the first place to alert emergency services. The alarms should be connected with central emergency systems and traffic control systems, the latter to warn other road users in good time, prevent congestion and so on. Electronic aids can also be used for supervising the assistance.
Speed, reliability and completeness of information play a decisive part.
In practice the communication function for road users has materialized in roadside emergency telephones and other telephone systems. The emergency services (ambulance, police and fire service) have already been using mobile telephone systems for a long time. There is not usually any direct link between the emergency services and the road users in the vicinity of the accident.
Electronics can play a greater part in alerting and in emergency services. Of special importance is apparatus that acts as a radiographic beacon for emergency services and other road users after an accident. In this connection the two-way communication systems with automatic location detection of the vehicle are of great interest.

7. THE INCORPORATION OF ELECTRONIC AIDS IN TRAFFIC

Electronic systems work similarly to human perception, decision-making and action: input, data processing and output. What input information an electronic system requires depends on the function. In general the information is likely to be dynamic and therefore has to be measured permanently, either continuously or sampled. The correctness of the measured data usually has to meet high standards. Examples from present-day traffic - and from process industries - show that measuring presents many problems. Furthermore, derived data often have to be used, causing particular complications. In short, the information required cannot by any means always be obtained in sufficiently reliable form.

Data processing includes weighting and decision-making, which are extremely important in risk control. A good understanding of traffic is essential to the development of the required software; this includes knowledge of the way in which 'intelligent systems' such as humans transform input into output. The results of the data processing also have to be valid for specific cases. Numerous problems are associated with data processing: often large quantities of data on a limited number of characteristics are used. Inadequate understanding of traffic can result in the wrong choice of characteristics, with the attendant risk of suboptimization: solving one problem creates others. The large amount of data has to be aggregated. If the resulting generalized picture does not allow for exceptions, there is a danger that incorrect decisions will be taken for particular circumstances or groups of road users. The output has to be presented in some form or other for further use. If the user is not human, another system, not necessarily electronic, has to be activated. Mechanical systems are considerably slower than electronic ones, much more subject to wear and tear, and require more maintenance. In an electronic system with mechanical components the latter limit the system as regards speed and reliability. If the user is human, the output can consist of information or intervention in human action. When implementing electronic systems, allowance has to be made for the specific problems humans have when processing information:

Problems of capacity

The human brain has only limited space available for data processing, thus humans are inclined to choose all sorts of suboptimal solutions, such as selective absorption of information or use of simple decision rules. Electronic aids can in theory overcome this problem of capacity by representing the problem in the optimum way and applying a suitable but complex decision rule.

Problems of discrimination and interpretation

If humans have to collect and process their own information quickly, perceptual quantities which hardly differ can cause problems of discrimination. If the information is relevant to several traffic processes a problem of interpretation can occur. Electronic aids can present the information in unmistakable and unambiguous form.

Problems of motivation

Information which is not confirmed by the road user's experience can result in the road user ceasing to obey instructions and recommendations, certainly in the long run. The information must therefore be recognizably related to the reasons for its being given.

Direct intervention in human action may be designed to improve the quality of performance of tasks or to homogenize or ease performance, and can result in a shift of tasks. Tasks can be performed consciously (cognitively) or perceptually-motorically. In the latter case, which is found mainly in manoeuvring behaviour, information designed for conscious processing makes less sense; facilities which directly assist human functioning are more appropriate here (e.g. anti-locking or steering-wheel movement control systems). When intervention takes place in consciously performed tasks the possibility of a shift of tasks should certainly be considered, with the road user taking on a more supervisory role (supervisory control). Aspects of this are: influences on the nature and level of attention, creativity, 'freedom', informal thinking and action, etc. It is worth mentioning that drivers who carry out only supervisory tasks eventually become unable to perform actions: manual operations must be practised regularly. An excessive degree of automation makes this impossible, unless systematic use is made of realistic training simulators - as in aviation. The road user can also feel alienated from decisions taken at a great distance from him. He is not able to make the link between decision and data himself and must therefore just assume that the decision is right, even if it does not look right! Experience of these problems in aviation indicates that they are of considerable importance. As far as road traffic is concerned, it should be added that the fact that this more radical form of influence is usually likely to occur temporarily, merely complicates the problem: temporary influence creates a discrepancy not only in the nature of the driver's tasks but also - in practice - in the nature of the traffic conditions in which he performs them, since such influence can be expected to take place only on main roads. The 'transition' to, say, a residential area becomes much greater than is now the case, and more problematic. Solutions to the existing problems are currently being developed on the lines of zoning systems: residential, traffic and mixed areas. Obviously these applications of electronic aids should not be introduced until they can be structurally incorporated in solutions of this kind.

REFERENCES

(1) BENJAMIN, T.E.A. (1983). International overview of accident, traffic and travel behaviour systems. IDBRA, Neuilly.

(2) DORSEY, W.F. (1976). A status report on vehicle detectors. Fed. Highway Admin., Washington, D.C.

(3) KENTON, E. (1979). Highway traffic detectors and detection. Nat. Techn. Information Service, Springfield.

(4) SIFFERT, M. and BRIANT, G. (1976). Traffic analysis and control by means of magnetic loops and dynamic weighting bridges. Bulletin Liaison Laboratoire des Ponts et Chaussées (1976) 83: 39-52.

(5) DEAN, K.G., MACDONALD, D.E. and MORRIS, D.J. (1977). Vehicle detector loop configurations. Phase 4. AWA Research Laboratory, North Ryde.

(6) VAN ZIJVERDEN, J.D. and VAN DER VOORT, R.C. (1979). Geometrie van lusconfiguraties voor snelheidsmetingen. Verkeerskunde 30 (1979) 9: 422-424.

(7) ANDERSON, G.M., KOBLE, H.M. and TIGNOR, S.C. (1980). Suggested guidelines for locating freeway sensors. Inst. of Transp. Eng., Washington, D.C.

(8) RICHARDS, B.E. (1978). A microprocessor-based data acquisition system. Australian Road Res. Board, Vermont.

(9) HOOPER, D.E., HEDLEY, G.R. and HARTLEY, F.T. (1978). Extension of vehicle detection functions by the application of advanced engineering techniques. Institution of engineers, Barton.

(10) ANON. (1976). Device for the classified count of road vehicles: eight categories. Institut de recherche des transports, Arceuil.

(11) COMMISSION OF THE EUROPEAN COMMUNITIES (1981). Euco-Cost 30. European project on electronic traffic aids on major roads. Luxemburg.

(12) BAANG, K. and PETERSON, B. (1981). European project on electronic traffic aids on major roads. Report 9th IRF World Meeting 1981. Svenska Vaegfoerningen, Stockholm.

(13) MINISTERIELE WERKGROEP RADIOVERKEERSINFORMATIE (1982). Radioverkeersinformatie. Ministry of Transport, The Hague.

(14) CENTRALE POLITIE VERKEERSINFORMATIE (1980). Verkeersinformatie. The Hague.

(15) OEI, H.L. (1983). Route-information systems. In: Man and information technology: towards friendlier systems: 19-37. Delft University Press, Delft.

(16) MAMMANO, F.J. (1979). Driver information and motorist aid hardware. In: Proc. Int. Symp. on traffic control systems, Volume I: 87-117. University of California, Berkeley.

(17) DAWSON, J.A.L. (1983). Electronic road pricing in Hong Kong: the pilot stage. Traffic Eng. Control 24 (1983) 8: 372-377.

(18) JEFFERY, D.J. (1972). A low cost detector developed for use on roads. LR-453. TRRL, Crowthorne.

(19) COOPER, L and MOORE, R.L. (1972). Fog and road traffic. LR-446. TRRL, Crownthorne.

(20) BLACKBURN, R.R. (1976). Pavement and bridge icing. TRB/TRR-576. TRB, Washington, D.C.

(21) MACWHINNEY, R.C., LOVELL, C.C. and RUDEN, R.J. (1975). Snow and ice detection and warning systems. Fed. Highway Admin., Washington, D.C.

(22) LEIFER, J.C. (1979). Present status of the bridge ice detection program at FHWA. SR 185. TRB, Washington, D.C.

(23) RAVENSCHOT, W.H., VERSLUIS, A. and VAN DER VOORT, R.C. (1979). Windwaarschuwingssysteem bij de Moerdijkbrug. Verkeerskunde 30 (1979) 3: 68-70.

(24) WOUTERS, P.I.J. and MOOYMAN, G.L. (1980). Wind - een gevaar op de weg. Verkeerskunde 31 (1980) 3: 104-108.

(25) MAKELA, M. (1979). Development of automatic detection of bad weather conditions. Finnish Meteorological Institute, Helsinki.

(26) COLLINS, J.F., HOPKINS, C.M. and MARTIN, J.A. (1979). Automatic incident detection. SR-526. TRRL, Crowthorne.

(27) EUROPEAN COOPERATION, SCIENTIFIC AND TECHNICAL RESEARCH (1982). The international public demonstration on electronic traffic aids on major roads. Brussels.

(28) JENESON, J.H. and KLIJNHOUT, J.J. (1982). Beheersen van congestie. Het Nederlandsche Wegencongres, The Hague.

(29) MAES, W. (1976). The automatic detection of incidents on motorways. Ann. Trav. Publics (1976) 5: 377-400.

(30) ANON (1979). Chicago area expressway surveillance and control. Final report. Illinois Department of Transportation, Springfield.

(31) PAYNE, H.J. and TIGNOR, S.C. (1978). Freeway incident-detection algorithms based on decision trees with states. Fed. Highway Admin., Washington, D.C.

(32) JEFFERY, D.J. (1981). Ways and means for improving driver route guidance. LR 1016. TRRL, Crowthorne.

(33) DUDEK, C.L. (1979). Human factor considerations for in-vehicle route guidance. Transportation Research Record (1979) 737: 104-107.

(34) NAGAI, K. et al. (1979). An in-vehicle information system for drivers. In: Proc. Int. Symp. on traffic control systems, Volume 2B: 109-132. University of California, Berkeley.

(35) BOESEFELDT, J. and EVERTS, K. (1979). Traffic guidance and information systems for motorway networks: strategy and applications. In : Proc. Int. Symp. on traffic control systems, Volume 2C: 186-206. University of California, Berkeley.

(36) FENTON, R.E. (1979). On future traffic control - advanced systems hardware. In: Proc. Int. Symp. on traffic control systems, Volume 1: 118-137. University of California, Berkeley.

(37) BRAEGAS, P. (1980). Function, equipment and field testing of a route guidance and information system for drivers (ALI). IEEE Transactions on Vehicular Technology. 19 (1980) 2.

(38) DUUNK, C.J. (1982). Road-vehicle communication in the Ariadne route guidance system. Technische Hogeschool Delft, Delft.

(39) TOWNSIN, A. (1983). Putting a stop to speeding. Coach Bus Rev. 51 (1983) 12: 25-26, 48.

(40) ANON. (1979). Automatic regulation of speed wins a prize. Lastbilen 48 (1979) 6: 46-47.

(41) JAUSET, D. (1980). Les aides à la conduite et à la circulation - les régulateurs de vitesse automobile. J. SIA (1980) 2: 52-57.

(42) BROWN, S.J. JR. (1977). Point-follower automatic vehicle control: a generic analysis. John Hopkins University, Laurel.

(43) MASSON, A.L. (1979). Automatic car-following - a study of possible controllers. In: Proc. 29th IEEE Vehicular Technology Conference : 37-43. Institute of Electrical and Electronics Engineers, New York.

(44) BELOHOUBEK, E.F. et al. (1977). Microcomputer control for the car of the future. RCA Engineer 23 (1977) 1: 26-31.

(45) FARIS, W.R., TRESSELT, C.P. and YEE, H.C. (1979). Collision avoidance radar braking systems investigation - Phase III study. NHTSA, Washington, D.C.

(46) REINECKE, E. (1978). Vergleich unterschiedlicher Blockierschutzregelsysteme (ABV-Systeme) bezüglich aktiver Sicherheit und Kosten. Verkehrstechnik (1978) 31: 279-290.

(47) LEIBER, H. and CZINDZEL, A. (1979). Electronic control unit for passenger car antiskid. In: Proc. 29th IEEE Vehicular Technology Conference: 65-69. Institute of Electrical and Electronics Engineers, New York.

(48) ANON. (1979). Programmierte Sicherheit. Lastante-Omnibus 56 (1979) 9: 24-28.

(49) MISCHKE, A. (1981). Aufbau und Wirkung des Antiblockiersystems ABS für Nutzfahrzeuge. Automobiltech. Z. 83 (1981) 9: 439-446.