THE AUTOMATIC CORE CENSUS OF ROAD TRAFFIC IN GREAT BRITAIN

K Russam[1], and A D Butler[2]

1) K Russam
Transport and Road Research Laboratory
Department of Transport
Crowthorne, Berkshire
RG11 6AU, England

2) A D Butler
Statistics Directorate
Department of Transport
Romney House, 43 Marsham Street
London SW1P 3PY, England

Introduction

In order to develop a national policy of road construction, improvement or repair, many factors have to be taken into consideration. Foremost amongst these is the need to know existing levels of traffic both nationally and along specific roads. Upon an understanding of historical patterns of traffic can be built estimates of future traffic requirements and the Department of Transport has introduced two censuses to enable this to be done, the core census and the rotating (or link based)(1) census.

The rotating census of traffic involves manual counts on every motorway, trunk and principal road section between major junctions (about 12,000 sites), as well as at about 4,500 sites on minor roads. In any one year (over a 6 year period) counting takes places at a sixth of these sites for one 12 hour day.

The core census of traffic is more intensive but limited to a smaller number of sites and is designed to give estimates of national traffic trends by type of vehicle and road. For trunk and principal roads, sites are selected by sampling road stretches in each region in such a way that for each road class the chance of selection is proportional to its length. Minor road selection ensures that whatever variation between regions there may be in traffic trends, each region is given an appropriate weight in the national estimates. At the present time, data collection for the core census is carried out at 169 sites using people at the roadside classifying and counting the vehicles that pass each hour between 6am and 10pm. Each site is counted for 3 days each month (a given weekday, a Saturday and a Sunday).

Contracts have now been let by the Department of Transport and the Scottish Development Department to Ferranti Computer Systems Limited, with Golden River as Sub-contractor, for the production of hardware and associated micro-processor software to enable the core census to be automated.

Advantages of automation

With the present system there can be a significant loss of precision if abnormal conditions, such as bad weather, cause the base flows to be depressed on the counting days at some sites. Continuous 24-hour data from an automated site would ease the assessment of abnormal conditions on isolated days and give much more information on daily profiles during a week and on seasonal effects. It would also obviate the need for special continuous whole-week long manual counts which are used to supplement the core and rotating censuses in deriving factors used to obtain the annual average daily flows (AADF) from single day counts and enable those factors to be frequently updated. AADF information is of course essential to almost every branch of highway engineering and planning.

It is anticipated that the greater quantity and probably more consistent data obtained from automatic equipment than that collected by manual enumeration will allow a reduction in the number of sites counted without any loss of precision in the national estimates. By analysing core census and other count data together, traffic estimates required for operational purposes such as road scheme evaluations can be produced more efficiently and this should also reduce the level of traffic counting. High costs and practical difficulties often associated with many manual surveys will thus be eliminated in this census and the substantial reduction in the local authority manpower for the core census alone is likely to yield considerable savings.

Not only will flow data be available for periods when manual enumerators may be unwilling to work, eg, public holidays or inclement weather, but night-time records will be obtained. Reliable hourly profiles of traffic by road and vehicle class, which are of value in the prediction of traffic flow and hence in road planning and management, will be more rapidly produced and made available. Speed data will also be provided by the equipment, allowing a major reduction in the periodic national speed surveys, together with information about lane occupancy, which is difficult to obtain and is of use for road maintenance planning and the determination of highway standards.

The equipment can, when required, provide data about each individual vehicle that passes a site, and about inter-vehicular spacing facilities which will be extremely useful for special exercises and research purposes.

Sensors and Vehicle Classifier

The inductive road loop sensor, consisting of one or more turns of wire embedded in the road, is extensively used to indicate the presence of vehicles. When coupled with a microprocessor which cyclically powers the loop for a short time and compares the loop inductance value to that previously obtained, a very sensitive indicator of vehicle parameters is obtained. Signals proportional to the change in inductance as the vehicle passes over the loop can thus be used as a measure of the vehicle chassis height in addition to its overall length.

The methodology of vehicle classification is based on such signals from an array of axle sensors and an inductive loop in each traffic lane, Fig.1 (2). A special design for the inductive loop, a 'Double-D', has been developed in order to compromise between the need for sensitivity to vehicles passing over the loop and to the presence of vehicles in adjacent lanes which would cause spurious signals. The roadside microprocessor calculates the speed of the vehicle from the time taken to traverse the known distance between two axle detectors, counts the number of axles on the vehicle and then computes the distance between them. These data, together with overall length and chassis height, enable the vehicle to be classified via a series of look-up tables, into one of the 20 categories shown in Fig.2.

Special axle sensors were developed for use in the array. A tribo-electric sensor in the form of a screened cable encapsulated into a block or urethane is mainly used for vehicles other than pedal cycles, the block being permanently fixed into a slot cut in the road surface. Trials of this axle sensor have indicated a mean time before failure exceeding 3 years even under motorway traffic conditions. To detect pedal cycles and mopeds, two additional very sensitive axle sensors are installed which consist of a copper-sheathed coaxial cable with a piezo-electric powder acting as the dielectric. The cable is encapsulated in an epoxy resin and again sealed in a slot cut in the road. These sensors have been shown to be usable for this purpose provided correct installation techniques are adopted and, since they provide an output signal approximately proportional to the wheel load, it is hoped that they may be developed in future to give axle weight information.

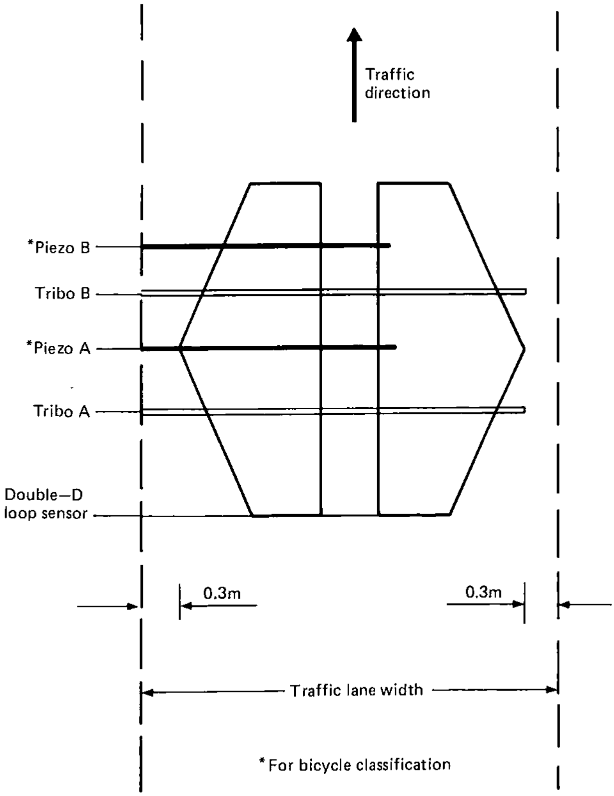

Fig. 1 Road sensor array for vehicle classification

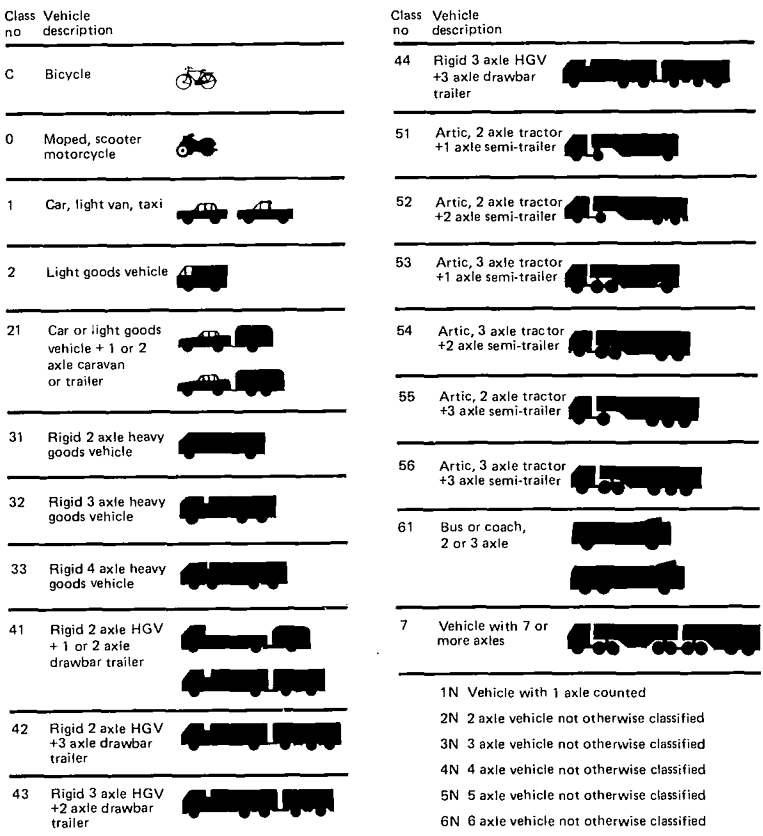

Fig. 2 Vehicles categories for the UK DTp National Core Census

During development of the equipment by the Transport and Road Research Laboratory several comparisons were made between the automatic equipment and manual enumeration. Photologging techniques were also used to determine not only the classification accuracy in each vehicle category but also the probable reasons for any misclassification. Some results from these studies are given in Table 1 as a guide to achievable accuracies over a 5-day test period at two typical sites, Guildford where the traffic is free-flowing and Evesham, an urban site where some queueing occurs.

TABLE 1

COMPARISON OVER 5 DAY PERIOD AT TWO SITES BETWEEN AUTOMATIC AND MANUAL CLASSIFIED COUNTS

Class No:	Evesham, A435		Guildford, A3	
	Automatic	Manual	Automatic	Manual
0	605	601	332	348
1	28206	28126	37853	37900
2	2656	2671	2641	2714
21	398	417	238	264
31	2310	2121	2069	2038
32	211	204	113	106
33	128	137	170	175
41	78	54	31	46
42	2	1	5	2
43	5	11	1	1
44	0	0	1	1
51	246	227	128	108
52	821	837	524	550
53	9	0	2	2
54	60	61	39	39
55	173	193	139	136
56	20	21	9	11
61	402	438	302	357
6	9	0	2	1

One factor that limits the classification accuracy in free-flow conditions is the degree to which vehicles straddle lanes. Vehicles that are not central over the inductive loop and yet are not straddling enough to be detected on sensors in adjacent lanes, tend to be misclassified as a result of incorrect chassis height and overall length measurement. This results from the strength of the inductive loop's magnetic field being weaker away from the loop centre. If vehicles are detected as straddling between the two lanes by simultaneous events on adjacent sensors, then in the present system the chassis height is automatically corrected by the microprocessor to aid identification.

Other problems arise when congestion causes vehicle speeds to drop below about 5mph and gaps between vehicles to shorten to below the effective length of the inductive loops. With slow moving traffic the impact of the tyres on the axle sensors is reduced and lightly laden axles such as those of motorcycles and pedal cycles are often missed by the tribosensors. Short inter-vehicle gaps can be mistaken over the loop sensor for the link between the tractor and trailer of articulated vehicles. There is also a particular problem when motorcycles cross the array of sensors at the same time as larger vehicles and are consequently not picked up.

At one urban site which has been chosen for the core census and which is prone to severe congestion, some 20 per cent of vehicles have been found to cross the sensors at less than 5mph during the period of peak traffic flows. Errors will thus be relatively high during such periods but these conditions tend not to be long-lasting. This effect is thought to be of very minor significance over the census as a whole.

Manual comparisons made in the late 1970's have indicated that overall enumerator error leads to expected coefficients of variation for daily totals at a single site of about 5 per cent for cars and about 15 per cent for other vehicle types. The acceptance trials of the prototype commercial equipment which took place in Autumn 1985 used video equipment as well as manual observers for comparison purposes. The results obtained suggested that under free flow conditions the error from the automatic equipment was substantially less than that experienced using manual enumeration. At the time of writing this paper there is still some concern about systematic bias but this is less of a problem when changes in flow, are more important than absolute values. However, where large seasonable variations in flow occur as, for example, with two-wheeled vehicles, it may be necessary to monitor closely any changes in this bias and in some cases apply corrective scaling factors to the automatic counts. It is hoped however that further possible improvements will remove bias. Research is continuing with a view to improving automatic counting in congested urban conditions (3).

Distribution of sites and linkage to the centre

The roadside microprocessor at each site will accumulate and store the data in hourly totals for each class of vehicle. Automatic dial-up procedures will be used to retrieve this data via telephone lines every 24 hours using a minicomputer in London for sites in England and Wales and one in Edinburgh for sites in Scotland. Each minicomputer will act as a back-up for the other in case of machine failure. The minicomputers will monitor possible faults in power and communication lines and automatically call for maintenance and repair staff. In addition diagnostic checks will be applied to the data to detect possible defective records and patch them with estimated figures if found to be necessary.

Present plans are that a total of 120 sites will be instrumented for the automatic core census, 90 in England, 10 in Wales and 20 in Scotland. The distribution is given in Table 2.

TABLE 2

DISTRIBUTION OF 120 CORE CENSUS SITES BY ROAD CLASS

Road Class	Built-up Speed limit 40mph	Non-Built-up Speed limit 40mph
Trunk	5	16
Principal	14	16
B	6	6
C	6	10
Unclassified	7	6
Motorway	28	

The manual core sites were chosen to enable particular changes in traffic by vehicle type or road class to be estimated to pre-determined levels of accuracy at a national level. For example, the proportional change in all motor vehicle traffic on trunk roads should be estimated to an accuracy of ± 4 per cent with 95 per cent confidence. The sample size is however not large enough to give acceptable estimates at the regional level. Partly for this reason in addition to 20 sites for the core census in Scotland a further 80 sites are planned to be instrumented to meet specific Scottish requirements.

Automatic axle weighing equipment for the core census

Deterioration of roads is mainly caused by heavy goods vehicles and the damaging effect of any particular axle loading is approximately proportional to its weight raised to the fourth power. Ideally, therefore, a detailed knowledge of the likely spectrum of axle weights on a road is thus required for the selection of design methods and construction materials for new roads and the maintenance of existing ones. Similarly steel, brick and masonary bridges suffer from the repeated application of traffic loadings and the maximum load that any bridge can be allowed to carry must be based on the possible loads generated by queueing traffic.

Two kinds of axle weight data are thus required:

i. national trends in average weight by vehicle type and road class,

and ii. for every link of the major road network, the average axle weight for each type of vehicle over an annual period.

Present representative data on axle weights and vehicle loadings in Great Britain are limited to those collected during special surveys when vehicles are selected for static weighing and to those data obtained from dynamic weighbridge sites installed by the Transport and Road Research Laboratory for research purposes.

The TRRL dynamic weighbridges are fixed installations in the roadway, capable of measuring half-axle loadings over the range of speeds up to 90mph [4]. These loadings will differ from the static wheel load because of the differing interaction between the vehicle suspension and the road profile on the approach to the weighbridge. The wheel, after passing over even a small bump in the road, could be partially airborne as it passes over the weighbridge plate and the device will give a lower reading than the static wheel load. Conversely if the wheel is coming down after being partially airborne, the impact will result in a higher reading than the static wheel load. The ratio of the average dynamic weight to static wheel load is known as the impact factor.

The design of the TRRL dynamic weighbridge measures the peak loading on a 2ft wide plate, ie, wider than the tyre print, hence it tends to produce a slightly high systematic bias to the correlation between dynamic and static wheel loading. Another systematic bias is introduced at each site by the road surface profile on the approach to the weighbridge and it is important that the approach to the dynamic weighbridge is maintained in good condition. It is the combination of systematic errors which are characteristic of each individual dynamic weighbridge site. They can be obtained from a large number of readings of dynamic axle loads from vehicles with known static axle loadings. As an example tests involving 14 different heavy goods vehicles at 10 sites enabled a total of 4035 measurements to be taken over a speed range of 20 - 60 mile/hour and indicated a mean impact factor of 1.09 and standard deviation of 0.16 [5].

Individual vehicle types will have their own suspension characteristics and these will produce differing impact factors around the mean value for a site. However, it is possible to adjust the calibration of the equipment at a site so as to provide reliable estimates of the static axle weight for particular types of heavy vehicles. In general the mean axle weights of most heavy vehicle classes will then be within 10 per cent of their static weights. It is intended that the dynamic axle weighing equipment will be used with the classifier at six motorway core census sites initially so as to obtain the axle weights associated with particular classes of vehicles. This will enable the monitoring of national trends of loadings to begin and estimated loadings at other motorway sites can de deduced from the number of vehicles in the various classes.

An alternative means of getting information about axle loadings is being researched using the piezo-electric sensors already referred to. These devices are much cheaper to install but are less accurate; trials have indicated a mean impact factor of 1.25 with a standard deviation of 0.19 [5]. The large error may be acceptable if systematic bias can be eliminated as the statistical law of large numbers would ensure that from a large number of observations a good approximation of the axle weight could be obtained. Since piezo-electric sensor costs are much lower than for the TRRL dynamic axle weighing equipment, piezo detectors could be employed to group vehicles into crude bands of 'light', 'medium' or 'heavy' which would able deductions to be made as to whether a vehicle is empty, half or fully laden. Such information would be significantly more than exists at present and greatly facilitate design and maintenance of the road system in Great Britain in future years.

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