

Developments in Maintenance Management in the United Kingdom

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This paper reviews the development of maintenance management of roads in the United Kingdom since 1936 when the trunk road network was first established. It ranges from the first national study of road maintenance in 1970, includes the introduction of the National Road Maintenance Condition Survey, the development of maintenance codes of practice and concludes with the current development of design, build finance and operate. The involvement of both national and local government is covered and a case study in one county area is described.

The paper identifies three important changes in the approach to road maintenance. The first is the move away from a public sector monopoly in road maintenance towards a mixed economy with an increasing role for the private sector both as manager and contractor. The second is the recognition that the management of maintenance deserves as much attention as new construction. It is now accepted that the management of the road infrastructure will increasingly focus on maintenance and operational management as each country seeks to maximise capacity and minimise the whole life cost of existing assets. The third is the development of maintenance management into asset management with the emphasis on the role of the customer and the recognition that the road network must be managed as a business. Looking ahead it is likely that major roads could become seen as yet another utility and removed further from governmental control by franchising maintenance and operation to the private sector.

Keywords: Roads, maintenance, management, private, public, competition

INTRODUCTION

Road maintenance has never appeared to receive as much attention as road design and construction. It rarely featured in formal engineering education and few engineers sought maintenance experience. As a result road maintenance was left to a few enthusiasts and to those who, possibly by default, found them-

selves in a maintenance organisation. Considerable knowledge was gained almost exclusively from experience, yet little was written down and it is only in the last 10 years that maintenance textbooks have been published in the UK. But over recent years attitudes to road maintenance have changed and it is now high on the public and political agenda.

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This paper reviews the development of maintenance management of roads in the United Kingdom since 1936. The aim is to identify the major changes that have occurred and the reasons behind such changes. The paper also looks ahead to anticipate further change.

BACKGROUND

Prior to 1936, road maintenance in the UK was the responsibility of local authorities. In 1936 the government sought a more strategic approach and defined a national trunk road network for which it would take direct responsibility for development and maintenance. The government now exercises this responsibility through its Highways Agency, and the trunk road network includes the majority of motorways built in the UK. These are the most important roads comprising 5% of the whole road network but carrying over 30% of all traffic measured in vehicle km.

There are currently about 200 local highway authorities in the UK with a mixture of county councils, district councils, metropolitan districts in the major conurbations, and London boroughs. These authorities are responsible for the maintenance of all other roads (referred to as non-trunk or local roads), ranging from country lanes, housing estates, town streets to main roads; 95% of the network carrying up to 70% of traffic.

There are strict laws protecting the right of the public to use public roads and there is also a duty imposed on the highway authority to maintain the roads in a reasonable condition. The law does not prescribe what that condition should be in terms of technical standards, and it is up to a Court of Law to adjudicate if a complaint is made. Each highway authority is independently responsible for the roads in its area and, as a result, standards of road maintenance have varied throughout the country according to local tradition and traffic volumes. It was also traditional for highway authorities to carry out much of the maintenance work by their own direct labour organisations. Until recently local highway authorities have also undertaken the maintenance of trunk roads and

motorways on behalf of the Highways Agency although, in this case, they work to policies and standards laid down by the Highways Agency.

The first significant Act of Parliament relating to road maintenance was passed in 1555. This gave each community the responsibility to nominate a surveyor to look after the maintenance of roads, and all the adults in the community had to work for four days a year on the repair of roads. From this beginning, road maintenance developed as a matter of experience rather than engineering science. This background, together with the numerous authorities responsible for road maintenance, meant that not only did standards vary considerably but also the efficiency with which the work was done varied. Road maintenance was rarely taught in any of the universities unlike road and bridge design. By the 1960s the government became concerned about the amount of money spent on road maintenance, the different standards being applied, and the efficiency with which the work was being done. It instituted a major inquiry into these issues and the resulting Marshall Report (Dept. Transport, 1970) recommended:

- national standards for road maintenance
- improving the management of road maintenance
- training for all personnel involved in planning and executing the work

The government for its own trunk roads and motorways adopted the recommended standards but it was up to each local highway authority to adopt the standards for its own roads. Unfortunately the oil crisis during the early 1970s greatly increased the cost of road maintenance and it became impossible to finance the recommended maintenance standards. These standards, therefore, were unsustainable and lost credibility. The Marshall Report did have a beneficial effect on the organisation and management of road maintenance and led to the development of two major systems for assessing the condition of road; the CHART (Computerised Highway Assessment and Rating) and MARCH (Maintenance Assessment, Costing and Rating of Highways) systems (Atkinson, 1997). The CHART system was developed by the then Department of Transport and was more useful

for rural roads. The MARCH system was developed by some of the urban highway authorities and was more useful for urban roads. Both of these systems are still in use today. By using these systems it was possible, for the first time, to have an objective measurement of the condition of the road surface, and also to assess the relative priorities for maintenance work.

NATIONAL ROAD MAINTENANCE CONDITION SURVEY

Economic problems, together with the government's view that road maintenance funds were not used efficiently, led to a series of reductions in maintenance expenditure. Road engineers were concerned that the reduced expenditure would result in irreparable damage to roads, particularly since traffic volumes continued to grow. Following much debate between highway authorities, it was agreed that a national survey should be instituted to record the condition of the country's roads (Dept. Transport, 1996). A committee of engineers was set up to supervise the survey, and the following details were agreed:

- Roads would be divided into seven categories; trunk, principal, classified and unclassified, with the latter three local road categories being sub-divided into urban and rural.
- The survey would cover a sample of sites, each 100m long, representing each category and be of sufficient size for everyone to have confidence in the results.
- The CHART survey technique would be used.
- All roads, except motorways and those roads with concrete carriageways, would be surveyed. It was considered too dangerous to try to survey on motorways, and the CHART system could not adequately cater for concrete carriageways.
- The survey would also include footways, kerbs and verges as well as the surface of the carriageway.
- Each highway authority would be given an allocation of surveys to undertake which would then be added together to form a national survey.

- The results would be published each year.

The NRMCS started in 1977 when over 9,000 sites were included. The survey has been carried out each year since then and there are now nearly 11,000 sites surveyed each year. The sites are randomly selected for each category of road.

The CHART system normally requires a team of three technicians to record the visual condition of the road surface. The information collected for each 100-metre length of road includes major, minor and edge deterioration, cracking, rutting, patches and potholes. The definition of each defect is carefully set out in the training manual for the technicians.

The results of the NRMCS for trunk and non trunk roads from 1977 to 1995 are shown in Figures 1 and 2.

Following a period when roads generally got better, probably due to improved efficiency, road conditions then got worse, probably due to reduced budgets. The government then agreed that more money was required for highways maintenance and, in general terms, road conditions have stabilised and are very similar to the original condition in 1977. It is still a matter of debate whether the conditions of 1977 are acceptable for current traffic volumes and growing public expectation.

MAINTENANCE CODES OF PRACTICE – LOCAL ROADS

The NRMCS records the condition of road and footpath surfaces but it does not establish standards of maintenance or maintenance procedures. In response to the continuing political disquiet about road maintenance expenditure and efficiency, local highway authorities joined together in 1983 to produce the Code of Good Practice for Highways Maintenance (Local Authority Associations). This was the first attempt since the Marshall Report to define recommended maintenance standards. The code gave advice on the data to be collected, the use of assessment systems such as CHART, MARCH, Deflectograph (to measure strength) and SCRIM (to measure skid

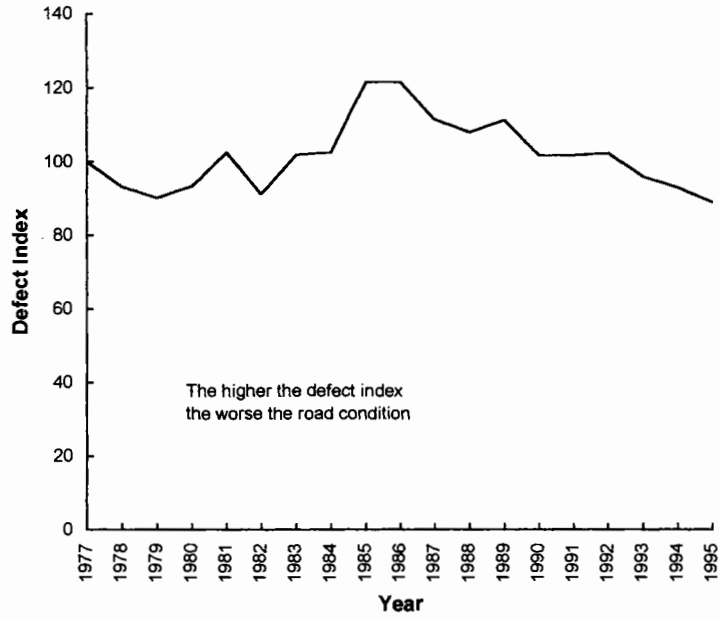


FIGURE 1 NRMCS for Trunk Roads

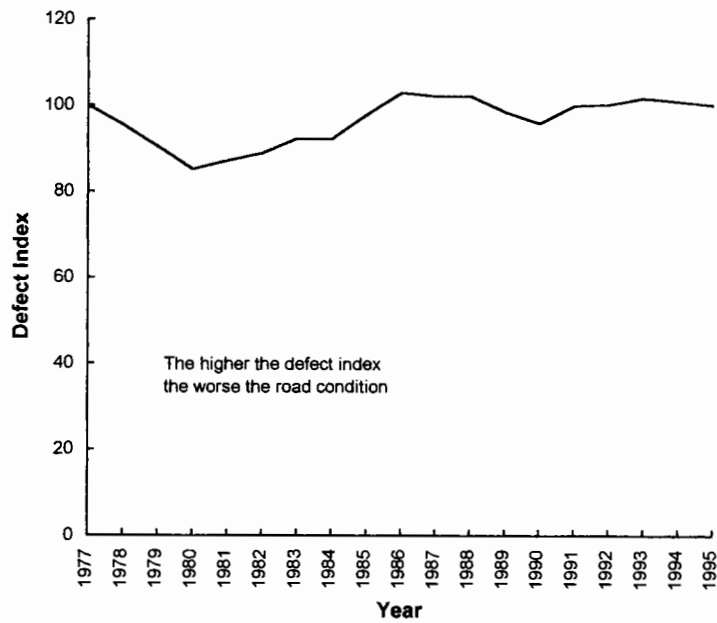


FIGURE 2 NRMCS for Non-Trunk Roads

resistance), and also gave advice on the management and organisation of road maintenance.

The Code of Good Practice had to recognise that each highway authority was autonomous and, therefore, flexibility was required to enable each authority to choose the best approach for their area. Highway authorities could choose to have different standards but the choice must be justified and related to the efficiency of maintenance. Since authorities would be working within limited budgets, one of the most important aims of the code was to ensure that whatever money was available was spent effectively and that the maintenance process should be open to public scrutiny.

For these reasons the Code of Good Practice was both an advisory document for maintenance engineers, and also an information document for politicians so that they understood the maintenance process and their responsibility in setting maintenance standards. It was considered vital for politicians to be involved in the whole maintenance process if they were to be convinced of the amount of money required to fund the desirable maintenance standards.

The first edition of the code was published in 1983 (Local Authority Associations) and received political support from the government and local authorities. A second edition was published in 1989. The local authority Code of Good Practice has changed attitudes to road maintenance both by engineers and politicians. It has made a major contribution towards

increased maintenance efficiency in the United Kingdom. The principles underpinning the code are listed below and the systematic process is shown in Figure 3.

- categorise the road network into a defined hierarchy related to use
- collect inventory information
- set maintenance standards
- assess the condition of the network
- identify maintenance activities
- prioritise activities against the available budget
- plan and implement the work

A supplement to the local authority code dealt with winter maintenance policy and practice and was published in 1991 (Local Authority Associations).

MAINTENANCE CODES OF PRACTICE – TRUNK ROADS

The first maintenance code of practice for trunk roads was published by the Department of Transport in 1984 and dealt with winter maintenance. It contained a statement of service, which defined priorities for action, and specified operational standards and techniques. It included rates of spread for salt and policies regarding vehicles and plant. A second edition was published in 1990 (Dept. Transport).

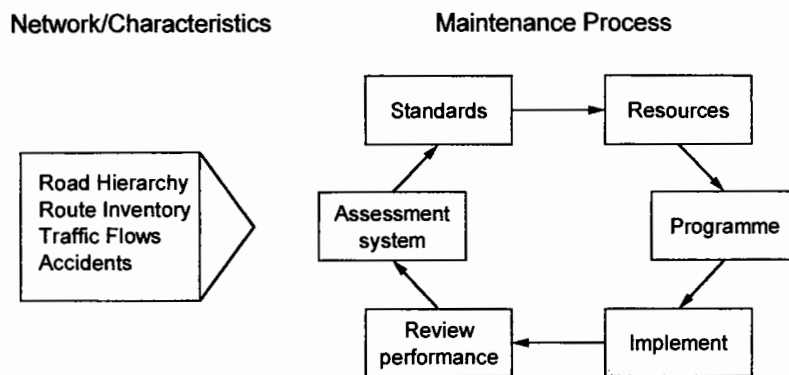


FIGURE 3 Maintenance Management Process

In 1985 the Department of Transport published details of its routine maintenance management system for motorways and all-purpose trunk roads (see References). There were three components:

- a code of practice which sets out inspection and reporting procedures, actions to be taken and standards to be met.
- an inventory of highway infrastructure and furniture, collected and stored in a consistent manner.
- a data filing/handling system which allows the interrogation and cross referencing of information.

MAINTENANCE MANAGEMENT IN SHROPSHIRE

The author, as County Surveyor of Shropshire County Council was responsible for roads in that county, and in a position to test the local authority code of practice.

Shropshire County Council approved the code of practice in 1984 and agreed to implement its recommendations. The implications of this decision were:

- the establishment of a maintenance policy unit
- the establishment of an annual county road maintenance condition survey (CRMCS) of a sample of roads in the country using the CHART survey technique
- the publication of an annual maintenance plan setting out both the policies and standards to be aimed at. The plan also shows how the budget is allocated.
- a separate maintenance review to monitor the effectiveness of maintenance policy and its implementation
- inventory data would be collected so that engineers had better knowledge of the road network.

The first maintenance plan for Shropshire was published in 1987 (Shropshire County Council). It created great interest with the politicians who were asked to consider and debate the various highway maintenance policies and standards. Politicians were also surprised as to how little inventory information was

then available recording the details of the highway network. The key to the Shropshire maintenance system is the careful monitoring that takes place to evaluate the effectiveness of the previous year's maintenance plan and budget. The annual CRMCS is the most important element of the monitoring programme since it not only records the condition of a sample of roads, but from it trends can be established which indicate whether the previous maintenance policies have been successful or not. It is also possible to examine the details of the survey including whether particular defects are increasing or not. For example, if edge deterioration is increasing, then it indicates that there is a need to consider widening the road. An increase in the number of potholes means that more money must be allocated to localised repair of the highway.

The CRMCS now involves a sample survey of 1,200 sites within the county, split between the three non-trunk road categories and sub-divided urban and rural in the same way as for the NRMCS. This number of survey sites, which are randomly chosen each year, gives a statistically sound base for evaluating the condition and trend of the different road categories over a 3–5 year period.

In addition to the visual survey, the machine based Deflectograph and SCRIM are used to assess the strength and skidding characteristics of the main roads throughout the county. Separate surveys are also made of the condition of footways and of drainage problems. For example, a record has now been established of the location and number of days when a road is flooded for more than half of its width. This information helps to determine the priority for improvements to the drainage system.

The policy is to allocate maintenance money to identified need wherever possible. However, experience has shown that this can never amount to 100% of budget and the local maintenance engineer must be allowed some flexibility to deal with unplanned emergencies. By 1996 some 85% of the county maintenance budget was allocated on the basis of surveys and priority assessment and the budget process is shown in Figure 4. Having set aside money for emergencies and fixed costs, the first task is to allocate suf-

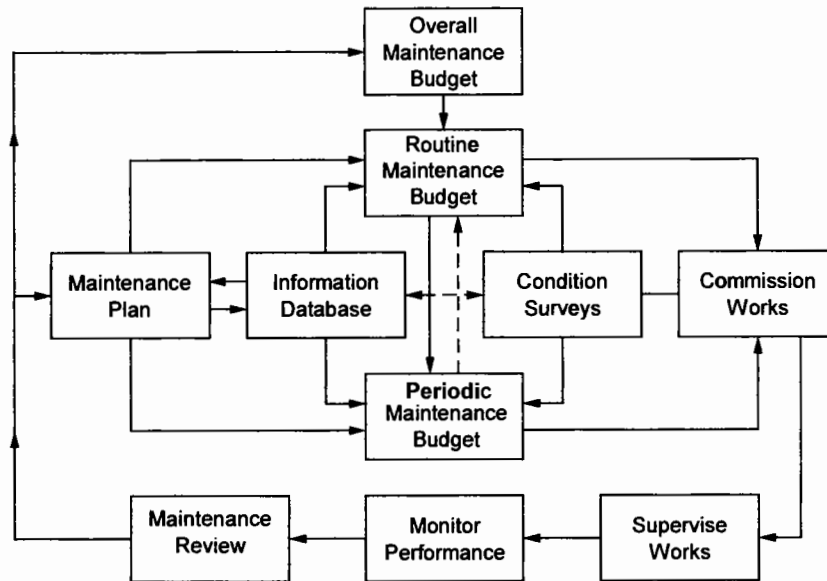


FIGURE 4 Maintenance Budget Process

efficient money for routine maintenance based on the number of items or area of activity multiplied by a unit cost rate. The rest of the budget is then allocated to periodic maintenance using priority assessment.

RESULTS

In order to assess the effectiveness of the new maintenance management system in Shropshire it is necessary to understand the changes in traffic volume and road mileage that have occurred since 1984. This information is set out in Figure 5 and shows that traffic volumes have increased by 70%, road mileage by 5% whilst the maintenance budget has fallen by 5% in real terms.

Road condition in Shropshire can now be compared with results of the NRMCS and this is shown in Figure 6. Since 1985 Shropshire's roads have improved relative to the national average, and the trend has been towards further improvement.

Improvement could arise from having a relatively high budget, details of which are shown in Figure 7.

In the UK the government controls the expenditure of local authorities and over the period in question set guidelines for maintenance budgets. Shropshire County decided to adopt a lower level of provision and transferred money away from road maintenance and towards other budget heads such as education and social services.

The improvement then can only be explained by the more effective use of resources due primarily to the introduction of a rational maintenance management system and, to a lesser extent, improved efficiency by the direct labour organisation (DLO) referred to below. The budget was below the national guideline and had fallen in real terms over the period under review.

COMPETITION FOR MAINTENANCE WORK

In 1981 the government introduced the first of a series of legislation measures that required direct labour organisations (DLO) to compete with private contractors before carrying out road construction or mainte-

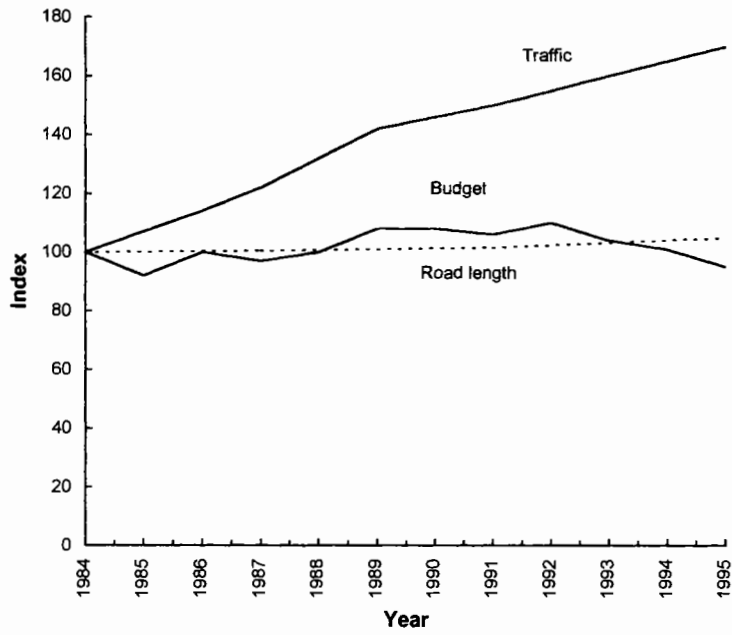


FIGURE 5 Traffic volumes, road length and budget for Shropshire County

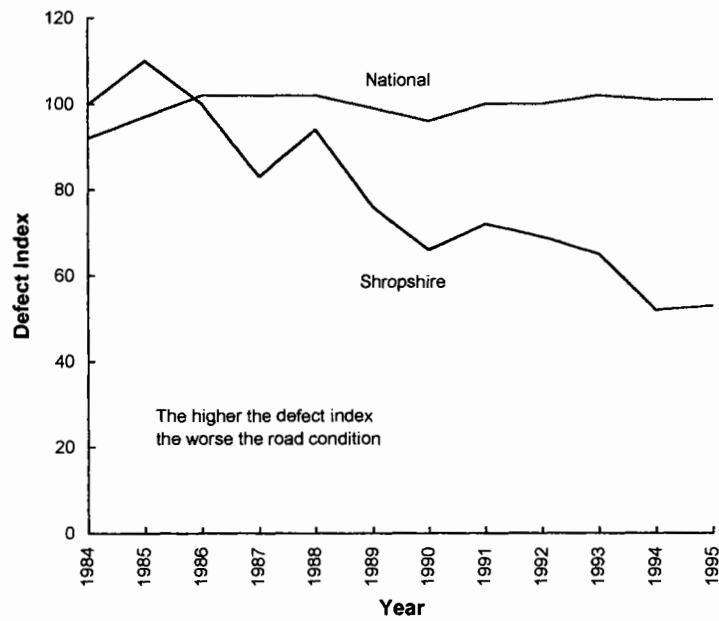


FIGURE 6 Road condition, Shropshire County and NRMCS

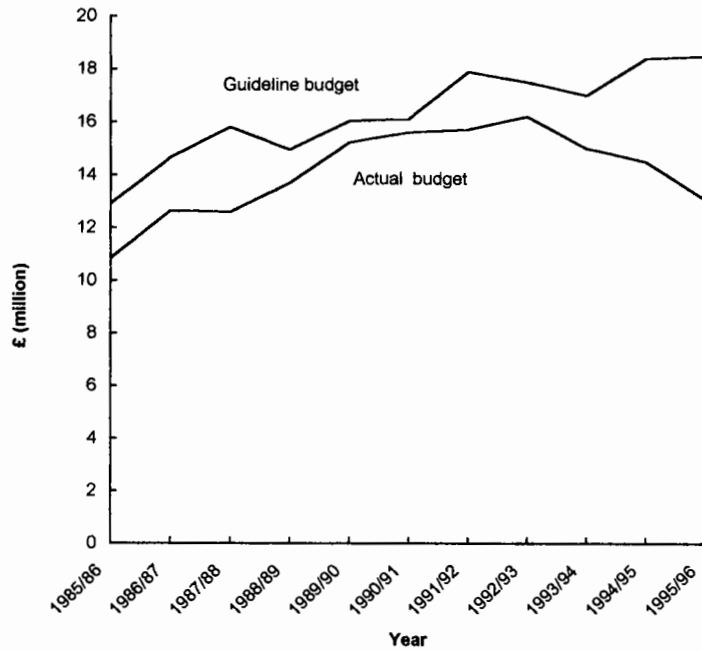


FIGURE 7 Shropshire County, budget guidelines and actual provision

nance work. Local highway authorities were required to:

- invite competitive tenders from private contractors for road construction or maintenance projects worth >£100,000
- obtain written estimates from the DLO for all work undertaken
- establish a separate trading account for the DLO. The account could only be credited with the value of written estimates or tenders submitted by the DLO and must be debited with all of its costs including a fair proportion of overheads
- achieve a 5% profit on the DLO trading accounts based on the value of the assets owned by DLO.

The government took powers to close down any DLO that failed to meet the 5% profit target over a three-year period. The government then increased the severity of the rules over a number of years.

- 1982 – all projects > £50,000
- 1983 – all projects > £50,000 + 30% of projects < £50,000

- 1987 – all projects > £25,000 + 30% of projects < £25,000
- 1988 – all projects > £25,000 + 60% of projects < £60,000
- 1996 – 100% of all projects to be subject to competitive tenders.

Prior to 1996, the government had always accepted the need for a DLO to exist in order to deal with emergencies and that a DLO must be given some basic work to undertake in order to be usefully employed. In 1996, the government decided to require all work undertaken by DLO to be won in competition with private contractors. The government placed further restrictions on a DLO by only allowing them to work in their local geographic area and only for public bodies as defined in legislation. e.g. Shropshire DLO could only work within the boundaries of Shropshire County and could not work for any private organisation (even if invited).

The consequence of these changes of policy was that DLOs became vulnerable to a reduction in work-

load and to predatory bidding by private contractors. This resulted in many DLOs deciding to negotiate a merger with private contractors as the best way of safeguarding employment for their work force. Such transfer of skills and equipment from the public to the private sector was normally arranged by seeking tenders for a comprehensive maintenance contract for a five-year or longer duration. This provides the stability needed for a contractor to absorb such a major change. The majority of large specialised road maintenance DLOs have now been transferred to private contractors. However, a study by the PIARC Road Management Committee has not found any evidence of cost savings by making more use of private contractors. But the study did show that DLOs became more efficient when subjected to the discipline of competing with private contractors (Madelin, 1995). These findings have been confirmed in a recent report by the Transport Research Laboratory (Parkman et al, 2000).

The current government has modified the policy of requiring direct competition with private contractors by introducing in 1999 the concept of "Best Value". Public authorities are now required to demonstrate that their policies and implementation will deliver overall best value to the community and in particular:

- secure continuous improvement in services
- that services are responsive to the needs of users and service providers
- that services are efficient and delivered to high standards

The performance of DLOs should be tested at regular intervals against private contractors but there is more flexibility in the current system. Best Value will be monitored by inspection teams from the independent Audit Commission already established in the UK.

THE HIGHWAYS AGENCY

Prior to the formation of the Highways Agency, the government employed the large county councils to carry out construction and maintenance on the trunk

roads, thereby ensuring that operational management remained integrated with all other roads in the area.

In 1994 the government reorganised the Department of Transport and established the Highways Agency to discharge its responsibilities for the trunk roads network in England (different arrangements apply to Scotland and Wales). The Highways Agency remains a public body, reporting to the Minister of Transport, but it is encouraged to operate in a more business like way. The Highways Agency are charged with securing cost savings in the management of trunk roads and to support the governments intention of making more use of the private sector. The most significant change to occur was the reorganisation of maintenance and operational management of trunk roads. The Highways Agency decided that the trunk road and motorway network could be managed by 24 enlarged agency areas, and invited private consultants and local highway authorities to bid for the work in a series of contracts.

The first phase of new "super" agencies came into effect in April 1997 and all of the six contracts offered were awarded to private consultants and private contractors were employed to undertake maintenance tasks. In most cases existing public sector staff and workforce were transferred to the consultants and contractors along with the work. The Highways Agency claim that cost savings will result in the management of trunk roads but local highway authorities claim that they will have to bear additional costs in managing the remaining local road network on a more fragmented basis. It is too early to assess the public reaction but from an operational basis, long distance traffic may see an improvement from integrated route management, but local traffic will cross several management boundaries.

The Highways Agency plan further changes in trunk road management, partly a natural development of the experience of super agencies and partly in response to the policy of Best Value. The aim is to integrate the consultant and contractor roles and let single operate and maintain contracts. Several options are being explored and changes are expected during 2000. (Highways Agency, 1999)

UNITED KINGDOM PAVEMENT MANAGEMENT SYSTEM (UKPMS)

UKPMS is a development of the MARCH and CHART systems. It is designed to enable engineers to project the future condition of roads and to assess the priority of treatment on economic based criteria. Priority lists are established based on maximising the economic rate of return of the available budget (McCandless, 1997).

The ability of UKPMS to predict future conditions allows different budget strategies to be tested to minimise whole life cost, or to predict the condition of the network for given budgets.

The concept of UKPMS was developed in the late 1980s by a joint Department of Transport and local authority initiative. A detailed specification was produced and tested in practice. Unfortunately before a production version was authorised, the new Highways Agency decided to withdraw from the project and concentrate only on systems that were suitable for trunk roads.

The local authorities, supported by the Department of Transport and the Department of Environment Roads Service in Northern Ireland, have continued the project by inviting the private sector to develop systems that comply with the UKPMS specification. Private sector systems that pass a performance test will be given a "seal of approval". It is expected that the government will require all major maintenance expenditure and related government grants to be evaluated using an approved UKPMS system. By January 2000, five contractors had gained stage 2 approval and the final stage 3 approvals are expected by March 2000.

NETWORK CONDITION MODEL (NETCOM)

NETCOM was developed by The University of Birmingham and the Transport Research Laboratory in 1992. (Kerali & Snaith). It is a computer model that uses visual condition data from NRMCS to predict the medium to long-term performance of road networks. NETCOM predicts the effect of maintenance

and rehabilitation on the future condition of the network using observed distributions of pavement defects and trends in pavement deterioration.

Sensitivity tests were conducted to validate the relationships built into NETCOM by predicting conditions and then comparing actual results from the NRMCS. The DoE Roads Service is now extensively testing NETCOM in Northern Ireland.

DESIGN, BUILD, FINANCE AND OPERATE

The concept of DBFO was introduced by the government in the late 1980s to assist with the financing of special projects such as the new Queen Elizabeth Bridge over the River Thames in London and the second River Severn crossing between England and Wales.

DBFO is a competitive tendering process that involves the private sector in:

- designing, funding, constructing and maintaining the new bridges
- taking over the toll income and maintenance of existing bridges and approach roads
- tendering on the basis of a 30 year franchise
- operating the asset to defined standards

These projects were successful due to the ability to raise direct income from tolls to fund the costs involved. The closer integration of design and construction also produced cost savings.

In 1995 the government extended the DBFO principle to the existing trunk road network. As part of the Highway Agency's review of the network, 12 suitable DBFO projects were to be identified. These were in addition to the 24 new super agency areas referred to previously, and meant that the trunk road network is now being managed by 36 operational units: 24 of which are directly controlled by the Highways Agency and 12 of which are controlled by private operators. There is now more operational fragmentation of the trunk road network than expected but it is too early to come to conclusions about the consequence to users, maintenance efficiency or overall pavement condition.

These current DBFO projects are different to the first group since a longer length of existing network is involved and direct tolling of traffic is not possible. Instead the government has agreed to pay the successful private operator a "shadow toll" based on actual traffic volumes using the roads. A review of a group of DBFO projects has recently been completed and average cost savings of 15% are claimed compared with traditional forms of provision (Highways Agency, 1997A).

REGIONAL TRAFFIC CONTROL CENTRES

Forecasts show that traffic volumes on trunk roads could double by the year 2025 if demand for road space is unconstrained. The Highways Agency aim to make the best use possible of the existing networks and one proposal is to establish a series of Regional Traffic Control Centres (RTCCs). (Highways Agency, 1997B).

These centres will become a focal point for driver information by assembling data on traffic volumes and congestion and broadcasting advice by radio or variable message signing systems. The aim will be to control movement over the whole network and route traffic away from congested sections.

Three RTCCs are planned for England and the government hope that the private sector will fund and operate the centres. The possibility of using traffic data for commercial income producing services is being explored.

ASSET MANAGEMENT AND THE ROLE OF THE CUSTOMER

Maintenance management is moving ahead rapidly and is now being transformed into asset management. Asset management is about managing the maintenance, operation and development of the road network in a businesslike way to preserve its value and to meet the changing needs of its customers. The Highways Agency has already established a valuation

of the trunk road network as an aid to investment justification and local highway authorities are now developing Best Value plans to demonstrate their effectiveness in asset management. There is worldwide interest in asset management and in 1999 the OECD set up a working party, including the Highways Agency, to give practical advice. There is no doubt that asset management will feature strongly in the future development of maintenance management.

The main emphasis in asset management is the businesslike discipline and the acknowledgement of the customer as the main justification for the performance of the asset. These changes will have a big impact in the future on the role of the politician and road engineer.

FUTURE DEVELOPMENTS AND CONCLUSIONS

The importance of road maintenance has become re-established. The introduction of objective and needs-based maintenance management systems has improved value for money and provided a basis for informed dialogue with politicians and customers. The move away from significant major road construction has focused attention on getting the best out of the existing network, and the management of maintenance is being integrated with traffic management in the form of asset management. In future investment decisions will be more influenced by the establishment of a business case and less by politics. Public attitudes and expectations will grow in importance and maintenance policy and standards must reflect public as well as technical priorities. Communication between the maintenance engineer and the public in general, and the road user as customer in particular, must be developed.

The private sector is now a major player in road operations and maintenance and the trend away from the public sector will continue. The pace of change will depend upon methods of funding road management and maintenance. The private sector can best operate where there is a direct funding mechanism such as tolls. Traditional toll facilities will always be

difficult in the UK and so the development of electronic means of tolling or road pricing is awaited with interest. There is a case for transferring the management of all major roads to the private sector and DBFO projects are the forerunner. Unfortunately DBFO road projects have been introduced in the UK in a fragmented way and so could inhibit the logical extension and integration of private sector management.

References

1. Atkinson, K. (Ed), (1997). *Highway Maintenance Handbook*. London: Thomas Telford, second edition.
2. Department of Transport, (1970). *Inquiry into Road Maintenance*, (Marshall Report) HMSO, London.
3. Department of Transport, (1985). *Code of Practice for Routine Maintenance on Motorways and All-Purpose Trunk Roads*, Department of Transport, London.
4. Department of Transport, (1990). *Winter Maintenance of Motorways and Trunk Roads, Statement of Service and Code of Practice*, Department of Transport, London.
5. Department of Transport, (1996). *National Road Maintenance Condition Survey*. Statistics Bulletin 96, (30), London.
6. Highways Agency, (1997A). *DBFO – Value in Roads*, Highways Agency, London.
7. Highways Agency, (1997B). *Regional Traffic Control Centres*, Highways Agency, Bristol.
8. Highways Agency, (1999). *Paving the Way*, Highways Agency, London.
9. Kerali H.R, and Snaith M.S., (1992). *NETCOM, The Visual Condition Model for Road Networks, Contractor Report 321*, TRL, Crowthorne.
10. Local Authority Associations, (1983). *Highway Maintenance: A Code of Good Practice*. Association of County Councils, London.
11. Local Authority Associations, (1991). *Winter Maintenance Supplement*, Association of Metropolitan Authorities, London.
12. Madelin K.B., (1995). *Road Management Committee Report C6*, World Road Congress, Montreal. PIARC, Paris.
13. McCandless D, (1997). *United Kingdom Pavement Management System*, Institution of Highways and Transport Alan Brant Workshop, Leamington Spa, UK.
14. Parkman C, Madelin KB, Robinson R. (2000). *Improving the Delivery of Road Maintenance*, TRL, Crowthorne.
15. Shropshire County Council, (annually from 1987). *Highway Maintenance Plan, (also Highway Maintenance Review, and Highway Maintenance Standards)*, Shrewsbury, UK.