Development of United Kingdom Pavement Management System

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The United Kingdom Pavement Management System (UKPMS) is a computer system currently being designed for the economic management of the structural maintenance budget of a road network. It is being promoted and funded by most highway authorities in the United Kingdom, representing owners of all classes of roads, from congested city streets to narrow rural roads. It will incorporate a new system of visual data collection, data analysis, and budget allocation for all paved areas within the highway boundary and will combine data from different types of condition surveys. Other significant features include the ability to project condition data into the future; this enables the user to take account of the economics of alternative maintenance treatments when deciding where and what treatments should occur. Because the economics of alternative maintenance strategies are considered, UKPMS is, in essence, prioritizing the solutions to structural road maintenance rather than, as many systems do, prioritizing the problems. To test the innovative principles of UKPMS, and to test the new data collection techniques, prototype software has been written. It is being used by highway maintenance practitioners themselves during the current design stage. The core philosophy of UKPMS is to defer treatments where it is cost-effective and safe to do so and to give priority instead to preventive maintenance.

There are more than 360 000 km of road in the United Kingdom, of which about 270 000 km are in England. The most heavily trafficked routes in England—the national roads—are looked after by the Department of Transport (DoT). The national road network includes about 2000 km of superhighways and some 8000 km of all-purpose trunk roads. Although they represent only 4 percent of the network, the national roads carry about 30 percent of all traffic and about 55 percent of heavy goods vehicle (HGV) traffic.

The remainder of the network in England—the local roads—is the responsibility of the local highway authorities: the county councils and metropolitan councils. Together they look after nearly 260 000 km of roads, which vary from small, lightly trafficked country lanes to densely trafficked urban routes.

Central and local governments spend a significant amount of money each year on the maintenance and management of the road network. The following table presents the level of road maintenance expenditure in England in 1991–1992:

	Expenditure (£ millions)	
Maintenance Type	*National Roads*	*Local Roads*
Structural	400	480
Routine (cyclic) and winter	160	320

Pavement Management Before UKPMS

To control expenditure and ensure the best value for money, highway authorities have designed various systems for maintenance management. For example, the DoT has introduced a management system for the routine (cyclic) maintenance of the national roads in England. It enables inventory data—road, footpath, and shoulder width and type; drainage provision; road markings; and so on—to be collected using hand-held computers and subsequently transferred for processing onto mainframe or personal computers.

However, the need for structural, or noncyclic, maintenance on British roads is assessed by highway authorities in different ways. For example, the DoT uses a two-level system. The first level—a coarse assessment—is carried out using the High-Speed Road Monitor (HRM). The HRM, developed by the Transport Research Laboratory (TRL), makes use of contactless laser technology to measure, among other things, longitudinal profile and permanent deformation (rutting) of the road surface. These measurements are taken at up to 80 km/hr and are recorded automatically for later computer analysis. The entire national trunk road network is covered by one machine every 2 years, without inconvenience to the road user. The HRM provides a quick and relatively inexpensive method of assessing the serviceability of the national road network.

The second level of assessment—the detailed assessment—is carried out at the time of scheme design using a combination of machine measurement and visual assessment. The machine surveys are carried out using the deflectograph, which measures the transient deflection of pavements under a known wheel load. It is used both to assess the structural condition of the pavement in terms of the residual life and to provide information for use in the design of strengthening treatments.

Visual assessment methods are also used to record defects. Measurements of the surface condition are recorded using hand-held computers and automatically analyzed to provide needs-led priorities and recommendations for treatment.

A Sideways-Force Coefficient Routine Investigation Machine (SCRIM), which travels at 50 km/hr, is used to measure the wet skidding resistance of the road surface; it covers the national road network on a 3-year cycle.

As good as all the current systems are, they produce data sets that are not coordinated. All the systems are separate; they are related, for the department's roads, by a common referencing system, but data are not combined in any way. An engineer may be faced with several survey results for the same section of road; some in paper form, some computerized. Deciding on priorities in these circumstances is difficult.

A particular problem for local highway authorities arises because not all the survey methods are relevant to all classes of road. A county with an extensive rural network may not wish to use expensive laser technology; similarly, techniques used on these roads may not be relevant to an authority with a large urban network with many service provider openings, such as those for water and electricity supply, in the highway.

Pavement Management with UKPMS

History of Project

The Local Authority Associations (LAA) and the DoT established a joint initiative in the mid-1980s to consider a new pavement management system (PMS) that would replace the various existing methods of visual road condition assessment and be able to combine this visual data with machine-based assessments. But it was important that any PMS should manage the maintenance of all roads: from heavily trafficked trunk roads to little used local roads, both in towns and on interurban routes. In short, the need was for a national PMS, now known as UKPMS.

The total project is being managed in three stages. Stage 1 was a feasibility/design study that established draft user requirements and delivered to sponsors a preliminary design for a UKPMS. It concluded that there were significant benefits to be gained by taking UKPMS forward.

All parties therefore decided to proceed with a full-scale system design and prototype testing program—Stage 2. Fifty percent of funding is provided by DoT, and the rest by 91 local authority sponsors from England, Scotland and Wales, and the Department of the Environment for Northern Ireland. A contract was established in July 1990 with the aim of producing a logical design for UKPMS together with the testing of prototype software; a logical design being a machine- and data base–independent specification of a computer system.

The final stage of the project, Stage 3—the implementation of UKPMS by each sponsoring highway authority—is being discussed and planned; it will begin in 1994.

Brief Description of System

An engineering view of the structure of UKPMS is shown in Figure 1. It is recognized that UKPMS must protect investment already made in data by the various highway authorities. Standard format interfaces have therefore been specified to enable links to be made to existing systems.

UKPMS is being designed to enable highway authorities to

- Monitor the condition of the existing road network,
- Formulate options for maintenance treatments,

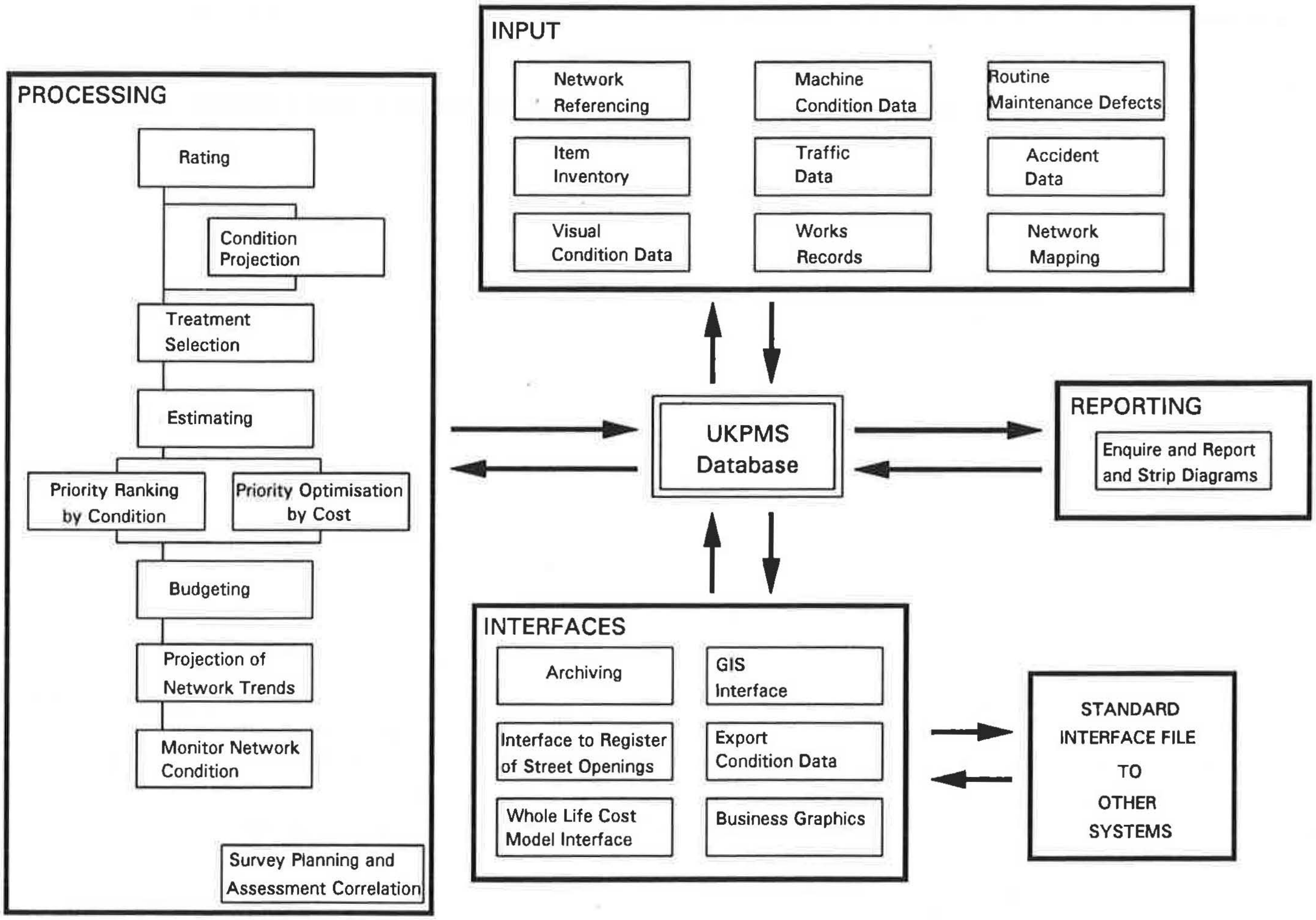

FIGURE 1 Engineering view of UKPMS.

- Manage maintenance priorities, and
- Allocate limited resources on the basis of best value for the money.

It will introduce significant innovations, which include

- A common auditable approach to road assessment nationwide, based on both condition and economic priorities;
- A flexible approach capable of use in all types of highway authority and on all paved areas on all types of road; and
- Cost-effective methods of data collection.

The remainder of this paper discusses in more detail some of the innovative aspects of the system:

- The ability to tailor condition surveys to the needs of a highway authority,
- Network analysis and the creation of schemes,
- Projection of condition data; and
- Priority optimization by cost—that is, economic ranking.

Collection of Condition Data

Condition data used by UKPMS can be described as collection by visual or manual methods or by machine or automatic methods.

Four new visual inspection systems have been designed to take account of both the strengths and weaknesses of current visual inspection systems currently in use in the United Kingdom:

- Annual engineering inspection (AEI),
- Coarse visual inspection (CVI),
- Aggregated visual inspection (AVI), and
- Detailed visual inspection (DVI).

The AEI is essentially a windshield survey to give a rough estimate of pavement condition. The output is aimed at planning further surveys. Both AVI and DVI are detailed surveys carried out on foot.

Machine inspections that UKPMS can use are

- HRM,
- Deflectograph,

- SCRIM to measure wet skidding resistance, and
- Any other machine data whose output can match that of those just given.

The user can pick and choose which survey to use for particular types of road. On a rural network only a coarse visual inspection may be necessary to formulate maintenance schemes. On extensive super highway networks, all the various detailed surveys may eventually be needed; UKPMS can accommodate these extremes and all other situations in between. This graded approach ensures that the demands for data and analysis are kept in proportion to the cost of the works.

Network Analysis and Scheme Creation

General

The highway maintenance engineer, so as to decide the right treatment, strives to ensure that the right amount of data are gathered at the right time. To help this, the operation of UKPMS falls into two distinct passes. The first is the automatic pass, where UKPMS will process data for the entire network automatically to provide a coarse ranking of maintenance schemes for final design or to identify those schemes warranting more detailed investigation before final design is carried out. The maintenance engineer uses the second pass—the interactive pass—with the results of the automatic pass, and other data available within UKPMS, to combine defective lengths of the network to produce maintenance schemes and undertakes the detailed design of the works.

Automatic Pass

The automatic pass is intended to analyze the entire network, or convenient subsets of it, to determine priorities for investment in maintenance works. The central processing functions of UKPMS work as follows:

1. Sections of road are split into lengths of uniform defectiveness known as "defect lengths," which are defined as lengths of a feature (roads, sidewalks etc.) in a single cross-sectional position (e.g., lane) in uniform condition.
2. Defect lengths are rated on a scale of 0 to 100, where
   –0 is "good," or where further improvement would not be of any significance, and
   –100 is "bad," or where further deterioration would not be of any significance.
3. Defect ratings are combined into condition indexes (CIs); those used in UKPMS are
   –Surface,
   –Structure,
   –Edge (bituminous surfaces only),
   –Joint (concrete surfaces only), and
   –Overall.
4. To allow condition assessment to use up-to-date information, the condition is projected on a time basis, to the current date.
5. CIs are input into algorithms to produce treatments for each defect length.
6. Cost estimates are produced by multiplying estimated treatment quantities by unit rates.
7. Priority indexes are produced by comparing CIs with user-defined thresholds. Highest priority is given to those indexes exceeding the thresholds by the greatest amount.
8. Budgets are prepared for treatments under user-specified budget heads.

As a result of extensive research carried out at TRL, rules and parameters have been identified and tested. The starting point of the research was to identify the level of defect that would trigger a change in treatment. Figure 2 shows, for a selection of flexible pavement defects, the level of measured defect required to trigger a particular treatment, together with an example of defects that work in combination to cause particular treatments to be triggered. Defect ratings for a selection of bituminous defects are given in Table 1. (In Table 1, residual life is the number of years until the road becomes critical and requires major strengthening by overlaying; it is calculated from pavement deflections measured by deflectograph and from past and future traffic loading. Whole carriageway major cracking is wide single cracking greater than or equal to 2 mm or multiple cracking and coarse crazing. Wheeltrack rutting is the depression of the wearing surface in the vehicle wheelpaths relative to the rest of the wearing surface. Wheeltrack major cracking is wide single cracking greater than or equal to 2 mm or multiple cracking and coarse crazing occurring within the wheelpaths.)

CI rules define how the various rated defects are combined to give CI values that will identify the need for treatment. Within these rules, precise values of coefficients had to be specified to ensure that boundaries between treatments occur at particular measured defect values. For example, the structural CI for a flexible pavement is the highest rating of

$1.0 \times$ residual life

$0.95 \times$ WC major cracking

$0.5 \times$ residual life $+ 0.6 \times$ WC major cracking

$0.75 \times$ WT major cracking $+ 0.3 \times$ WT rutting

$0.3 \times$ WT major cracking $+ 0.75 \times$ WT rutting

or

$0.8 \times$ failed patching/reinstatement

where WC is whole carriageway and WT is wheeltrack.

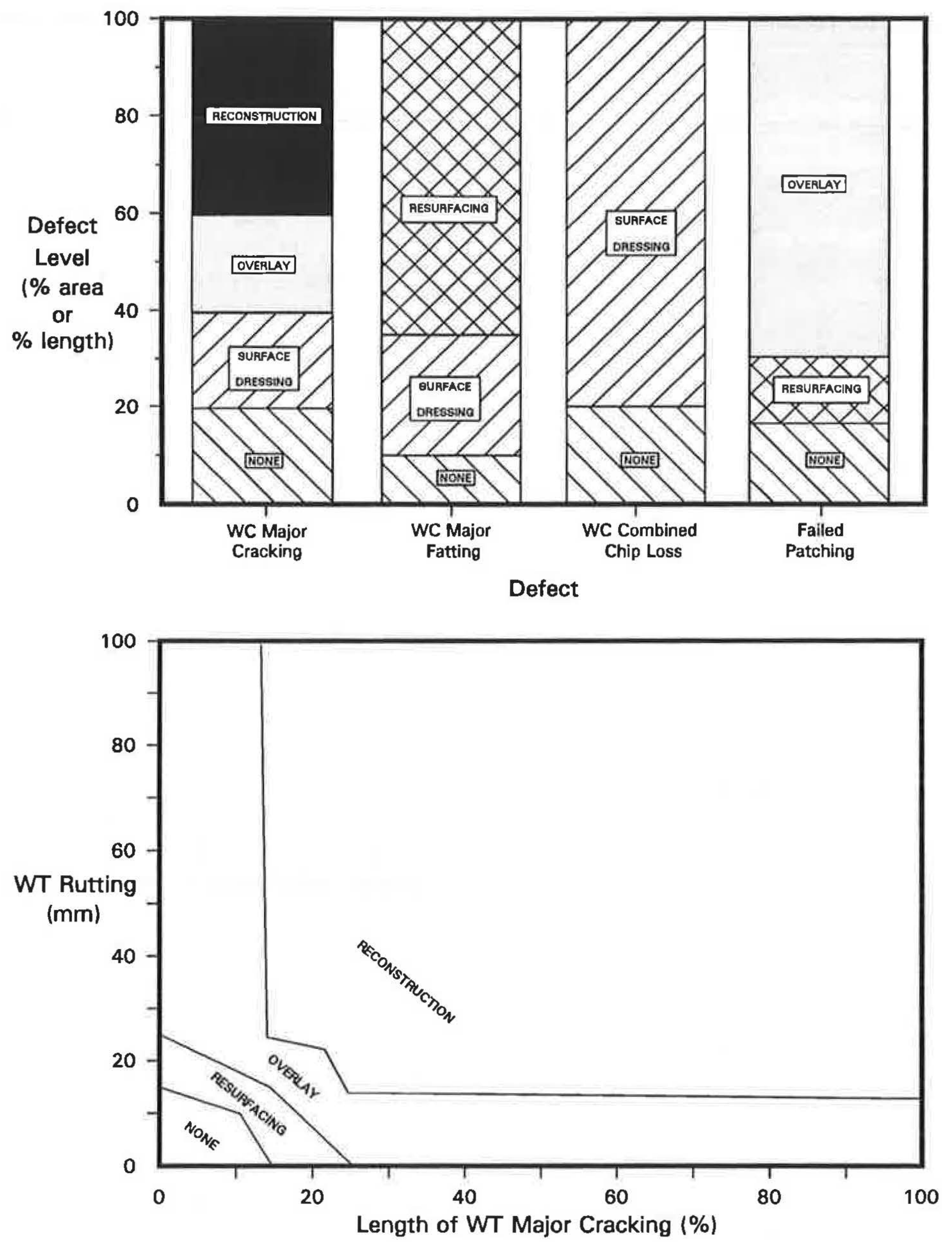

FIGURE 2 Treatments required for levels of defects on flexible pavements.

The automatic treatment selection procedure is controlled by sets of rules. Each rule, in a set, defines the values of various CIs—such as surface, structure, and edge—that will trigger a treatment. An example of a typical rule could be

When

Structural CI ≥ 70,

Surface CI ≥ 40, and

Edge CI ≥ 0,

Then treatment is strengthened by bituminous overlay.

However, within UKPMS, the rules use not CI values directly but numbered treatment selection thresholds (TSTs). Each TST rule comprises a set of CI values. These TSTs allow the condition of the road pavement to be compared with a set of CI values. One treatment is associated with each TST. The assignment of TST variables to rule sets within UKPMS is fixed, but the user assigns the CI values to each TST depending on road classification and type of pavement. The TST values proposed for flexible pavements in the DoT road network are shown in Table 2.

For each defect length the treatment selection process tests the CI values against each rule of the appropriate rule set, in turn, until the CI values satisfy a rule. The

TABLE 1 Defect Ratings for Flexible Pavements

Residual Life		Wheeltrack Major Cracking	
Mean Life Years	Rating	% Length	Rating
20	0	0	0
4	50	15	66.67
2	70	25	93.34
0	90	100	100
-10	100		
Whole Carriageway Major Cracking		**Wheeltrack Rutting**	
% Area	Rating	Depth (mm)	Rating
0	0	0	0
20	52.64	15	66.67
40	73.69	25	93.34
60	94.74	100	100
100	100		

treatment associated with that rule is then assigned to the defect length. The treatment selection rules proposed for DoT flexible pavements are given in Table 3.

As an example of how the automatic treatment selection process works, assume the condition of a length of road is

Structural CI = 78

Surface CI = 20

Edge CI = 40

Each rule in Table 3 is tested against these values.

- Rule 1 fails because the structural CI of 78 is less than the TST6 value of 90.
- Rule 2 fails because the edge CI value of 40 is less than the TST1 value of 50.
- Rule 3 passes the test, so the treatment of overlay is assigned to the defect length.

TABLE 2 Treatment Selection Thresholds for Flexible Pavements

Treatment Selection Threshold	Condition Index Value
TST0	0
TST1	50
TST2	40
TST3	70
TST4	90
TST5	80
TST6	90
TST11	90
TST12	80
TST13	70

Although it is possible to use raw defect data to trigger treatments, defects need to be rated so that network condition can be monitored and network trend analyses carried out.

It should be noted that within UKPMS, as well as the definitions of all defects, all the calculations concerned with combining and rating defects, and indeed the CIs themselves, are parameterized. Consequently, any new or different defect or new machine collecting techniques can easily be incorporated into the system. This has been adopted throughout the design of UKPMS to ensure maximum flexibility.

Interactive Pass

It is recognized that the rules embedded in the automatic pass—for example, those for treatment selection—will not match the skill and knowledge of an experienced engineer. The engineer can refine the allocation of the available budget and the details of treatments to be applied using the interactive pass. The interactive pass uses the same processing as the automatic pass, but the user "steps through" the modules and progressively builds up treatments and schemes for possible implementation within next year's allocated budget. It is intended that the priority list of treatments identified in the automatic pass forms the basis of the detailed analyses in the interactive pass, but the user is free to select the schemes to be evaluated and can choose to evaluate the entire network on this basis. When working interactively, the user may access other data held in UKPMS, such as

- Network section data (e.g., length),
- Inventory (e.g., width, surface type),
- Traffic data (e.g., daily flow),
- Accident data (type and number),
- Condition surveys (e.g., raw condition data),
- Results of automatic processing, and
- Construction and maintenance records.

From this information, the user can then define

- Treatment lengths (i.e., lengths over which the treatment is constant and that typically span several of the defect lengths produced by automatic processing),
- Treatment length options (i.e., treatments that could be applied to cure some or all defects within a treatment length), and
- Schemes and scheme options, which typically comprise several treatment length options.

As treatment lengths options and scheme options are created, their priority indexes are calculated (see next section).

TABLE 3 Treatment Selection Rules for DoT Flexible Pavements

Rule Number	TSTs Structural	Surface	Edge	Treatment
1	≥ 6	Any	Any	Reconstruction
2	≥ 3	Any	≥ 1	Edge reconstruction + Overlay
3	≥ 3	Any	< 1	Overlay
4	≥ 1	Any	≥ 1	Edge Reconstruction + Overlay
5	≥ 1	Any	< 1	Resurface by Inlay
6	< 1	≥ 1	≥ 1	Edge Reconstruction + Overlay
7	< 1	≥ 1	< 1	Resurface by Inlay
8	< 1	≥ 2	≥ 1	Edge Reconstruction + S Dress
9	< 1	≥ 2	< 1	Surface Dress
10	< 1	< 2	≥ 1	Edge Reconstruction
11	< 1	< 2	< 1	None

Note: from Table 2, TST1 = 50; TST2 = 40; TST3 = 70; TST6 = 90

Projection of Condition and Priority Ranking

UKPMS can be classed as a third-generation PMS when compared with the more common first-generation systems currently in use in the United Kingdom. (Second-generation systems include basic facilities that enable conditions to be projected so that trend analyses can be carried out.) The important third-generation facility is the ability to carry out optimization of multiple options of treatments for all sections of the network for the budget in the treatment year. This ability to maximize economic benefit under conditions of budget constraint is included within UKPMS. This facility is of particular interest to the DoT because, in the analysis of cost implications for future years, it has been shown to give rise to substantial benefits.

Priority optimization is a method of setting priorities for maintenance expenditures, when budgets are constrained, by minimizing the longer-term costs. In other words, the method requires that in addition to considering the cost implications this year, the implications for future years must also be taken into account. This is a fundamentally different approach to that adopted by many other systems that react to current conditions, rather than looking at the consequences of likely changes in conditions and, therefore, costs with and without treatment.

Condition Projection

For priority optimization to work, the system must have the ability to project pavement condition into the future. This gives immediate benefits, since treatments are not normally undertaken until at least 1 year after condition surveys are carried out, given the time required for relative prioritization and establishing funding. Whereas many systems determine next year's treatment on the basis of this year's condition, UKPMS determines next year's treatment on the basis of condition projected forward to next year from the current condition. This improves the basis for decision making, because decisions on treatments are based on conditions prevailing at the time the treatment is needed, rather than at the time of the assessment.

Prediction of pavement conditions is also required for longer periods into the future so that historical data can be projected forward and future trends in network condition estimated. UKPMS takes a pragmatic approach to this by using standard-shaped curves relating condition to time, which extend between (0,0) and (1,1) in two-dimensional space. The relationships are generalized using five constants (a, b, c, d, and k) to define the curve given by Equation 1.

$$y = k\left[a + (b - a) \times f\,\frac{(x - c)}{(d - c)}\right] \qquad (1)$$

where

y = defectiveness,
x = time,
$y = a$ when $x \leq c$,
$y = b$ when $x \geq d$, and
$k = 1$ (in first implementation).

The relationship is shown diagrammatically in Figure 3.

Deterioration curves for a defect on a particular section of road are user-definable and are specified as a series of discrete points; intermediate values are determined auto-

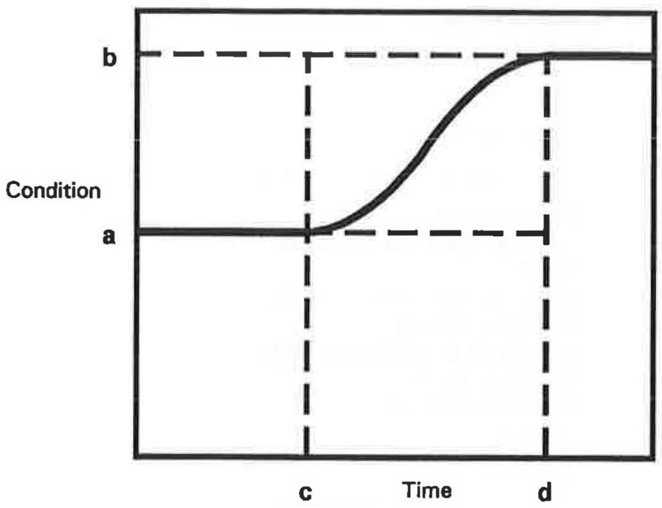

FIGURE 3 Generalized deterioration relationship.

matically by linear interpolation. Alternatively, default curves have been proposed for the first implementation of UKPMS, given that users may not have the data from which to define curves.

Selection of Deterioration Curves

As a result of a comprehensive research study carried out by TRL, the generalized curve form to most appropriately represent the long-term deterioration trend for each of the defects on each pavement construction type was derived in two stages

1. Deterioration trends exhibited by each of the defects were identified; and

2. A standard curve form was assigned to fit the observed trend. Standard curves include linear, exponential, quadratic, and S-shaped curves.

An extract from the catalog of curve types proposed for fully flexible DoT roads is shown in Table 4. (In Table 4, PCV is the proportional change in variance, which is the proportional difference over 2 years in the variance of the deviation from the 3-m moving average of the pavement's profile measured by the High-Speed Road Monitor. WT major tracking is as defined for Table 1. Whole carriageway major fretting is loss of material other than chippings from the wearing surface to the degree that the original wearing surface is no longer discernible. Whole carriageway minor fretting is loss of material other than chippings from the wearing surface although the original wearing surface remains discernible.)

Once the choice of curve function has been made, its shape can be changed by altering the values of *a, b, c,* and *d*. For skid resistance values, for example, *a* is greater than *b* so that the relationship gives decreasing values over time.

To predict future values of defects, it is necessary to fit the curves to existing measurements of condition. For the curves to fit current condition data measurements, they are shifted along the time axis to pass through the current value. Where historical data exist, curves are stretched or shrunk along the time axis to give the best fit to past data but weighted to give more emphasis to recent data.

A comprehensive sensitivity analysis has also been carried out that shows that the projection of defects, for up to about 4 years, is not sensitive to small differences in definition of the base curve. It is considered that reasonable projections can be obtained over the limited number of years necessary for priority optimization to operate.

TABLE 4 Selection of Pavement Deterioration Forms

Carriageway Defect	Measurement Units	Curve Form	Maximum Defect Limit	Duration (Years)	
				Start	Finish
WT Rutting	mm	Cubic	100 mm	0	40
WT Major Cracking	% Length	S-curve	100%	10	30
WC Major Fretting	% Area	S-curve	100%	10	30
WC Minor Fretting	% Area	S-curve	100%	6	20
PCV	%	Exponential	600%	2	40

Setting Priorities

Since maintenance budgets are normally constrained, choices must be made about which maintenance should be undertaken now and which should be deferred for another year or more. Current maintenance systems give priority to remedial measures on those roads in worst condition but do not help the choice between the more expensive treatments and their timing. However, it can be shown that such an approach inevitably leads to a backlog of work building up.

UKPMS can make recommendations with a view to minimizing future, or whole life costs. In particular, the following costs are included

- Future maintenance costs, and
- Costs to the road user: accidents and delay costs at times of maintenance.

Basing priorities on the principle of minimizing longer-term costs overcomes the problem of a backlog of work building up. This is the basis of priority optimization, which defers treatments where there is little immediate cost penalty of doing so. In essence, this gives more priority to preventive treatments, which are more cost-effective over time.

An approach to setting priorities in this way is to use a whole life cost model to determine the net present value (NPV) of each option by comparing the costs associated with carrying out the treatment, the do-something case, with those costs associated with doing either nothing or the minimum treatment possible, the do-nothing or do-minimum case. The option providing the highest NPV should be given priority.

When budget constraints apply, choice of schemes and treatments of schemes, in terms of highest NPV-to-works cost ratio, will ensure that the NPV is maximized within the constraints.

Within the context of UKPMS are several problem areas when applying the NPV test:

- There is a need to make traffic projections for long periods into the future to cover the whole of the evaluation period:
- Capacity problems are likely to occur on major roads if traffic continues to grow through the evaluation period; UKPMS would need a comprehensive traffic model when considering costs and benefits of capacity improvements on new routes.
- The identification of appropriate future maintenance treatment (and road user) costs relies on the projection of pavement condition, both in the do-something and the do-minimum cases, over the whole evaluation period.
- Decisions on future maintenance treatments—as is the case with all long-term evaluations—require assumptions to be made about their economic viability and about the availability of budget for their funding.

The DoT has developed a whole-life cost model, to be known as COMPARE, that addresses these issues, but its data requirements are such that it is inappropriate for use by the smaller highway authorities on their local roads. As a result, a different approach had to be sought.

The alternative method of priority optimization proposed for UKPMS is based on a technique developed during the UKPMS design study. A similar but simpler technique had been used by Rendel et al. (Department of Transport, unpublished document, 1989) in a project they had previously carried out in an overseas country. It involves determining priority rankings, which are based on the benefits derived in the first year of operation only, and on the annualized costs of the first and subsequent treatments. Annualized cost is the "equal annual cost which, when discounted and summed over the life of the treatment, is equivalent to the total cost of the treatment."

In this proposed simplified method, the ratio of NPV to cost, which would be the normal criterion for ranking schemes, is replaced by an economic indicator (EI). This is calculated for each treatment option by considering the costs resulting from carrying out a treatment now and those resulting from deferral of the treatment, as follows:

$$EI = 100 \times \frac{(T_{dm} - T_{ds})}{C} \quad (2)$$

where

T_{dm} = sum of total annualized costs resulting from deferring a treatment or doing a holding (minimum) treatment (do-minimum case);
T_{ds} = sum of total annualized costs resulting from carrying out a treatment now (do-something case); and
C = cost of do-something treatment minus cost of do-minimum treatment

Annualized costs are calculated for

- Pavement structural maintenance and/or surface maintenance, and
- Routine maintenance costs;

plus, if the user wishes,

- Cost of traffic delays during works, and
- Costs of increased accidents at roadworks.

The value of EI can be considered as a surrogate for the NPV-to-cost ratio; the larger its value, the higher the scheme is placed in the priority list. A negative value of EI indicates that the treatment cannot be justified on economic grounds.

Highest economic cost indicators arise for "doing something" when either

- A more expensive treatment will be needed next year if the treatment is deferred this year, or
- The treatment provides a longer-lasting solution than a minimum holding treatment with a relatively high cost and a short life.

An example of this approach is shown for the scheme in the following table:

Treatment Type	*Year*	*Life*	*Treatment*	*Cost (£ thousands)*
Do minimum	5	20	Reconstruct	27
Do something	0	15	Edge reconstruct	12
	1	8	Surface dress	0.35

The calculations to produce the economic indicator for this scheme are given in Equations 3 through 9, where Equations 3 through 6 show the calculations for the do-something case, Equations 7 and 8 show the calculations for the do-minimum case, and Equation 9 shows the final calculation necessary to produce the EI.

$$AC_1(\text{year } 0) = \frac{(12 \times 0.07)}{(1 - 1.07^{-15})} = 1.32 \quad (3)$$

$$AC_2(\text{year } 1) = \frac{(0.35 \times 0.07)}{(1 - 1.07^{-8})} = 0.059 \quad (4)$$

$$AC_2(\text{year } 0) = \frac{0.059}{1.07} = 0.055 \quad (5)$$

$$AC_{(1+2)} = 1.32 + 0.055 = 1.375 \quad (6)$$

$$AC_1(\text{year } 5) = \frac{(27 \times 0.07)}{(1 - 1.07^{-20})} = 2.55 \quad (7)$$

$$AC_1(\text{year } 0) = \frac{2.55}{1.07^5} = 1.82 \quad (8)$$

$$EI = 100 \times \frac{1.82 - 1.375}{12 - 0} = 3.7 \quad (9)$$

where AC is the annualized cost and AC_t (year y) is the annualized cost for treatment t in year y.

This approach requires the projection of pavement condition and traffic flow for a maximum of only 2 years beyond the present year. It is anticipated that it can therefore be used by maintenance engineers with greater confidence. In particular, it avoids the complications of considering future capacity limitations on roads when assessing maintenance works.

Benefits

Priority optimization within UKPMS will be provided to enable

- Treatments to be identified that provide a return greater than their cost,
- Most cost-effective treatments to be chosen from a range of possible treatments, and
- Priorities for investment to be determined under circumstances of budget constraint.

Analysis carried out as part of the UKPMS design study has demonstrated convincingly that the priority optimization method proposed leads to not only lower costs for highway authorities, but also improved road conditions over time. The DoT recognizes the significant benefits to be gained in adopting such an approach for determining priorities of maintenance schemes. The availability of priority optimization in UKPMS will enable all highway authorities to take advantage of its benefits.

Conclusions

In essence, the answer to one question will decide both the treatment and its timing. Will the treatment cost any more in real terms if it is delayed until the next year? If it will, and there is sufficient budget, program the work; if not, defer the scheme for 1 year. Under that principle, costly reconstruction schemes will no longer have an automatic first call on the maintenance budget. UKPMS will thus encourage funding of less expensive but more cost-effective treatments than systems that choose treatments on the basis of condition alone. The core philosophy of UKPMS is to defer treatment where it is cost-effective and safe to do so and give priority instead to preventive maintenance.

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