Review of UKPMS core functionality – the minimum functionality all PMS should embody in the UK

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The minimum functionality all PMS should embody in the UK

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Review of UK Pavement Management System
Core Functionality

Client: Department for Transport, Regional and Local Major Projects
Edward Bunting

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Abstract

Local highway authorities require pavement information and decisions systems to support the management of their transport infrastructure assets in the delivery of their transport objectives. The purpose of this study was to produce a specification to replace the existing UKPMS specification as the minimum functionality that all PMS should embody in future to meet the evolving needs of local highway authorities and national governments in the UK for local roads.

Local authorities need confidence that the systems they use for asset management store, analyse and report on the data consistently and accurately to ensure that asset management decisions and financial information reports are correct. They need a nationally consistent approach to pavement asset management systems wherever the results have to be compared between authorities, or combined across a wider area. Also wherever authorities are required to justify their recommendations, decisions or actions so that they can demonstrate they have applied professional judgement in the context of nationally agreed guidelines or approaches adapted to local needs, rather than in an arbitrary or idiosyncratic way. Furthermore, local authorities need to be confident that the systems they use for asset management consistently store, analyse and report on the data accurately. This is required to ensure that the asset management decisions made and financial information reported are correct.

This report determines the priorities and produces a rationale for the commonality of PMS functions across local authorities and systems, taking account of the increasing importance of an asset management approach. It sets out the proposed core functional specification and maps its implementation to an indicative timetable and budget, taking account of where the costs are likely to fall and the ability of the market to deliver. It identifies where there are gaps or techniques that would benefit from further research.

Executive summary

The DfT awarded a contract to a consortium led by TRL Limited, including Atkins and specialist sub-consultants, to review the UKPMS specification in the light of the Halcrow and Ebert reports, to ensure that it addresses local authorities' future highways data analysis needs.

The objective of the commission was to produce a specification for highways engineering software systems, which would replace the current UKPMS specification as the minimum functionality that all PMS for UK local roads should embody.

There were three elements to the commission:

a) determining the priorities for support and promotion;

b) developing the specification;

c) mapping the agreed specification to an indicative timetable and budget.

Previous studies have identified that the current UKPMS specification for UKPMS does not meet the needs of local highway authorities in a number of ways, and for a range of different reasons. During the workshops carried out as part of this project, local authority representatives have commented that they have been waiting too long for some of the designed functionality in UKPMS to be delivered in practice.

It is not simply a question of adding new functionality to the existing UKPMS specification to meet those needs. Fundamental changes will be required in the overall architecture, as well as many of the details of the specification. This, in turn will quite probably lead to changes in the design of the commercial systems that deliver the functionality to local authorities.

However there are many elements of the existing specification that should be retained, either because they are a good way of delivering the requirements, or to enable local authorities to continue to use historic data and historic methods. Some elements will
have to be replaced, either because they do not deliver the requirements or to enable local authorities to use new data and new methods.

The core requirements for the new specification (those things that must be done consistently between systems, and between local authorities and perhaps most importantly, to allow systems used by local authorities to be independently audited for accuracy) include:

- Network referencing
- Location referencing
- Section attributes
- Importing data
- Exporting data
- RCI processing (to support national reporting)
- Automatic pass processing (until replaced)
- National reporting
- Financial information to support asset management calculations

In order to deliver those requirements in a flexible and manageable way, and to create a framework for future development, a modular approach to the specification and independent accreditation has been proposed.

There are a number of advantages to a phased approach. It would allow time to ensure that the specification and implementation are “right first time”, so avoiding the loss of confidence produced by repeated changes in the specification (as happened with the BVPI calculations using CVI and DVI data, and with the introduction of the SCANNER RCI). It would also enable those local authorities and their service providers, who use the current systems extensively or intensively, time to adapt their business processes to the change from the current UKPMS specification to a new modular specification for PMS in the UK. Our recommendation is that it should be a gradual, evolutionary process that delivers revolutionary change.

Therefore a phased programme of technical development is proposed, including some elements of research that will transform UKPMS over the next four years into a tool that fully supports effective pavement asset management planning for local roads in the UK, delivering strategic life cycle plans (typically over 30 years) and tactical 3 to 5 year maintenance programmes. This technical development work includes:

- Network and data referencing using GPS and GIS
- Improved (alternative) file formats for importing and exporting data to supplement, and possibly eventually to replace, ) HMDIF
- Treatment selection, scheme identification and programme building, using SCANNER and visual survey data
- Predicting the future condition of the pavement and the road network from readily available and affordable data
- Developing whole life costing and life cycle analysis based on data readily available in the UK
- Developing simple scenario modelling and investment optimisation techniques relevant to UK local road conditions

The direct cost of the technical development work will be of the order of £1.3 million (to be funded centrally), and the consequent costs to the current UKPMS suppliers will be of the order of £3.6 million (which would be recovered through charges to users over future years).
To set these figures in context, the current centrally funded cost of supporting PCIS for the UK (at present UKPMS and SCANNER) is of the order of £450k per year. The current cost of using PCIS to local authorities in England alone is of the order of £9 million per year, and this in total is about 0.7% of the total investment in planned carriageway maintenance (for local roads) in England each year which is estimated at about £1.3 billion.

If the new specification for PMS for local roads in the UK improves the efficiency, economy and effectiveness of planned carriageway maintenance by only 1%, (an extremely conservative estimate), the annual benefit to England would be of the order of £13 million in England alone, and the cost of investing in its development would be recovered in the first year after full implementation. The overall benefit to the UK would as a whole be proportionally even greater, of the order of £18 million. In the current economic conditions, the benefits are likely to be realised through local authorities being better able to target their scarce resources with confidence.
1 Introduction

1.1 The objective of the commission

The DfT awarded a contract to a consortium led by TRL Limited, including Atkins and specialist sub-consultants, to review the UKPMS specification in the light of the Halcrow and Ebert reports, to ensure that it addresses local authorities’ future highways data analysis needs.

The objective of the commission was to produce a specification for highways engineering software systems, which would replace the current UKPMS specification as the minimum functionality that all PMS should embody.

There were three elements to the commission:

- determining the priorities for support and promotion;
- developing the specification;
- mapping the agreed specification to an indicative timetable and budget.

A project steering group was set up, chaired by Chris Capps (Cambridgeshire), including Pete Burnham (Worcestershire), Steve Finley (Rotherham), Danny Rawle (Leicestershire) and Edward Bunting (DfT).

1.2 Methodology

Our approach to the project is shown in Figure 1.

To meet the requirements of the commission we carried out the project in three stages:

- In the first stage of the project we reviewed the current core functionality incorporated in UKPMS and the current issues with SCANNER and UKPMS. This established the context in which a new specification is needed for UKPMS, including the business needs, objectives and priorities for the UKPMS specification, and what a PMS should offer to meet them.
- In the second stage we determined the rationale for commonality of functions across local authorities and systems, building on the conclusions of the first phase. This included identifying the areas that would benefit from a preferred or “good practice” specification, identifying the elements that should be included in a (functional) specification, and developing the functional specification in more detail.
- In the third stage we mapped the agreed functional specification to an indicative timetable and budget and identified the gaps or techniques that would benefit from investment in further development or research.

In undertaking the project our aim was to identify local authorities’ business needs and objectives that must be met by the UKPMS specification. However, the commission made it clear that previous work (Halcrow, 2006; Ebert, 2006) had considered these needs (in part) and we were not required to re-cover that ground. Nevertheless, there was a need to identify the key conclusions of the previous work, to review the developments achieved since their delivery (e.g. new tools for asset management such as SCANNER), and hence deliver a clear justification for the future requirements of the UKPMS specification. Therefore we reviewed the previous reports, and identified where there have been developments since they were produced, to identify the priorities for the specification of UKPMS resulting from these reviews. Our findings are summarised in Appendix A.
The project commenced on 14th November 2008, with the project inception meeting on 2nd December. We held a one day consultation workshop with the UKPMS developers on 15th January 2009. A draft final report was delivered on 19th May with the project completion meeting on 1st June 2009.

1.3 Stakeholder involvement and challenge

A fundamental requirement of this commission was to secure the support of the various groups of stakeholders for the proposed changes to UKPMS. We identified several different groups of key stakeholders.

- In 2008 there were four administrations (England, Scotland, Wales and Northern Ireland) that have overall responsibility for local road management policy.
- In England there were 150 local highway authorities, with a very diverse range of road networks in terms of length and mix of urban and rural roads; construction types; design or evolved pavements; etc. Each authority having different requirements of their road networks (and by implication of their pavement information management systems).
- In Wales there were 22 local highway authorities, in Scotland 32 local road authorities and, in Northern Ireland 23 local road areas. Again there were considerable differences in the lengths of the networks, their makeup, the extent to which they serve rural or urban areas and local requirements.
There were five systems developers who have accredited systems to the current UKPMS requirements.

There were a number of organisations that supply services – management, consultancy and works – to local road and local highway authorities.

There were a number of organisations with a commercial interest in different types of machine survey, such as the Deflectograph, the Falling Weight Deflectometer, Griptester, Ground Penetrating Radar, SCANNER and SCRIM.

There were a number of organisations with a direct interest in visual pavement condition surveys of various types, both within local authorities and the private sector, using both walked and driven surveys and supplying equipment for such surveys.

There were a number of organisations with an interest in visual surveys to locate and identify inventory assets other than pavement condition, some of whom are developing new techniques, tools and approaches to record and store information about asset condition.

The Highways Agency which has experience covering most, if not all, aspects of asset and pavement management systems including many of those needed by UK authorities managing local roads.

It was practically impossible to identify and consult all those who might have had an interest in the specification for UKPMS. However, we believed it was important to involve as many points of view as possible in determining the priorities and in approving the proposed specification. We therefore extended a wide invitation to contribute information using the PCIS Newsletter and direct e-mail and telephone contacts.

We also believed it was very important that our proposals were challenged, so that we could be sure that they were robust and well founded. Therefore during the project we held two facilitated workshops with groups that represent the diversity of interests, as well as a range of expertise:

- The first workshop, earlier in the project on 17th February 2009, challenged and commented on our determination of the business needs and the priorities for support and promotion of technological capabilities, and our views of what a “good practice” PMS should include.
- The second, towards the end of the project on 22nd April 2009, challenged and commented on our proposals for the new specification, the requirements for further research and development, and the timetable and budget for implementation.

1.4 Extent of this investigation

The development of successful Information and Communication Technology products includes several stages as shown in Figure 2. This functional specification only encompasses the first stage of this lifecycle, highlighted in bold in Figure 2. At the commencement of this commission it was acknowledged that, following the delivery of the functional specification, it would be necessary to develop detailed technical specifications. It would then become the responsibility of the Pavement Condition Information Systems (PCIS) support contractor to facilitate implementation through a parallel contract, working with local highway authorities and PMS suppliers.

This investigation therefore ONLY covers the first two stages in the development of the new PMS specification for the UK:

- Defining the business requirements and processes, and
- Defining the functional specification.
(1) Defining the business requirements and processes (analysis)
(2) Defining a functional specification (for what the software will do)

(3) Defining a technical specification (how the software will do it)
(4) Designing a system (to meet the functional and technical specifications)
(5) Programming (writing the code to carry out the defined tasks)
(6) Testing (checking that the system does what is intended)
(7) De-bugging (identifying and correcting faults as they are found)

(8) Delivering the system (on hardware, to customers)
(9) Training (in both the processes that support the business requirement and the systems that have been provided)
   (10) Support (to the users)
   (11) Maintenance (of the system)

Figure 2 Development of an ICT product
2 Recent developments

2.1 Asset management systems

Over recent years the concept of “infrastructure asset management” has been widely accepted, and applied to the management and maintenance of highways and highway pavements.

Since the completion of the previous reports (Halcrow, 2006; Ebert, 2006), there have been significant developments in highway asset management. Following the publication of the Framework for Highway Asset Management in July 2004 (CSS, 2004) and the Guidance Document for Highway Infrastructure Asset Valuation in July 2005 (Roads Liaison Group, 2005) there has been extensive adoption of Highway Asset Management Plans (HAMPs) and Transport Asset Management Plans (TAMPs) in England, Scotland, Wales and Northern Ireland. In England, for example, in the second edition of the guidance on preparing Local Transport Plans published in January 2006 (DfT, 2006), the Department for Transport encouraged local authorities to draw up Transport Asset Management Plans (TAMPs), informed by their Local Transport Plans and other services and corporate plans.

As part of this project we have carried out a review of pavement asset management systems currently available on the market. We identified them through searches within the TRL library knowledge base, relevant conference proceedings, the internet and discussions with experts. The review was carried out in the English language and therefore only identified systems that were described in English. There may be other systems that are only described in other languages.

Our review identified 21 different systems (listed in Appendix B). The databases used to store all the data are designed in Oracle, SQL or MS Access and the majority of the systems use GIS for data viewing and reporting.

Generally, a pavement asset management system includes analysis and prediction tools such as current and future condition and remaining life-time prediction, whole life cost analysis for maintenance and construction, deterioration models, assessment of value of the asset, risk based analysis and prioritisation of projects at both network and project level according to strategies and budgets. Most of the systems reviewed include either one or several of these analysis tools.

Some of the systems are specifically compatible with externally specified standards. The three main standards are:

- UKPMS (the UK national specification for pavement management systems)
- HDM4 (a systematic approach, developed for the World Bank, used for techno-economic analysis of road investment)
- GASB34 (the United States Governmental Accounting Standards Board’s requirements for valuing infrastructure assets)

2.2 Financial information and valuing infrastructure assets

Transport Asset Management Plans (TAMPs) and the underlying records and systems to support them were already in place or were being developed by local authorities in 2006. As well as their local role, these plans may be used by central government in policy development and to inform resource allocation. However an initial small scale study by HM Treasury in 2005 suggested that linking local authorities accounting and financial management information to the TAMPs would enhance information for a wide range of users. As a result HM Treasury and the Department for Transport commissioned a
review of accounting, management and finance mechanisms for local authority transport infrastructure (CIPFA, 2008).

In the light of responses to consultation the report recommended that 2010/11 – which would be the year in which local authorities completed the transition to International Financial Reporting Standards (IFRS) – should also be the first year for which current value accounting information about infrastructure assets should be reported, but that this should be treated as a ‘dry run’ year. The main financial statements would still be on a historic cost basis but authorities would disclose information on a current, Asset Management Plan (AMP) based, accounting basis in the notes to the Accounts.

The change to the Statement of Recommended Practice (SORP) treatment could then be implemented in 2011/12. A ‘prepare and decide’ approach should be adopted, with the possibility kept open of making 2011/12 a further dry run year. The final ‘switchover’ decision would then be made in the light of progress made for the 2010/11 dry run year.

This approach should strike a balance between concerns about the work involved in implementing a significant change to infrastructure accounting alongside the move to IFRS based accounts, and the need to make early progress in developing sound financial information to support better asset management.

In 2010/11, the year before the proposed full adoption of the new AMP based accounting policies, dry run information would be used to inform Whole of Government Accounts (WGA) consolidation returns. However an interim approach will still be required for 2009/10, which would then be the first year of WGA publication, as well as for the 2008/09 dry run.

The consultation proposed an interim approach to address the WGA information requirements, using a combination of national unit costs, asset inventory and condition information already held by local authorities. This approach was explored further in discussion with central government, the Audit Commission and the National Audit Office and some local government practitioners, and is reflected in the report (CIPFA, 2008).

In summary, this proposed that a high level Depreciated Replacement Cost (DRC) valuation for WGA purposes could be produced in a way that used mostly existing data from local authorities, and was based on determining valuations for the road pavement and underlying land which, experience suggested, together comprised the overwhelming majority of the highway infrastructure asset value.

The report suggested the development of inventory and condition data should be driven by asset management planning considerations rather than simply being seen as an accounting requirement. The key to this would be effective prioritisation of work, concentrating initially on the high value/high spend assets, and then gradually extending the coverage and detail over time.

The report recommended that UK national administrations should consider whether and how to support local authorities to deliver to a fixed early timetable in order to deliver the significant ongoing efficiency savings available. Otherwise the timetable for any change to the accounting would depend on the natural progress of the slower authorities, and the substantial potential benefits from the asset management plan based approach were unlikely to be realised for some years. In response to the draft consultation report, the DfT announced that it would provide £15m to support development of transport asset management by local authorities in England. This figure has subsequently been increased to £23m.

### 2.3 Other research and development

There has also been a considerable amount of other relevant research carried out for the Department of Transport and the Highways Agency which could potentially be implemented through UKPMS as it has already been implemented through the Highways
Agency pavement management system (HAPMS) and Integrated Asset Management System (IAMS). The research has lead to the development of asset management tools in a number of areas:

- The HA SAS (scheme analysis system) tools for all the major highway assets (pavements, structures, drainage, geotechnics, etc.)
- The HA Whole Life cost tools – SWEEP.N and SWEEP.S, (Software for the Whole-life Economic Evaluation of Pavements where .N = Network level and .S=Scheme level) which form part of HAPMS
- The HA WLCM (whole life cost model) which has been used for analysing future budgeting requirements for the Annual Spending Reviews by HM Treasury over the past years.

Other areas of research which influence asset management have included

- Highway Service Levels (Ramdas et al, 2007),
- Traffic Speed Deflection measurements,
- a series of projects supporting the HA Integrated Asset Management plans and developments in automated surveys of carriageway condition.
  - Development of the SCANNER RCI (McRobbie, 2007), subsequently revised to reflect engineers’ requirements more closely (McRobbie et al, 2007).
  - Consideration of Smaller, quicker, cheaper automated carriageway condition surveys for local roads (Gallagher et al, 2009), leading to a new specification for Surface Condition Assessment for Minor Roads (SCAMR) surveys.

Further details are given in Appendix C.

2.4 Developments in machine survey technology

There have been significant developments in machine survey technology, and these developments are possibly one of the most significant drivers for change in the management of survey data within UKPMS.

In 2005 the SCANNER specification was being used for the first time in England (following the TTS specification that was used in 2003-04 and 2004-05), the B and C roads were being surveyed for the first time, and the SCANNER Road Condition Indicator was being developed by the Defects Index Working Group. Since then (2005-06 to 2008-09) there have been four years of surveys in England using SCANNER accredited vehicles, covering the A and B roads at least twice in each direction, and the whole length of the C road network in one direction, providing a comprehensive set of measurements.

The SCANNER specification has also been adopted in Scotland for the SRMCS, in Wales for the national performance indicators and is being used in Northern Ireland for the first time this year. In the past year (2008-09) more than 134,000 km were surveyed in Great Britain to the SCANNER specification.

The SCANNER survey itself has also undergone significant development, stimulated by the research programme. The research, to which TRL made a key contribution, lead to the delivery of new methods for measuring condition in ride quality, edge condition, cracking and texture variability. These have been implemented through the SCANNER Accreditation and QA process, and delivery of these new measures commenced in the 2007/08 survey data.

At the same time there has been a significant reduction in the extent to which visual inspections (Coarse Visual Inspections, CVI and Detailed Visual Inspections, DVI) are being used on classified roads, although some local authorities have continued to use...
them either for reasons of continuity, or because they prefer to use the information gathered by visual inspections, or to ensure coverage of footways as well as carriageways.

Currently the data available to local road authorities on classified road carriageways are mainly derived from machine surveys and on unclassified road carriageways are mainly derived from visual inspections.

The measurements obtained from SCANNER surveys are described in more detail in a subsequent section (3.6), and the relative costs of SCANNER surveys and visual condition surveys are considered in Appendix D.

As well as the development of TRACS and SCANNER, there have been parallel developments in the use of Ground Penetrating Radar (GPR) and research into the use of the Traffic Speed Deflectometer (TSD), described in more detail in section 3.8 and Appendix C.
3 Determining the priorities

The aim of the first stage was to produce a rationale for commonality of functions across local authorities and systems. In particular:

- the increasing importance of an asset management approach,
- the need for financial information such as asset valuation,
- SCANNER and similar machine based condition data functionality,
- outstanding issues from the Ekins-Hawker report, and
- the potential for making better use of existing research

3.1 Our approach

Our aim was to identify the business needs and objectives that must be met by the UKPMS specification, leading to a rationale for commonality of functions across local authorities and systems.

Our review of the core requirements for UKPMS therefore encompassed:

- The need for consistent, accurate processes and systems
- The context in which UKPMS should provide service – which could be considered to relate to business management
- Technical components – which could be considered to relate to asset management
- Requirements for national reporting – how UKPMS could assist in the assessment of the asset at the national level
- Addressing new technologies – how a new UKPMS should cater for recent developments

3.2 Initial consultation

We consulted the five developers who have accredited systems to the current UKPMS specification and the three main survey contractors who have accredited machines to the current SCANNER specification and accredited visual surveyors at a workshop on 15th January 2009. We discussed with them:

- The scope and objectives of the project.
- What a PMS is for; and what local authorities need a PMS to do for them.
- What the core functionality should be; what all systems should do in the same way; what UK local authorities need to be done in the same way, and why. Also what we meant by ‘the same’, distinguishing between ‘identical’; ‘within tolerances’ and ‘broadly comparable’.
- The current requirements of UKPMS to provide financial information to support asset management.
- The issues for implementing a new specification for UKPMS; including the practical issues and the technological challenges, both for UKPMS developers and for local authority clients.
- What further research is needed, what could be developed commercially, and what would require central funding.
- The project delivery plan and the issues to be discussed at the 2 workshops.
- How systems might be accredited in future, and how their performance might be audited.

We also posted a short questionnaire on the UKPMS website and invited responses through the Pavement Condition Information Systems (PCIS) Newsletter. This initial consultation provided input to stimulate the approach to the first stage of the project and provide direction for the first workshop. As only a few questionnaires were completed initially, we asked those attending the first workshop to complete the questionnaire before the workshop. In total we received 15 completed questionnaires.

In summary, the overall conclusions were that local authorities want pavement management systems to be able to deliver the functionality offered by the current UKPMS specification consistently and accurately, with some additional capabilities.

- Local authorities need to be able to analyse highway data to support various decision making processes.
- These processes feed information into several different areas covering local authority policy, strategy and finance.
- Information is required for strategy and policy which may be defined in many ways, including the Local Transport Plans (LTP) in England and Highway Asset Management Plans (HAMPS) and Transport Asset Management Plans (TAMPS).
- Information is required for budgeting purposes, which may start by being analysed at a network level but which ultimately relates to the need for the design implementation of individual schemes.
- Information is required to assess whether the objectives of policy and strategy are being met and whether the budgets are being used wisely.

The type of detailed information and analysis that may be required therefore includes:

- How much money is required to maintain the road network now, and will be in future.
- How expenditure could be prioritised to meet budgets and Best Value requirements.
- The effects of budget uplift or constraints on current and future objectives.
- The most cost effective treatments based on condition and available budget.
- The most effective timing for maintenance treatments.
- Whether pre-determined service levels are being achieved or how they could be met.
- How resource allocation and maintenance decisions are affecting the condition and underlying value of the pavement asset.
- What the Key Performance Indicators are, and how they are changing with time.

### 3.3 Business requirements and priorities

#### 3.3.1 Local road networks in the UK

There were four administrations (England, Scotland, Wales and Northern Ireland) within the UK that had overall responsibility for local road management policy in 2008. The arrangements and responsibilities for managing local roads differ between the four administrations.

In England, Wales and Scotland, local roads are the responsibility of elected local government. The Northern Ireland Roads Service is the sole road authority in Northern
Ireland, responsible for ensuring that the public road network is managed, maintained and developed.

In England, in 2008, there were 150 local highway authorities with very diverse road networks, ranging in size and total length of network as well as proportion of urban and rural roads, types and methods of construction including designed or evolved pavements, etc. Each authority having very different requirements of their road networks and, by implication, of the functionality, inputs and outputs of their pavement information management systems. Local government re-organisation in England has slightly increased this number, as some county and district authorities were combined, or in some cases divided, in April 2009 to create new unitary authorities. In Wales there were 22 local highway authorities, in Scotland there were 32 local road authorities, and in Northern Ireland 23 local road service areas. Again, there were considerable differences in the lengths of the various local road networks, their makeup and the extent to which they served rural or urban areas.

The overall length of local road networks is summarised in Table 1, based on data published by the Department for Transport (DfT, 2008) and the Department for Regional Development, Northern Ireland (DRDNI, 2008).

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of local authorities (2008)</th>
<th>Trunk roads (km)</th>
<th>Principal roads (km)</th>
<th>Other roads (km)</th>
<th>Total local roads (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>England</td>
<td>150</td>
<td>7,286</td>
<td>27,959</td>
<td>266,195</td>
<td>294,154</td>
</tr>
<tr>
<td>Wales</td>
<td>22</td>
<td>1,688</td>
<td>2,619</td>
<td>29,554</td>
<td>32,173</td>
</tr>
<tr>
<td>Scotland</td>
<td>32</td>
<td>3,227</td>
<td>7,481</td>
<td>48,870</td>
<td>56,351</td>
</tr>
<tr>
<td>Northern Ireland</td>
<td>24*</td>
<td>1,228</td>
<td>1179</td>
<td>22,732</td>
<td>23,911</td>
</tr>
<tr>
<td>Totals</td>
<td>228</td>
<td>13,429</td>
<td>39,238</td>
<td>367,351</td>
<td>406,589</td>
</tr>
</tbody>
</table>

* Local road service areas in Northern Ireland

### 3.3.2 Annual pavement maintenance expenditure

Information is published in a number of places on the annual expenditure on road maintenance, including local authority financial accounts and national transport statistics. However, because of the differing ways information is aggregated before publication, it is quite difficult to obtain precise and detailed information about expenditure on pavement maintenance on local roads in the UK.

Transport Statistics Great Britain (TSGB) reports that total public investment in road infrastructure in 2006/07 was £4,756 million, which included all “patching” (DfT, 2008a). The same source reports local government expenditure on roads in England, Scotland and Wales, divided into capital and current/resource expenditure. Northern Ireland Transport Statistics reports public expenditure on all Northern Ireland roads (DRDNI, 2008).

This information is summarised in Table 2.

<table>
<thead>
<tr>
<th>Country</th>
<th>Capital expenditure outturn (2006/07) £million</th>
<th>Current/resource expenditure outturn (2006/07) £million</th>
<th>Total expenditure £million</th>
</tr>
</thead>
</table>

Table 1 Road lengths in the United Kingdom (2007)

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of local authorities (2008)</th>
<th>Trunk roads (km)</th>
<th>Principal roads (km)</th>
<th>Other roads (km)</th>
<th>Total local roads (km)</th>
</tr>
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<tr>
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<td>13,429</td>
<td>39,238</td>
<td>367,351</td>
<td>406,589</td>
</tr>
</tbody>
</table>
TSGB also reports expenditure on roads in England (DfT, 2008b). This shows a total of £2,720 million expenditure in 2006/07 on local road new construction and improvement for highways, lighting, road safety and structural maintenance and a further £1,069 million expenditure on routine and winter maintenance (which excludes revenue expenditure on bridge structural maintenance and strengthening, on road safety and on public lighting).

The figures in Table 2, derived from table 1.15 in TSGB, relate to net expenditure, whereas the total of £2,720 million, derived from table 7.13 in TSGB, relates to gross expenditure. For this reason, and certain differences in coverage, the totals differ.

The figure of £2,720 million includes expenditure on technical surveys, expenditure recorded on local authority capital expenditure returns and also structural maintenance recorded on revenue returns. Structural maintenance includes reconstruction, overlay, resurfacing, patching and surface dressing as well as works on drainage, footways, bridges, earthworks and fences. The figure of £1,069 million on routine maintenance includes verges, sweeping, gullies, signals, signs and marking. Winter maintenance includes salting, snow clearance and the maintenance and operation of ice detection equipment, etc...

Maintenance expenditure on roads in England is also reported in a Transport Statistics Bulletin, Road Conditions in England (DfT, 2008c). This is summarised in Table 3.

### Table 3 Maintenance expenditure by road class in England (2006/07)

<table>
<thead>
<tr>
<th>2006/07</th>
<th>Structural (£million)</th>
<th>Routine and other (£million)</th>
<th>Total (£million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trunk roads and motorways*</td>
<td>504.6*</td>
<td>482.0*</td>
<td>986.6*</td>
</tr>
<tr>
<td>Principal roads</td>
<td>510.7</td>
<td>317.7</td>
<td>828.3</td>
</tr>
<tr>
<td>All other roads</td>
<td>1,203.3</td>
<td>722.3</td>
<td>1,925.6</td>
</tr>
<tr>
<td>Total, local roads</td>
<td>1,714</td>
<td>1,040</td>
<td>2,754</td>
</tr>
<tr>
<td>Total, all roads</td>
<td>2,218.6</td>
<td>1,522</td>
<td>3,740.6</td>
</tr>
</tbody>
</table>

*Figures on an accruals basis

From this, it would seem that local authorities in England spend of the order of £1,714 million on maintaining carriageways, footways and bridges each year. The relative proportions of expenditure on carriageways, footways and bridges vary between authorities. Typically, smaller urban authorities spend a higher proportion on...
maintaining footways and figures up to 50% have been quoted. Whereas larger rural authorities spend a lower proportion and figures down to 5% have been quoted. Allowing for length, an approximate figure of 75% of maintenance expenditure on carriageways (i.e. excluding footways and bridges) would be of the order of nearly £1,285 million per annum, in England, over nearly 300,000 km of road length. If this were spread equally across the network, it would amount to approximately £4,300 per kilometre per year but, as we describe below, planned maintenance is only applied on a small percentage of the network each year.

3.3.3 Annual maintenance treatment lengths

The lengths of road receiving maintenance treatment by road class and type of treatment in England are reported in Road Conditions in England (DfT, 2008c). This is summarised in Table 4.

Table 4 Maintenance treatment lengths in England 2006/07

<table>
<thead>
<tr>
<th>Treatment type</th>
<th>Principal roads</th>
<th>Other roads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% length</td>
<td>Estimated (km)</td>
</tr>
<tr>
<td>Strengthening (reconstruction and overlay)</td>
<td>1.8</td>
<td>503</td>
</tr>
<tr>
<td>Resurfacing</td>
<td>2.4</td>
<td>671</td>
</tr>
<tr>
<td><em>Sub total</em></td>
<td>4.2</td>
<td>1,174</td>
</tr>
<tr>
<td>Surface dressing and thin surfacing</td>
<td>3.4</td>
<td>951</td>
</tr>
<tr>
<td><em>Total</em></td>
<td>7.5</td>
<td>2,097</td>
</tr>
</tbody>
</table>

3.3.4 Other business areas

We have identified three separate business areas with which the new UKPMS will need to relate effectively:

- **Financial management.** All local authorities have to manage their finances, highway responsibilities imply income and expenditure. Modern approaches to accounting, such as resource accounting and budgeting, require the valuation of assets, capitalisation of accounts and explicit treatment of depreciation. Therefore pavement information management systems are very relevant to financial management. For pavement information systems to be able to analyse the cost effectiveness of pavement maintenance strategies, pavement treatments, etc. they need to be able to import financial data from the financial accounts. Therefore one of the important requirements for the new specification is about the interface between pavement information systems and accounting systems.

- **Contracts and works.** All local authorities procure work on their highways, they have to specify the work, measure the work and monitor progress, make payments for work properly done, etc. Modern approaches to managing work are based on computerised systems. There is a need to be able to link the management of maintenance systems to pavement information systems. Records of where and when work has been done, the costs of different types of treatment, etc.
• **Network management.** Under the Highways Act 1980, highway authorities have a duty to maintain the road in a safe condition. As well as their statutory duties, local highway authorities invest considerable time and other resources to improve road safety and reduce the number and severity of traffic accidents. Under the Traffic Management Act 2004, local authorities have a new range of network management responsibilities. However, the functions of managing road safety and developing the network in terms of new build, improvements, use of highway space, and the links to traffic and transport planning, etc. have historically been separate from road maintenance. All need information about the quantity, quality and condition of highway infrastructure, and hence links to pavement information systems, so that everyone in a local authority and their service providers is able to look at the same set of information. This includes information about others who work on the highway, or under the highway, such as the utilities and their service providers.

### 3.4 Asset management

Highway asset management is:

> "A strategic approach that identifies the optimal allocation of resources for the management, operation, preservation and enhancement of the highway infrastructure to meet the needs of current and future customers." (CSS, 2004).

An asset management approach is likely to require five main changes:

- "a strategic approach – taking a longer term view to planning and programming,
- whole of life – the introduction of life-cycle modelling to identify the best whole life option for the asset,
- optimisation – greater use of asset performance information to enable better informed decisions,
- resource allocation – the allocation of resources based on assessed need
- customer focus – explicit consideration of customer expectations and documentation of levels of service." (CSS, 2004).

Local Authorities are increasingly taking a planned asset management approach to their highway assets, influenced by the requirements and recommendations of central governments. This, combined with budget and resource pressures plus the need to demonstrate good value, means that they want to be able to make sound decisions and be able to make better decisions, by improving the decision making process at ALL levels:

- Operational (project or scheme level)
- Tactical (project selection or prioritisation level) which requires forward works programmes (3 – 5 year rolling programme) and
- Strategic (network level) which requires life cycle plans (5 to 30 year plans).

At the project level, the road maintenance manager has to determine the most economical maintenance treatment capable of satisfying the overall project requirements. Regardless of whether the project is an improvement or a maintenance scheme, the objective of project-level analysis is to select the most appropriate treatment option, assuming various constraints (including funding).

At the selection and prioritisation level, the local authority has to assess projects to establish a multi-year (typically 3 to 5 year) capital maintenance programme. Pavement management data, including inventory, condition and cost data, are evaluated to prioritise network needs and develop listings of recommended schemes and their respective treatments, based on budget allocations.
At the strategic level the local authority has to assess overall network need and develop longer term life cycle planning, typically up to 30 years ahead for long (or indefinite) life infrastructure assets, such as road carriageway pavements.

3.5 Asset valuation

HM Treasury and the Department for Transport commissioned a review of accounting, management and finance mechanisms for local authority transport infrastructure (CIPFA, 2008). The objective of the review was to evaluate the issues associated with implementing an asset management plan-based approach to accounting, managing and financing local authority transport infrastructure assets, including the best way to use such information to:

- Support good financial management locally;
- Provide good information to support policy development and resource allocations;
- Produce financial accounts complying with relevant International Financial Reporting Standards (IFRS) requirements; and
- Deliver consistent high quality information for Whole of Government Accounts (WGA) and National Accounts purposes.

The review identified that comprehensive transport asset management had the potential to deliver significant value for money benefits and improvements in the services delivered to users. The report concluded that an Asset Management Plan (AMP) based approach was the only one capable of delivering all the objectives of the review. In particular, it was the only one capable of fully supporting sound financial management decisions and effective long term stewardship of the asset base.

The AMP based approach should help authorities to take better informed decisions about spending priorities, by demonstrating the long term consequences of particular levels of investment, and help them to maximise the output that can be achieved for the chosen level of expenditure. Robust information about what authorities really need to spend to maintain transport infrastructure to defined levels could also better inform future national spending decisions.

The report also concluded that, if the benefits of an AMP based approach were to be realised quickly and in full, an early change would be needed in the relevant accounting guidance contained in the Statement of Recommended Practice (SORP). Changing the current SORP treatment to an AMP based approach would require local authorities to have good quality, consistent information that would be able to withstand audit scrutiny.

In order to meet IFRS requirements, local highway authorities will have to calculate:

- Gross Replacement Cost (GRC)
- Depreciated Replacement Cost (DRC) and an
- Annual Depreciation Charge (ADC)

Requirements for financial information to support asset management are currently evolving and consistent, reliable data about the relevant aspects of road carriageway condition will be at the heart of any meaningful calculations.

3.6 SCANNER functionality and UKPMS performance

In total, a SCANNER survey reports thirty nine parameters to the current specification. These measure:

- Position and geometry
- Longitudinal profile (ride quality and deformation)
- Transverse profile (ruts and deformation)
- Edge condition (edge deterioration)
- Texture and texture variability (surface deterioration)
- Cracking intensity (structural and surface deterioration)

The SCANNER Road Condition Indicator was developed over a number of years as a way of combining a number of different SCANNER measurements into a single figure, but it is only based on a limited selection of six parameters. This is produced using a “weighting set” approach, which can be run more quickly, instead of the “automatic pass” calculation.

As part of the introduction of automated surveys, a method of calculating treatment requirements from SCANNER data was developed and subsequently refined. This uses the “automatic pass” approach in UKPMS, with treatment rules based on a limited subset of SCANNER parameters. Although it is possible to calculate indicative treatments from these SCANNER parameters, the rules were developed through informed discussion in workshops and have not been calibrated against results on local roads. In practice, it appears that very few authorities have attempted to use UKPMS to develop indicative treatments and budgets using SCANNER data.

Many authorities are unable to process SCANNER data to provide treatments (via the standard UKPMS processing routine – the Automatic Pass) because it simply takes too long (typically several days). There are several reasons for this unacceptable performance including:

- Larger volumes of data. The quantities of SCANNER data are very much larger than the other data sources (visual and machine) for which UKPMS was originally designed.
- The complexity of the Automatic Pass processing. While this is a powerful and flexible tool for processing many types of data together, it can be argued that firstly it is over complicated, and secondly, due to its generic nature, it cannot directly exploit the more structured nature of SCANNER data; it was designed to deal with all types of data (including the more sporadic defects recorded during visual surveys), and not just the continuous measurements provided by SCANNER surveys.
- Inadequate computing resources. Performance depends on the type and level of computing resources and these vary considerably from one authority to another.

We describe some of the issues with current UKPMS performance in more detail in Appendix E.

### 3.7 Issues from the Ekins Hawker report

The TTS scoping study report (Ekins & Hawker) did not specifically consider the impact of the change from visual survey to machine survey condition data on how the data are used by local authorities. The recommendations of the TTS scoping study were reviewed in the “end of term” report from the SCANNER implementation project (Willmington et al, 2008).

In summary, the main outstanding issue is the requirement for a third stage of review and revision of the overall “defects index” – which was delivered as the SCANNER RCI. The first stage developed the approach and specified the initial (original) set of parameters, thresholds and weightings. The second stage reviewed the working of the RCI on a wide range of local roads and recommended the revised set of parameters, thresholds and weightings. The third stage would have reviewed the working of the RCI and added additional parameters, thresholds and weightings for edge condition and surface variability, leading to an “enhanced” or “extended” RCI.
The SCANNER “end of term” report identified the need to use SCANNER data more effectively for:

- Treatment selection
- Asset valuation
- Deterioration modelling and condition projection
- National pavement condition reporting

It also identified the need for some specific tasks to develop and improve SCANNER capabilities.

### 3.8 Better use of existing research

The SCANNER research programme introduced a number of new measurements with potential to be used as part of local authority asset management; but without developing the tools to enable local authorities to use them effectively and with little practical guidance on how they could be used to enable system developers to develop the tools. There is hence a clear need to develop processes that would turn the wealth of data provide by SCANNER into information that local highway authorities can use to manage their pavement assets more effectively.

There has also been a considerable amount of other relevant research carried out for the Department of Transport and the Highways Agency (Appendix C) which could potentially be implemented through UKPMS as it has already been implemented through the Highways Agency pavement management system (HAPMS) and Integrated Asset Management System (IAMS). The research has lead to the development of asset management tools in a number of areas:

- The HA SAS (scheme analysis system) tools for all the major highway assets (pavements, structures, drainage, geotechnics, etc.)
- The HA Whole Life cost tools – SWEEP.N and SWEEP.S, which form part of HAPMS
- The HA WLCM (whole life cost model) which has been used for analysing future budgeting requirements for the Annual Spending Reviews by HM Treasury over the past years.

Other areas of research which influence pavement asset management have included:

- Highway Service Levels,
- Traffic Speed Deflection measurements,
- Smaller, quicker, cheaper automated carriageway condition surveys for local roads leading to a new specification for Surface Condition Assessment for Minor Roads (SCAMR) surveys.

There is a potential for future machine surveys to measure structural and other parameters such as the Traffic Speed Deflectograph (TSD) currently being developed on behalf of the Highways Agency. Other traffic speed techniques such as ground penetrating radar (GPR) may also be able to provide useful data to PMS in the future. This would again be likely to create large amounts of data for processing.
4 Developing the new specification

The aim of the second element was to develop the new specification. The commission specified that:

"It is important that commonality is not suggested purely on the grounds that local authority engineers say that they would like it. Each component proposed for inclusion in the core should be grounded in a firm rationale…"

"It is important to distinguish between:

- things that a good PMS should do (the state of the art);
- things that all PMS need to do in the same way (the common core);
- techniques that would benefit from research being conducted centrally"

4.1 What a PMS should offer (the state of the art)

Pavement Management is a business-like approach to the management of paved highway assets, including roads, kerbs, footways and cycle-tracks. The overall aim of pavement management is to maintain and improve the paved highway asset to support its current and future use in an efficient and safe manner, through the systematic assessment of condition and the identification and prioritisation of maintenance need.

As paved assets comprise by far the largest and highest value part of the highway network, efficient pavement management forms a vital component of any successful Transport Asset Management regime. It is essential for local authorities to be able to demonstrate effective pavement management processes within their Highway and Transport Asset Management Plans.

In addition, effective pavement management delivers real benefits in the form of financial and economic savings resulting from more appropriate and more timely maintenance treatments.

There is an important difference between ‘pavement management’ and a ‘pavement management system’.

‘Pavement Management’ is a management approach used by personnel to make cost effective decisions, whereas

A ‘Pavement Management System’ is a set of tools used to assist managers in reaching those decisions.

At a network or strategic level, determined by the highway authority’s wider strategic and policy objectives:

- Identify the overall need for pavement maintenance
- Determine the level of funding needed
- Select feasible funding options and strategies
- Determine the impact of different options on condition and level of service
- Develop the preferred funding option and strategy, and
- Identify the road lengths to be considered for maintenance under the available funding.

At a project selection or prioritisation (tactical) level, linking with the authority’s broader corporate and community objectives:

- Define the relative priority of the road section lengths in the maintenance programme within the available budget
- Identify suitable treatments,
- Improve cost estimates by including project work items that are not part of the pavement cost,
- Rate priority relative to the authority’s overall objectives, and
- Finalise the list of projects (or schemes) and the allocation of funds.

At the operational (and in the case of planned maintenance, the project or scheme level), linking with the authority’s local area objectives and service delivery plans:

- Assess the causes of deterioration,
- Identify practical maintenance options e.g. resurfacing or reconstruction,
- Analyse cost effectiveness of different treatments and alternative options,
- Define imposed constraints, e.g. cost, engineering, performance, environment, etc.
- Select the most cost effective option within the imposed constraints.

The main components of a PMS are illustrated in Figure 3 and described in more detail in Appendix F.

4.2 Rationale for consistency

There are a number of reasons why local authorities need a nationally consistent approach to aspects of pavement asset management systems.

Local highway authorities need the assurance that the systems they use produce accurate and consistent results. Also that the results are based on sound engineering principles and good practice. They need to be able to demonstrate to members, auditors and others that the asset management decisions they make are derived from good quality data, correctly processed and reported to provide relevant information for the assets both now and in the future.

In order to do this the systems they use must have an independent method of quality assurance. This is currently provided in UKPMS by the Annual Health Check which ensures systems correctly load, process and report data. To provide an economically feasible independent audit and accreditation of UKPMS systems for the future, core
modules would need to provide consistent results between different developers systems and would therefore have to be essentially “the same”.

Local highway authorities need consistency wherever the results have to be compared between authorities, or combined across a wider area. For example:

- where a local authority is required to report a value as a performance indicator that will be compared with the performance of other authorities (such as NIs);
- where values are to be combined to form a national indicator (such as NRMCS);
- where values are used to determine the allocation of (scarce) resources, such as budget allocations (from Central Government, Regional Government, etc);
- where values are used as part of other statutory reports (such as financial accounts);

They need consistency wherever local authority officers are required to justify their recommendations, decisions or actions, such as for public scrutiny. For example:

- when proposing budget allocations for highway maintenance programmes;
- when recommending maintenance programmes or schemes;
- when defending an authority’s performance of its statutory duties against claims from third parties or in court proceedings

A nationally consistent approach is required to enable officers to demonstrate that they have applied their professional judgement in the context of nationally agreed guidelines and standards, with approaches adapted to local needs, rather than in an arbitrary, idiosyncratic or untested way. Thus consistent and reliable systems are needed to support the approach set out in codes of practice, such as Well Maintained Highways

Local highway authorities need consistency for commercial and business efficiency. They should not be prevented from switching between service providers by artificial constraints. Barriers such as:

- Different suppliers developing different and potentially contradictory approaches at the “core” level,
- Not being able to easily transfer data from one system to another,
- Not being able to implement best practice from other authorities using different systems

4.3 What PMS need to do in the same way (the common core)

The following key areas were identified where consistency is paramount:

- National reporting including reporting financial information
- Regional reporting (e.g. benchmarking between regions or within regions)
- Data interfaces. (i.e. input and output data requirements and file formats)
- Enabling asset management, and Asset Management Planning

In addition to these key areas, those at the first workshop also identified a need for independent testing of some functionality to provide reassurance that national guidelines were being followed.

It was also considered that there is a need to accommodate historic data and allow this to be processed to maintain continuity with previous results. However, we believe this should be accomplished, as far as possible, without compromising or inhibiting the future development of PMS in the UK.
4.4 Current national reporting requirements

Currently the national administrations in England, Wales and Scotland have specified the use of SCANNER survey data, processed through a UKPMS compliant system to report the condition of their classified road carriageways.

In Northern Ireland CVI surveys are used on all roads except motorways, trunk A roads and other A roads. The results are processed using a UKPMS compliant system, and used to inform the depreciation charge in the Annual Report and Accounts.

The current national reporting requirements are summarised in Table 5 and more detailed information is in Appendix G.

Table 5 Summary of national reporting requirements

<table>
<thead>
<tr>
<th>Country</th>
<th>Classified Roads</th>
<th>Unclassified Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td>England</td>
<td>SCANNER RCI using the UKPMS weighting set approach (full coverage)</td>
<td>UKPMS Condition Indices from CVI surveys using the automatic pass approach (full coverage) (RCE survey)</td>
</tr>
<tr>
<td>Scotland</td>
<td>SCANNER RCI using the UKPMS weighting set approach (full coverage)</td>
<td>SCANNER RCI using the UKPMS weighting set approach (sample survey)</td>
</tr>
<tr>
<td>Wales</td>
<td>SCANNER RCI using the UKPMS weighting set approach (full coverage)</td>
<td>No national reporting requirement</td>
</tr>
<tr>
<td>Northern Ireland</td>
<td>A roads: Deflectograph residual life plus SCRIM surface friction requirements (full coverage)</td>
<td>UKPMS Condition Indices from CVI surveys using the automatic pass approach (full coverage)</td>
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<td>B &amp; C roads: CVI and CRUT data through UKPMS automatic pass (full coverage)</td>
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4.5 Asset management requirements

In order to be able to produce the “high level” results from a PMS, there are a number of pre-requisites. The following paragraphs include them, as well as the ultimate requirements.

Reporting current pavement condition:
- Identifying the local condition (from place to place);
- Condition of parts of networks (by area, by road type or by road class); and
- Condition of whole networks of roads (within defined areas, by road type or class).

Reporting changes in condition between years:
- From one year to the next, or
- Comparing individual years or
- Comparing over several years to establish trends

Identifying current treatment requirements (and costs):
- Local maintenance requirements (from place to place);
- Parts of networks (by area, by road type or by road class); and
Whole networks of roads (within defined areas, by road type or class).

Predicting future treatment requirements (and costs) profiled over time:

- From one year to the next, and
- Over longer periods

Assembling practical maintenance schemes or programmes from current and predicted treatment requirements:

- Identify and build schemes from treatment needs (at a local, project level).
- Assemble lengths into schemes, based on condition and / or treatments.
- Assemble schemes into programmes, based on types of road, types of treatment, etc.

Prioritising schemes by condition:

- Prioritise schemes based on current condition and / or treatment requirements.
- Prioritise schemes within programmes, based on condition / treatment / road type, class, etc.

Prioritise schemes based on whole life cost (WLC) principles (economic ranking).

- Prioritise schemes within programmes, based on anticipated future condition / anticipated future treatment requirements / road type, class, etc.
- Prioritise between years (from one year to the next, or comparing individual years), and over several years (trends)

Report financial information, to calculate the

- Gross Replacement Cost (GRC),
- Depreciated Replacement Cost (DRC) and
- Annual Depreciation Charge (ADC).

Based on the extent, and condition of the whole road network (paved areas) including carriageways, footways and other paved areas (e.g. cycle tracks).

Scenario modelling and optimisation: Predict the consequences of investment decisions based on anticipated or defined budgets, identifying changes between years and over several years, in terms of their effect on:

- Future road condition and serviceability,
- Future maintenance requirements,
- Scheme delivery and prioritisation, and
- Asset value (Depreciated Replacement Cost)

Local road authorities are increasingly looking to develop and implement tools such as:

- Value management
- Multi-criteria analysis
- Treatment rationalisation
- Network improvement planning

4.6 The components of the system

The core functional requirements for UKPMS are to be specified in terms of the activities which local authorities need to do, not a specification of the IT processes which will achieve them. In other words, what local authorities want the system to produce, the
types of outputs required and the processes required to deliver them. The concept can be illustrated by considering the pavement management system as a “black box” system, as shown in Figure 4.

![Diagram](https://via.placeholder.com/150)

**Figure 4 A “black box” system approach**

Each of the components in Figure 4 can be greatly expanded to cover the range of requirements to be met within the PMS. We have taken a systematic approach to identifying these requirements, as shown in Figure 5.
Pavement management systems have been developed with treatment selection processes, condition projection techniques and costs based on relatively little information. However, the whole approach to pavement management is generally based on regularly gathered and detailed information about pavement condition. This is then combined with a detailed method of network referencing and comprehensive inventory data.

**Figure 5 A systematic approach to defining the functional requirements**
Ideally, a pavement asset management system should incorporate a self learning feedback process to enable the system to compare observed values with previously predicted values, and thereby provide information to improve the way in which it makes future estimates and calculations.

4.7 Development requirements

The development requirements (techniques that would benefit from research being conducted centrally) are described in more detail in Appendix H.

4.7.1 How road networks and data are referenced in the new PMS for the UK.

UKPMS is currently based on ‘stand alone’ sections with little or no connectivity, but the data gathered by machine surveys (such as SCANNER) are continuously located using GPS. Lack of precision in accurately pinpointing survey section start and end points in SCANNER surveys means that the current process of ‘fitting’ the survey data to the network degrades the positional accuracy of the data longitudinally along the road, and hence its value for subsequent analysis and use in asset management. Local authorities also increasingly use GIS to display information, including road condition, and to analyse information from their PMS. There are three aspects that need further investigation and development:

- the technical issues and barriers relating to the use of geographical referencing, and how these could be resolved,
- the organisational and data handling issues and concerns that would affect the implementation of geographical referencing, and how these could be resolved,
- a functional specification for the application of geographical referencing in pavement condition information systems.

4.7.2 How data are imported (loaded) and exported (reported) in PMS.

The current data file format, HMDIF, was specifically designed for visual survey data and currently loading machine survey data to (some) UKPMS can be very time consuming. There is a need for faster, simpler, processes for loading machine survey data, including techniques for identifying and dealing with “improbable” values.

Currently no export file formats are defined in UKPMS. There is a need for basic, industry standard, file formats to enable PMS to export data to other information systems, such as financial information systems, geographic information systems, and business management systems.

4.7.3 Treatment selection, scheme identification and programme building.

Currently UKPMS has quite complex rules for indicative treatment selection and very limited facilities for indicative scheme building, using visual inspection data (and to a limited extent Deflectograph and SCRIM data). There are also rules for using a limited selection of SCANNER parameters to generate indicative treatments, but no rules for combining SCANNER survey data and visual inspection data in treatment selection and scheme building. There are therefore several areas that require further research and development to:

- Check the validity of the existing rules for developing indicative treatments from SCANNER data,
- Extend the rules to include other SCANNER parameters (in particular edge condition and surface deterioration measure by texture variability),
- Develop an approach and the rules for combining information from both machine (current and future) and visual surveys, and
- Develop a simple approach to indicative scheme building from either (or both) machine survey data and visual inspection data.

Developers have commented that a generic “rules & parameters” approach can be slow and therefore there are benefits in being able to “hard code” the algorithms. Our proposal is to move towards a performance based specification and to publish the underlying algorithms, rather than coding all the relationships into data tables. Thus enabling developers to “hard code” the calculations to achieve computational efficiency.

**4.7.4 How to predict the future condition of the pavement or the network from readily available or affordable information.**

In the case of local road pavements there will mainly be records from standardised visual inspections (such as CVI and DVI) or from routine machine surveys. The future condition (and hence the future need for treatment) can most simply be expressed in the same terms as the measurement of condition, be it visual inspection or machine survey. Further research and development is required to investigate:

- How to model the future condition of either an element of the network, or the whole of the network, from current and past measurements of condition, and
- What other data are required to enable reliable predictions over the short, medium and longer term (which might, for example, include construction type, traffic levels and maintenance history)

**4.7.5 Whole life costing and life cycle analysis.**

These require information on current and future treatment requirements and costs, as well as the effect of changing pavement condition on the extent and type of maintenance. There are a number of asset management systems that currently include whole life costing and life cycle analysis functionality, some designed for use on roads (but none specifically designed for use on local roads in the UK) and some designed for use on other types of infrastructure asset. This work would identify:

- The benefits and constraints offered by existing systems, and then
- Develop a simple basic approach to enable local authorities to carry out whole life costing and life cycle analysis, with functionality enabling them to enter different assumptions (based on local knowledge and experience) and see how they would affect investment decisions.

Initially two parallel approaches should be considered, using visual survey data, and using machine survey data, with the overall objective of developing a combined approach. At present there is no consistent and reliable way of substituting machine data for visual survey data – the two surveys measure and report different aspects of condition. Equally, local road authorities cannot be expected to carry out both visual and machine based surveys on all their roads. However, in the longer term, it would be desirable to be able to use the data interchangeably, or to combine both sets in a single analysis method.

**4.7.6 Scenario modelling**

From a road authority perspective, one of the most important functions of a pavement management system as a network level (strategic analysis) management tool is the
ability to do “what if” modelling. Rather than working from condition measurements to develop treatment requirements, maintenance schemes and programmes, and budget requirements, instead to be able to work from budget allocations to prioritise expenditure according to predefined criteria and calculate the effect on the overall condition of the network in future years (impairment of the asset), and the consequent requirements for investment in maintenance (investment optimisation).

Whilst there are a number of systems that purport to carry out scenario modelling and investment optimisation for infrastructure assets, this is perhaps the hardest and most testing application for a pavement management system. It requires the underlying information on deterioration modelling and condition projection, treatment selection and scheme building and whole life costing and life cycle analysis to be sufficiently detailed and reliable (robust) as an input to the scenario modelling functionality.

One approach would be to:

- Review the capabilities and limitations of currently available systems, and estimate the level of detail and reliability required from the input information to be able to make valid and useful predictions, and

- Define the performance requirements for the system, leading to a detailed technical specification for a basic level of scenario modelling and optimisation capability, based initially on using visual survey data, and using machine survey data, with the overall objective of developing a combined approach.
5 Implementing a new specification

5.1 What will have to change

The original logical design for UKPMS consisted of 30 modules that provided a blueprint for a comprehensive integrated system containing the following functions:

- **Engineering maintenance** related from survey data collection to project optimisation.
- **Data management** including specification of the scheme for digital record storage.
- Import/export for **data interchange** with an array of information systems for highway management - CSRWR, COMPARE, NRMCS.
- **Data visualisation** and graphical representation including map generation.

The original specification (Logical Design) was not offered to the marketplace directly; instead it was pared down, the requirements were revised to meet local road authority needs, and applied to the development and accreditation of UKPMS through the comparability test process.

The requirements were broken down into three tranches:

- **Tranche 1**: network referencing, asset inventory and condition survey data.
- **Tranche 2**: defect rating, treatment selection, estimating and budgeting and works records.
- **Tranche 3**: condition projection, economic analysis.

As eventually specified, the UKPMS functionality was incorporated into commercial systems that were intended to be developed, accredited and used by all local road authorities for full pavement management. Pavement Management Systems incorporating the UKPMS functionality were developed from systems that already existed with other functions. Consequently, UKPMS now resides in systems with very different functionality, data structures, etc. Only systems that developers accredited to all three tranches were considered to be ‘UKPMS accredited’; tranches 1 & 2 were simply steps along the way.

The functional requirements in the current UKPMS specification, which we describe in more detail in Appendix I, include:

- **Location referencing**: How data are located and identified in UKPMS.
- **Loading and maintaining data**:
  - Inputs: Loading data and the structure of the associated files.
  - Types of data.
  - Maintaining the network.
- **Processing**:
  - The Automatic Pass.
  - The Road Condition Indicator.
  - Parameters used when processing.
- **Reporting**:
  - National reports.
  - UKPMS reports.
A wide range of issues have been identified with current UKPMS performance in previous reports, which we describe in more detail in Appendix E. These include:

**The UKPMS Strategic Plan (Robinson, 2004)**
- Some algorithmic modelling deficiencies
- Inadequate reliability of input survey data
- Excessive level of detail
- High costs of operation (resources and data collection)
- Lack of awareness and understanding of objectives and potential
- Lack of proactive approach to pavement management
- Limited resources to address problems

**The UKPMS Strategic Development Study (Halcrow, 2006) and Using SCANNER data for maintenance management on local roads (Mott MacDonald, 2006)**
- The perceived lack of usefulness and relevance of UKPMS to the regular business of local road maintenance management
- The perceived difficulties of using UKPMS – resources and expertise required, time to load and process data
- The perceived unreliability of the results due to both the inconsistency of input survey data and limitations of the (complex) processing algorithms

Other technical issues we have identified include:
- Technical documentation that has not been kept fully up to date, and information on development and change that is not readily accessible.
- Limitations of the approach to network referencing and its effect on the positional accuracy of machine surveys data.
- Impact of machine survey data on overall system performance.
- Limitations of algorithms for using machine survey data.

As a consequence, UKPMS is only being used effectively by relatively few local authorities. In many cases it is being used for little other than to process survey data to calculate national indicators.

We concluded that fundamental change will be required in the specification of UKPMS, it will not simply be a question of some minor adjustments. Major surgery will be required.

Some elements should be retained,
- Either because they are a good way of delivering the requirements
- Or to enable local highway authorities to continue to use historic data and historic methods

Some elements should be replaced:
- Either because they do not deliver the requirements
- Or to enable local highway authorities to use new data and new methods

Therefore the renewal programme is likely to require considerable resources and to be phased over several years.

There is a need to develop consistent basic methods of meeting local authority requirements, which implies considerable investment in research & development. But there is no point in starting the process of transforming UKPMS unless there will be sufficient commitment and resources to maintain the process. ‘Stop-start’ funding
causes inefficiencies in development and longer term problems with maintaining a coherent set of support products (technical documentation, user documentation, weighting sets, rule sets, accreditation regimes etc)

5.2 Developing a new specification
We consider there are a number of general principles that will be essential in the design of the new specification and how it is implemented:

- It must be flexible so as to evolve as requirements change
- It must allow radical change to UKPMS within a framework which evolves from the current position
- It must facilitate accreditation of other PMS where these are able to provide the required functionality
- Both the specification and the accreditation must be manageable to maintain
- It must describe the requirements as outputs wherever possible

UKPMS requires fundamental change (as opposed to adjustments to the current model) in order to meet the future business requirements of the local road network owners. However, one potential issue in instigating a complete overhaul is that it could be high risk and expensive. Therefore, we recommend a framework with the potential to deliver far-reaching changes but in a controlled and lower-risk way with costs profiled accordingly... The method for achieving this is to rewrite the specification in a more modular way. This would place PMS for the UK on a new footing and would ultimately permit major changes, but within a well-controlled, affordable and lower-risk context.

We set out our approach to defining the functional specification for a new approach to PMS for local roads in the UK in Appendix J.

The new PMS specification would have new arrangements for accreditation, based on the modules, i.e. element by element. As a matter of principle, it would divide the specifications for data from the specifications for processes. Input data will have to be consistent, to enable any outputs to be consistent. But not all analysis processes will have to be consistent – only those that lead, directly or indirectly, to outputs that have to be consistent.

Therefore the new approach would also maintain accredited surveys:

- Visual condition surveys (i.e. currently CVI, DVI, etc.)
- Machine condition surveys (i.e. currently SCANNER, Deflectograph/FWD, SCRAM/ & Griptester)

With the potential to include other survey types in future

The modular framework would comprise a list of modules in the specification, referred to as the core modules. Each of these would be defined by a specification and be verified via accreditation. Alongside and supporting the core modules, UKPMS would require parameters to drive the processes and these parameter modules would also be organised using the modular approach and included in accreditation.

In addition to the specification and accreditation regime, the modular framework would accommodate guidance modules. These would provide a way to offer good practice guidance on a range of topics and a way of disseminating research information. The guidance modules would not be subject to accreditation and therefore would allow innovation by system developers and others who may wish to develop tools for use with the new PMS.

The catalogue lies at the heart of the new system. It pulls together and controls all the various documents and files which collectively describe the PMS specification. Defining
the catalogue in detail should form one of the earliest tasks of implementing the new core specification.

For the future new or existing modules could be added or removed from the specification to meet changing requirements for consistency. These could be based on the either the needs of the end users or the requirements of national governments.

5.3 What has to be consistent (the core modules)

The initial requirements for core modules include:

- Network referencing and location referencing
- Section attributes
- Importing data
- Exporting data
- SCANNER RCI processing and reporting
- Automatic pass processing and reporting (until replaced)
- Financial information (asset valuation) calculations

We set out the elements of the functional specification for a new approach to PMS for local roads in the UK in Appendix K.

The concept of this new approach to the specification is that developers would not have to accredit the whole system – they would only accredit those core modules that they wanted to sell to their customers as accredited. Therefore a system is not “UKPMS compliant”, but a system can deliver “UKPMS compliant” functionality. A subtle, but important, change from the current approach.

5.4 Identifying the elements

These may be identified in two groups:

Data management:

- Network referencing and location referencing
- Data interchange file formats for importing and exporting data
- Archiving data (data file management)
- Implementing new survey types

Processing Algorithms:

- National reporting (machine survey data)
- National reporting (visual survey data)
- Financial information to support asset management
- Schemes and programmes of work
- Deterioration modelling and condition projection
- Life cycle planning
- Scenario modelling

In terms of data management, there is a need to redefine network reference requirements to accept different methods of data referencing:
• BOTH by node and chainage (and cross section by lane), which suits manual survey techniques, and maintains continuity with historic data sets
• AND referenced to OSGR, which suits machine survey techniques, and allows data from other sources referenced by OSGR to be loaded as well development

Also to ensure the network reference requirements allow analysis on multiple overlapping networks. e.g.
• Road classification (A, B, C, etc)
• Carriageway hierarchy (1, 2, 3a, 3b, 4a, 4b, etc.)
• Footway hierarchy (1a, 1, 2, 3, etc.)
• NSG definitions
• User defined networks (e.g. cycle routes, bus routes, abnormal load routes, safe routes to school, etc.)

The HMDIF format will be retained to support visual surveys for the future and to enable use of historic data sets. In parallel alternative data transfer file format(s) are required to facilitate data loading from (e.g.) machine surveys and to facilitate data export to (e.g.) comprehensive asset management systems, which include other asset types.

There is also a need to develop new rules for loading and validating survey data – in part to simplify and speed-up the process, particularly for high-volume machine survey data; but also because a vital pre-requisite to producing consistent results is to ensure that all systems are consistent in how they validate survey data and how they handle any invalid data.

The requirements for archiving data, and the method of adapting the specification to accommodate new survey types (and new types of data) will also have to be defined.

In terms of the processing algorithms, the basic processing algorithms for converting the inputs into the outputs should be specified, to ensure consistency and comparability between authorities. The automatic pass functionality should be RETAINED in the short term to:
• Support visual survey data analysis for the (short term) future
• Enable comparison with historic analyses

In parallel with the automatic pass, a simpler analysis should be developed, using a weighting set approach to:
• Identify treatments
• Build schemes from condition or treatment
• Develop programmes from condition or schemes

These should be designed to combine data from different sources (i.e. visual and machine data)

Simpler condition projection models should be developed, in parallel with the automatic pass, to enable local authorities to:
• predict future needs for treatment and associated costs
• prioritise schemes on whole life costs
• optimise budgets by economic ranking

These should be designed to combine data from different sources (i.e. visual and machine data)

In parallel with the automatic pass, simpler asset valuation models should be developed to enable local authorities to
- Calculate Gross Replacement Cost (GRC)
- Calculate Depreciated Replacement Cost (DRC)
- Calculate Annual Depreciation Charge (ADC)

The financial information requirements will have to be specified to meet international financial reporting standards and national reporting requirements.

Budget scenario models and economic ranking of schemes will be needed to support life cycle planning. In parallel with the automatic pass, simpler budget scenario models should be developed to replace the current method.

These should be designed to combine data from different sources (i.e. visual and machine data)

### 5.5 Developing the new PMS

Figure 6 illustrates the stages of development of an Information and Communication Technology (ICT) product. For each element of the modular framework, there will need to be:

- A clear technical specification.
- A development programme including detailed design, programming, testing and de-bugging.
- An acceptance test process, possibly leading to accreditation.
- A product roll-out or delivery process, including training, user support and system maintenance.
- Ongoing quality assurance, possibly including independent audit.
The first stage of the development of a new PMS for UK local roads will be to prepare the technical specifications. Although many of these specification modules can be defined directly from existing UKPMS documentation, there are others where some technical development will be required, and some where both research and technical development will be required.

### 5.6 Accreditation and QA

Based on our experience of the UKPMS annual health check, the accreditation, QA and audit of machine surveys, and visual survey inspector accreditation, we anticipated that there would be a need for four separate elements in a successful accreditation, QA and audit regime:

- A process of acceptance testing, through which new systems (or new approaches to delivering the requirements) would be thoroughly tested, as part of the development process. This is identified as the “Accreditation” gateway in Figure 6.
- Some sort of annual re-accreditation process through which currently accredited systems (or systems that have been modified slightly) would be retested, to provide reassurance that they remained able to meet the requirements. Local authority representatives at the second workshop identified the importance of having an annual certificate of compliance, which they could rely on as part of their own internal quality assurance and audit processes.
• A formal quality assurance process, managed by the developers or service providers, to provide reassurance that the systems continued to meet the requirements through the year, and that could (and would) identify when systems were no longer meeting requirements.

• An independent audit process, to provide external verification of the whole process, and provide reassurance that the quality assurance process continued to meet the requirements and could (and would) identify when the quality assurance process was no longer meeting requirements.

5.6.1 Modular approach

However, as we developed the proposed modular approach to the specification for the new PMS for local roads in the UK, we modified the approach to:

• Accreditation,
• QA and
• Audit.

Conceptually, the acceptance testing (and accreditation) requirements would be specified for each module separately, as described in Appendix J. As the system would be specified in a hierarchy, accreditation of some modules would depend on accreditation of other modules that supported them.

The current Annual Health Check approach ensures that those elements that are tested each year (which can and does vary from year to year) do comply with the current specification. The proposed new approach to accreditation, QA and audit is summarised in section 5.6. Whilst accreditation describes a “one off” process for acceptance testing, the QA and audit processes must be designed to ensure that the systems remain compliant. This might, for example, be by having a time limited accreditation for each element, requiring re-testing at intervals.

5.6.2 Accreditation test

The accreditation test would be a once off, reference test. In order to meet local authority requirements for time limited accreditation, developers would be able to submit modules for retesting from time to time, according to the requirements specified for each module.

• If there is a new specification or a new requirement, developers would have to re-accredit all modules affected by the changes.
• If a developer amends any UKPMS module, then the developer has to re-accredit any modules affected by the changes.
• If a developer amends the system outside UKPMS modules, then the developer has to check whether there is any effect on any accredited modules.

5.6.3 Quality assurance

The specification for a new PMS for local roads in the UK should include a formal requirement for a quality assurance process. This would be (essentially) the developer’s responsibility, and the requirements should be developed and specified with the developers, building on their knowledge and current good practice.

It would be focussed on outputs rather than on the systems, as the clients (local road authorities and their service providers) are more interested in the quality and reliability of the results than the internal workings of the systems. However there will also have to be tests of the performance of the systems, to ensure that they do not compromise the
quality of the outputs. In principle, it would be the developers’ responsibility to devise tests that demonstrate satisfactory performance and compliance with the requirements of the specification.

5.6.4 Audit

Our experience of both UKPMS annual health checks and machine survey accreditation has shown the inevitability of mistakes, despite careful acceptance testing, accreditation and quality assurance. These are very complex systems and there always opportunities for misunderstanding or human errors to creep in, leading to a divergence between the intentions and outcomes.

Therefore there is a need for an independent verification process, carried out by suitably qualified and experienced individuals. This should be designed to check the performance of the developers’ quality assurance procedures as well as the performance of the whole system. The independent verification system (or audit) should include a technical consultancy service for any necessary problem investigation and dispute resolution.

5.7 The implementation plan (timescales)

The objective of the third element was to map the agreed specification to an indicative timetable and budget. Taking into account

- to whom costs are likely to fall, and
- the ability of the market (not just those currently UKPMS-accredited) to deliver

The budget and timing proposals should also take account of where the industry is currently, and how it would be expected to migrate.

The overall objective is that UKPMS should evolve to a more flexible and dynamic system, designed to adapt and change in a controlled way. There should be incremental change; a smooth transition without a break in service. The changes should be both:

- AFFORDABLE, and
- ACHIEVABLE.

But development funding is the key – there has to be both commitment and continuing support.

The current UKPMS arrangements, agreed with the system developers, include an annual update cycle, illustrated in Figure 7:

- Specification of requirements (April to June)
- Initial development of specification and feedback (July to September)
- Final development and Annual Health Check (October to December)
- Issue to local authorities and implementing (January to March)
Figure 7 Current annual review and development cycle for UKPMS

In effect this gives the developers several months to develop their systems (between June and December) and several months to test them (between October and January) as well as several months to deliver the systems to their clients (after passing the Annual Health Check). This phase also includes the time, often considerable, that local authorities require to install the new version and get up to speed. ‘Delivery’ is not a simple mechanical activity; it may include preparation and production of release packages, liaison with IT departments, upgrading hardware/software, training, data transfer and so on. This may involve a lot of work by both developers and local authorities.

As well as the time required to prepare the new technical specifications, the developers will need time to check that their systems comply with the new approach and any new requirements, and to carry out acceptance testing leading to accreditation. Therefore, it is practically impossible that the new approach could be introduced in time for delivery to their clients by March 2010, but it would be feasible to plan for delivery from March 2011 onwards.

Acknowledging that some of the specifications can be prepared from existing documentation, and others will require technical development, or both research and technical development, we set out a programme in three phases, illustrated in Figure 8:

- Phase 1 (by March 2011) – data and referencing
- Phase 2 (by March 2012) – treatments and budgets
- Phase 3 (by March 2013) – condition projection and scenario modelling
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**Figure 8 Outline implementation timetable**
For the coming year (2009/10) we propose “business as usual”. The Annual Health Check would be retained, as would the Automatic Pass. New requirements would be added, for the new Coarse Network Survey for footways (to be specified by the FCMG), for financial information reporting (to be specified by the CIPFA highway asset management financial information group, HAMFIG) and, if possible to introduce new SCANNER edge treatment rules.

In phase 1, commencing immediately, standardised survey data collection methods would be retained, but with the specifications outside the PMS specification. New technical specifications would be introduced for:

- Importing data
-Exporting data
- Network and location referencing

This would lead to a reduced list of core requirements and a new accreditation process.

In phase 2, commencing immediately with technical development, standardised processing rules (specifications) would be introduced to:

- produce condition information and suggested treatments
- identify schemes and build programmes
- provide financial information to support asset management (DRC and ADC)

These would be based on all available survey types, starting with visual inspections and SCANNER, leading to additional accreditation requirements.

In phase 3, commencing immediately with research and technical development, standardised processing rules (specifications) would be introduced for:

- deterioration modelling and condition projection
- life cycle planning and scenario modelling

These would be based on all available survey types, starting with visual inspections and SCANNER, leading to further accreditation requirements. The advantages and disadvantages of this approach are summarised in Table 6.

**Table 6: Advantages and disadvantages of sequential implementation**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivers all the functionality identified by local authority representatives to support asset management</td>
<td>Does not deliver all the benefits required by local authorities in the time they would like</td>
</tr>
<tr>
<td>Allows time for research, development and specification.</td>
<td>Additional funding is required to prepare new technical specifications (mainly from extant documentation).</td>
</tr>
<tr>
<td>Allows developers time to implement changes and gain accreditation.</td>
<td></td>
</tr>
<tr>
<td>Provides a technical specification for UKPMS, enabling more people (technical specialists and users) to engage with the onward development of UKPMS</td>
<td></td>
</tr>
<tr>
<td>The technical specification would be more manageable and easier to maintain.</td>
<td></td>
</tr>
<tr>
<td>The accreditation process would be more manageable and easier to maintain</td>
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</tbody>
</table>
The modular system would provide a flexible basis to accommodate changing requirements (e.g. those linked to asset valuation or future machine surveys).

Pares UKPMS down to a minimum core and thereby removes clutter.
Old requirements would be officially ‘discarded’ and would therefore become optional for individual developers rather than compulsory.

New systems could enter the market; offering genuine choice for users and different ways of meeting the UKPMS requirements.

Beyond the ‘do minimum’ transition phase, UKPMS would enable radical change and major improvements to be introduced but via an evolutionary process.

Obstacles to development would be removed and innovative functionality (unique to individual systems) would be facilitated.

### 5.8 Alternative implementation options

The developments required to enable the effective use of machine (SCANNER) data in a PMS, and the consequent changes in UKPMS, are not trivial. However, local authority representatives expressed serious reservations at the second workshop about a programme that would not deliver the main benefits for them until 2013. Therefore, we have considered two other options for implementing the specification for a new PMS for local roads in the UK.

- Do minimum (transition to a modular UKPMS)
- Accelerated (parallel) implementation

#### 5.8.1 Do minimum (transition to modular UKPMS)

In this option the specification for UKPMS would be changed from the current comprehensive (but incompletely documented) approach to a slimmer, modular approach. It would include a new approach to accreditation, based on core and optional modules.

This option would deliver the current SCANNER RCI (using the weighting set approach) from SCANNER survey data, meeting national reporting requirements in England, Wales, Scotland (and possibly Northern Ireland in future).

It would also deliver the former BVPI based on UKPMS condition indices, using the automatic pass approach, from visual inspections (CVI and DVI), meeting current reporting requirements in Northern Ireland. It would also enable the condition of unclassified roads in England to be monitored, and enable local authorities that currently use visual survey information as part of asset management to continue.
This would be delivered as a single step change, over 2 years, then opening up the way for future (unspecified) development of functionality to meet local authority requirements.

During the first year, 2009/10, UKPMS (and SCANNER) would continue with “business as usual”. The Automatic Pass functionality and the Annual Health Check would be retained. Developments anticipated in 2009/10 would include:

- The new coarse footway survey being developed and specified by the Footway and Cycle track Management Group (FCMG);
- Simplified financial information reporting being developed and specified by the CIPFA CSS and TAG Highways Asset Management Financial Information management Group (HAMFIG); and
- Simple rules for linking the SCANNER edge condition indicator (currently delivered through a weighting set) to the UKPMS edge treatment rules.

In parallel, starting immediately, the new technical specifications would be prepared for the core requirements, and the proposed accreditation, quality assurance and audit process would be developed in parallel. The standardised survey data collection methods would continue. Current arrangements for importing and exporting data would be retained (but re-specified) and current arrangements for network referencing would be retained (but re-specified).

The advantages and disadvantages of this approach are summarised in Table 7.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivers current minimum requirements for national (and local) reporting</td>
<td>Does not respond to local authority and user requirements obtained during the workshops that were conducted under this project.</td>
</tr>
<tr>
<td>Provides a technical specification for UKPMS, enabling more people (technical specialists and users) to engage with the onward development of UKPMS</td>
<td>Additional funding is required to prepare new technical specifications (mainly from extant documentation).</td>
</tr>
<tr>
<td>The technical specification would be more manageable and easier to maintain.</td>
<td>Does not resolve the issues of fitting machine survey data, referenced using GPS and GIS, to a network referenced by sections and nodes.</td>
</tr>
<tr>
<td>The accreditation process would be more manageable and easier to maintain</td>
<td>Additional funding is required to prepare a new accreditation process.</td>
</tr>
<tr>
<td>The modular system would provide a flexible basis to accommodate changing requirements (e.g. those linked to asset valuation or future machine surveys).</td>
<td>Does not resolve the issues of the HMDIF format for reporting machine survey data.</td>
</tr>
<tr>
<td>Pares UKPMS down to a minimum core and thereby removes clutter.</td>
<td>Perpetuates the “stop-start” approach to funding the development of UKPMS in the new functional specification.</td>
</tr>
<tr>
<td>Old requirements would be officially ‘discarded’ and would therefore become optional for individual developers rather than compulsory.</td>
<td></td>
</tr>
<tr>
<td>New systems could enter the market; offering genuine choice for users and</td>
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</table>
5.8.2 Accelerated (parallel) implementation

This is defined as delivering essentially the same functionality as the phased (sequential) implementation, but carrying out all the tasks in parallel to deliver results in 2011. It would include changing the specification for UKPMS to a slimmer, modular approach, including a new approach to accreditation, based on core and optional modules (i.e. the same as the do minimum – modular UKPMS option). It also includes developing the rules for using SCANNER data, and the rules for using machine survey data and visual survey data together, to meet local authority asset management requirements.

There are two sub-options within this option:

a. The first (less radical) would be to accelerate phase 3 and aim to deliver that functionality by March 2012. This is probably practical, within the available timescale.

b. The second (more radical) would be to attempt to accelerate both phase 2 and phase 3. There are also two sub-sub options within this:

   i. To aim to deliver the phase 2 functionality by March 2011, in parallel with phase 1, and the phase 3 functionality by March 2012, or

   ii. To aim to deliver both phase 2 and phase 3 functionality by March 2011, in parallel with phase 1 (most radical)

However, given the very short timetable in sub-option b(ii), the requirements would have to be kept as simple as possible, from the outset. Also there would be very limited time for testing and amending specifications in the light of experience, and for the developers to implement the changes.

The advantages and disadvantages of this approach are summarised in Table 8.

### Table 8 Advantages and disadvantages of accelerated (parallel) implementation

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
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</thead>
<tbody>
<tr>
<td>Delivers all the functionality identified by local authority representatives to support asset management</td>
<td>The robustness of the processes and algorithms for the individual functions is likely to be less due to the lack of time for full research and specification</td>
</tr>
<tr>
<td></td>
<td>Limited time available to develop technical specifications</td>
</tr>
<tr>
<td></td>
<td>Limited time for developers to implement changes and gain accreditation</td>
</tr>
<tr>
<td></td>
<td>Further work will be required in future to</td>
</tr>
</tbody>
</table>
refine the functionality and update the specifications accordingly. This may be less cost effective in terms of the UKPMS development costs.

5.9 Costs of implementing change

The total annual expenditure on carriageway maintenance on local roads in England is estimated to be of the order of £1.3 billion, over 300,000 km of road length. Of which approximately £400 million is spent on about 1,300km of strengthening treatments, approximately £350 million on about 2,300km of re-surfacing and approximately £550 million on about 11,000 km of thin surfacing and surface dressing.

The total annual expenditure of local authorities and their service providers in England on pavement condition information systems for local roads is of the order of £9 million (i.e. approximately 0.7% of annual carriageway maintenance expenditure).

The total funding required (in addition to the existing costs of the PCIS support contract and the SCANNER accreditation, QA and audit contract) to deliver the changes in the national specification will be about £1.3 million (i.e. about 15% of the annual expenditure on PCIS). However, the developers’ costs (which would be recovered through charges to local authorities and their service providers) will be in the region of £3.6 million (over 3 years).

The developers’ costs have been estimated as a ballpark estimate. As the final core functionality is not yet agreed, the estimate was based on the outline for the new functionality rather than a detailed specification. Not all of the core modules may be included in a developer’s system (e.g. National reporting may not be required for all countries).

Only the extra direct costs of developing the product have been included, they are the “pre-delivery” cost of development, with no allowance for overheads that would be in place whether or not this development took place. There is no allowance for sales and promotion – it is assumed existing customers will take what they need or must have. No allowance has been made for installation, training or consultancy support except for the global modification and preparation of manuals and training materials. Installation and post delivery training and consultancy costs would fall on the customer not the developer.

The following may affect the individual developer’s final development costs: software development costs; collateral development costs; accounting methods and cost centres; development resources and staff costs. Developers may also achieve efficiencies commercial opportunities and advantages by developing add-ons etc. as they progress the development of the core modules. These may all have an impact on how individual developers perceive the actual initial cost to them (which they should eventually recover from their clients but how this is done will depend on individual business models for the UKPMS or Integrated Asset Management System product.

TRL 46 PPR458
6 Conclusions and recommendations

The core requirements for the new specification (those things that must be done consistently between systems and between local authorities) include:

- National reporting, including financial reporting,
- Data and data interfaces,
- Pavement asset management requirements.

Previous studies have identified that the current specification for UKPMS does not meet the needs of local highway authorities in a number of ways, and for a range of different reasons. During the workshops carried out as part of this project, local authority representatives have commented that they have been waiting too long for some of the designed functionality in UKPMS to be delivered in practice.

It is not simply a question of adding new functionality on the existing specification to meet those needs; fundamental changes will be required in the overall architecture, as well as many of the details of the specification, and quite probably in the design of the commercial systems that deliver the functionality to local authorities.

However there are many elements of the existing specification that should be retained, either because they are a good way of delivering the requirements, or to enable local authorities to continue to use historic data and historic methods. Some elements will have to be replaced, either because they do not deliver the requirements or to enable local authorities to use new data and new methods.

Because there are users in local authorities and their service providers who use the current systems extensively or intensively, the change from the current UKPMS specification to a new specification for PMS in the UK should be a gradual, evolutionary process that eventually delivers revolutionary change.

Therefore we recommend a phased programme of technical development, including some elements of research, that will transform UKPMS over the next four years into a tool that supports effective pavement asset management for local roads in the UK. At the heart of this phased programme is the transfer of UKPMS to a new modular framework to provide the basis for onward development.

The direct cost of the technical development work will be of the order of £1.3 million (to be funded centrally), and the consequent costs to the current UKPMS suppliers will be of the order of £3.6 million (which would be recovered through charges to local authorities over future years).

To set these figures in context, the current (centrally funded) cost of supporting PCIS (UKPMS and SCANNER) is of the order of £450k per annum, the current cost of using PCIS (to local authorities in England) is of the order of £9 million per year, and this is about 0.7% of the total investment in planned carriageway maintenance in England each year.

If the new specification for PMS for local roads in the UK improves the efficiency, economy and effectiveness of planned carriageway maintenance by 1%, the benefits would be of the order of £13 million, and the total estimated cost of investing in its development (£4.9 million) would be recovered within the first year after full implementation. In the current economic conditions, the benefits are likely to be realised through local authorities being better able to target their scarce resources with confidence.
Acknowledgements

The work described in this report was carried out in the Infrastructure Group of the Transport Research Laboratory. The authors are grateful to Dr Alex Wright who carried out the technical review and auditing of this report, and made many helpful comments and suggestions. In particular we acknowledge the contributions of the following:

The Department for Transport’s project officers, Edward Bunting and Andrew Oldland, for their wise counsel and guidance.

Chris Capps (Cambridgeshire County Council) who chaired the project steering group on behalf of the UK Roads Board, for providing leadership and direction.

Pete Burnham (Worcestershire County Council), Stephen Finley (Rotherham MBC), Danny Rawle (Leicestershire County Council) who were members of the project steering group, representing local highway authorities, who guided the project.

The five companies that have accredited systems to the current UKPMS specification, and their representatives:

- EXOR (Rod Beardshall, Ed Thorpe)
- Pitney Bowes MapInfo Confirm (John Gomersall, Rob Hope)
- Symology INSIGHT (Mike Bartlett, Sean Ryan)
- WDM (Ian Butler)
- Yotta MARCH (David Lowe, Brendan Hole, Stacy Smith, Howard Urmenyi)

Those who freely gave their time to complete questionnaires (un-named) and to attend and contribute at the workshops listed in Table 9 and Table 10.

Dr Cathy Chung for reviewing currently available pavement asset management systems.

Dr Vijay Ramdas for reviewing recent research and development projects carried out by TRL for the Highways Agency and the Department for Transport.

Peter Davidson who contributed to the development of the project and through workshops and meetings.

Table 9 Attendees at workshop 1 – 17th February 2009

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<tr>
<td>Neil Anderson</td>
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<tr>
<td>Norman Ballantine</td>
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<td>Paul Boss</td>
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<td>Ian Butler</td>
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<td>Dr. Ro Cartwright</td>
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<td>TRL (project team)</td>
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<tr>
<td>Peter Davidson</td>
<td>Appia (project team)</td>
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<td>Ed Lawrence</td>
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<tr>
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<td>Pitney Bowes Business Information</td>
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<td>Steve Winstanley</td>
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Table 10 Attendees at workshop 2 – 22nd April 2009
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McRobbie, S; Walter, L; Read, C; Viner, H and Wright, A (2007). Developing SCANNER Road Condition Indicator parameter thresholds and weightings. PPR 199, Crowthorne: Transport Research Laboratory.

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SCANNER Road Condition Indicator Implementation Guidelines (UKPMS document 070v0104)


Society of Chief Officers of Transportation Scotland (2009) Local Authority Road Network Condition http://www.scotsnet.org.uk/ Road Condition Surveys: SRMCS RCI Results 2006_08.


UKPMS Document 71 SCANNER HMDIF Specification (UKPMS document 071v0108)


Appendix A  Overview of current UKPMS

A.1 What UKPMS is

The UK Pavement Management System (UKPMS) is the national standard for pavement management systems that allows for consistent assessment of local road network conditions and for the planning of investment and maintenance on paved areas of roads, kerbs, footways and cycle-tracks on local roads within the UK by different authorities.

In general, all pavement management systems consist of a representation of a road network divided into uniquely referenced road lengths. Against this network, it is possible to locate other data defining the physical aspects of the pavement (inventory) such as construction details and width information and condition data collected by visual or machine survey. By applying rules based on the inventory and using the condition data held against each section, it is possible to identify potential maintenance treatments. These treatments can be prioritised by condition or into an order that will give best value for money in the longer term.

The primary use of UKPMS is to assist Local Authorities in the planning of maintenance on the local road network through the systematic collection and analysis of condition data. Use of a UKPMS accredited system is recommended as good practice and is an essential component of an effective Highway Asset Management regime.

UKPMS supports local highway authorities’ maintenance management objectives by providing facilities to:

- Identify lengths of paved asset in need of maintenance, including treatment options and costs;
- Prioritise maintenance schemes to give best value for money;
- Identify network trends

A.2 History of development of UKPMS

The history of the development and implementation of UKPMS is described in more detail in the report of the UKPMS Strategic Development Study (Halcrow, 2006) and the UKPMS website. UKPMS was first conceived in the 1980’s, as a comprehensive system for the management of planned maintenance activities on paved areas of highway networks throughout England. The original logical design consisted of 30 modules, providing a blueprint for a comprehensive integrated system containing the following functions:

- engineering maintenance related from survey data collection to project optimisation.
- data management including specification of the scheme for digital record storage
- import/export for data interchange with an array of information systems for highway management - CSWR, COMPARE, NRMCS
- data visualisation and graphical representation including map generation

A decision was made that the system should be offered to the marketplace and that the costs of developing the system would be borne by the software developers as a commercial opportunity. Consequently the original specification (logical design) was pared down and the requirements were revised to meet the needs of those responsible for managing local roads, and applied to the development and accreditation of UKPMS through a comparability test process during the later 1990’s.
To implement UKPMS the requirements were broken down into three tranches:

- **Tranche 1** – network referencing, asset inventory and condition survey data. This defines how the network is to be referenced, how the asset inventory is to be set up and what condition survey data is to be recorded and stored. Condition data can include visual surveys (a main component of UKPMS which played a key role in its design), SCRIM, Deflection, HRM, SCANNER etc. Tranche 1 includes reporting on the basic data held within UKPMS.

- **Tranche 2** – defect rating, treatment selection, estimating and budgeting and works records. This provides the second level of reporting using data that has been processed within UKPMS. Defects are “rated” and combined to provide condition indices, which can be combined to identify indicative treatments. This enables estimates of the cost of applying treatments and building up of budgets and treatment schedules on a “worst first” basis.

- **Tranche 3** – condition projection, economic analysis. This provides the third level of reporting on the use of data within UKPMS. The condition can be projected forward (using deterioration models contained within UKPMS) and the benefits of early treatment can be compared with the benefits of leaving treatment until later. The future condition of the network can be predicted from the present condition and combined with the effect of treatment options to identify network trends for different levels of investment.

By breaking the project down into tranches tests could be designed and carried out in stages. Systems which met the requirements for all three tranches were accredited as UKPMS systems. The specification for UKPMS has been implemented in a number of commercial Pavement Management Systems (PMS). However, some PMS incorporating the UKPMS Specification were developed from pre-existing systems that included asset management systems with and without PMS modules. These form part of wider systems that have been developed to offer a range of other capabilities. As a result the systems that currently provide UKPMS functionality have very different inherent capabilities ranging from simple PMS-only to comprehensive systems designed to assist authorities with a wide range of their business activities.

The current core functionality of UKPMS is described in more detail in Appendix I.

### A.3 The UKPMS strategic plan

In 2003 an independent consultant was retained by the Department for Transport to consider how UKPMS should be developed and used until 2010 to provide a tool to enable highway managers to meet the needs of their customers in the most effective and efficient manner. He prepared a Strategic Plan for the future of UKPMS (Robinson, 2004), under the direction of the UKPMS Steering Group.

The Strategic Plan noted that UKPMS is a tool that converts data into information about highway pavements, and this information supports the highway decision-making process. As such, the strategic direction for UKPMS depended on the strategic direction in which the highway management process would move in the United Kingdom in the future. Initiatives in 2003 centred on delivery of Transport 2010: The 10-Year Plan, and its implications. The Strategic Plan proposed that UKPMS should be at the centre of these initiatives, which could not be achieved without a pavement management system to provide the basis for decision-making.

It recommended that, before the Strategic Plan could be developed fully, there was first a need to elaborate a strategic approach for highway management decision-making more generally; the UKPMS requirements to support this could then be determined. It recommended that the UK Roads Board undertake an independent UKPMS Strategic Development Study to determine the key pavement management needs required to support future highway management decision-making. This would identify the
developments needed for UKPMS to meet these requirements and provide a proposal, with estimated costs, for moving from the present situation to achieving the recommended outcome. A key issue for the Study to consider would be how best to obtain the potential benefits from UKPMS at both national and local levels.

Irrespective of outcome of the proposed study, the report identified a need for a short to medium-term programme for the development of UKPMS and put forward an outline work programme for UKPMS development, separating activities into short, medium and longer-term time scales (Robinson, 2004). Development costs, including contingencies, were estimated to be nearly £3 million over a six-year period, with annual management and support costs of at least £125,000.

As a result of these recommendations, a strategic review of UKPMS was commissioned by the Department for Transport on behalf of the UK Roads Board, and first reported during 2005.

A.4 The UKPMS Strategic Development Study

The UKPMS Strategic Development Study was commissioned to review the role of UKPMS and the strategic direction that future development and implementation should take. The study considered:

- Whether a nationally prescribed system was required, and if so
- Whether a fundamental redesign was necessary to reflect more closely present needs and technology.

The report (Halcrow, 2006) recommended that:

“A fundamentally revised UKPMS is adopted as the prescribed core for Pavement Management Systems in the UK. It should comprise the key mechanism for encouraging the delivery and support of consistent practice in Highway Pavement Maintenance Management and Asset Management.”

“It will be promoted as the cornerstone of a national strategy for providing data at a local level and for monitoring local authority roads. It will be developed progressively to support the adoption of Asset Management practice including valuation of pavement assets and estimation of the maintenance backlog.”

“UKPMS should be leaner, fitter, and funded”

“Funding for support and development should be assured for a minimum of five years.”

The report set out a proposed development programme in three phases over four years, commencing at the end of 2005. The relevant recommendations of the UKPMS Strategic Development Study (Halcrow, 2006).are summarised below:

- **UKPMS should consist of a set of nationally standardised modules providing a core of managed information about the paved asset, which is used for decision support in planning, budgeting, and prioritising maintenance activities and to report on the condition and performance of the paved asset.**

- **UKPMS should support local management of local authority highway networks through the incorporation of functions for the identification of schemes within prioritised programmes.**

- **UKPMS will thus also become a “standard tool for government” i.e. at all levels of government. It will become the primary instrument for co-ordination of maintenance efforts across all authorities and for national monitoring of pavement performance. The standard treatment of data from surveys will ensure that bias is reduced.**
UKPMS must become more user friendly. The underlying principles and functionality should be better explained to all stakeholders and include clarity and applicability of outputs. Its use should be encouraged by all authorities (its ease of use and functionality should enable this) It should be proliferated and universally adopted by the authorities through training, support, documentation and the promotion of communities of good practice.

"It is recognised that some of the features listed below already exist in UKPMS. However, there are (sometimes perceived) doubts about the validity of some outputs, and the fundamental handling of data is poor compared with current industry standards; UKPMS is not seen as user-friendly, or complete.

"UKPMS should be retained as the prescribed core of a national Pavement Management System to meet the following purposes:

- Highway Management
- Asset Management
- Asset Valuation
- Reporting of statistics (BVPI, NRMCS).

"As part of this process there will be the need for a review of the present UKPMS Specification with identification of any modules that can be superseded. The core modules for UKPMS could in future include:

- Network/Inventory
- Inspections/surveys
- Condition/Defects
- Treatments
- Condition state projection
- Economic prioritisation

"Work should be undertaken to integrate/ link a conforming UKPMS system with other highway management systems already operated by individual authorities.

"UKPMS should provide a common referencing system for pavement management and routine maintenance management, in line with current and evolving technology such as GPS and OS Mastermap. The referencing mechanism should be consistent with the requirements of BS7666.

"The existing HMDIF should be abandoned in favour of a more usable format such as a text file format. This will reduce problems with data loading and enable all types of survey to be stored in a common base. MSP should also be reviewed.

"The present condition projection module should be abandoned in its current format. It should be replaced with a process which counts the defects and the costs of those defect repairs as the base data for condition state projection. This process would be similar to that used by HAPMS. The principle will be to develop scheme level condition projections to optimise the timing and extent of intervention and to utilise the concepts of whole life costing of a scheme. Whole life costing has been included as a core module because of its likely influence on capital budgets.

"UKPMS should aid the move to Asset Management, Asset Valuation, and Backlog valuation by providing the means of applying centrally prescribed rules. There should, however, be sufficient flexibility to allow the adoption of local levels of service. There is therefore, the need to develop definitions for indicators and their threshold values.

"Consideration should be given to including a specification within UKPMS for a routine maintenance system for the shared network; inventory representation is required to interact for the shared use of the digital network and inventory.
"For smaller authorities where resources are very limited and skills may be in short supply it is recommended that “virtual groupings” of Authorities are set up. These groups should be self-financing using “economics of scale”.

"Additionally to support the skills gap a training and support contract should be developed to assist users in maximising the benefits from UKPMS.

"Following the significant changes to UKPMS, it is recommended that UKPMS is re-launched at a series of workshops arranged through the UKPMS Owner's Forum, emphasising its many new benefits including some or all of the following:

- ease of use
- data input
- treatment selection
- scheme building
- decision-making processes, optimisation of resources
- budgeting/planning
- asset management
- asset valuation
- programmes of works
- reports.

"The strategic direction post 2010 is not so clear, this is because of the speed of change highway maintenance is going through. There is the asset management/valuation agenda and whole government accounting. There are the requirements of the Traffic Management Act, looking at congestion rather than condition. On the horizon there are the traffic control centres which will provide the opportunity to a different approach to managing the network. More work may be required to map out all these areas of work and how they will impact on each other and the stakeholders.

A.5 The commercial development environment for UKPMS

The UKPMS Strategic Review (Development of a commercial development environment) (Ebert, 2006), was commissioned to address six questions about the potential for commercial development of UKPMS:

- The market for such software (around 230 local authorities across the UK) is small and saturated. Do local authority software procurement arrangements encourage migration over time towards more effective and cost-efficient systems?
- Only five software developers have successfully gained certification as UKPMS compliant. If such compliance were replaced with a non-compulsory best practice specification (with, perhaps, an accreditation scheme), would more developers enter the market?
- Given the size of the potential market, can we expect software developers to offer, without significant public sector investment, their own enhancements to the existing state of the art?
- If the public sector were to conduct research and make its results freely available, could the software industry be relied on to incorporate them into new or improved products without financial incentives to do so?
To what extent is are (a) the existing arrangements; and (b) a more commercial, hands-off approach, consistent with the Departmental policy framework for intelligent transport systems?

A major component of the suggested way forward (Halcrow, 2006) is to encourage greater use of pavement management IT in local authorities. How could individual software developers be encouraged to bundle this with their products?

The report responded to the questions individually, and went on to draw wider conclusions and make recommendations. The relevant considerations and the recommendations from the report (Ebert, 2006) are summarised below:

- There was nothing stopping local authorities from procuring PMS through either fully open tender or through a restricted set of preferred suppliers. However, where local authorities have invested in an integrated set of systems for handling various road-related functions, including PMS, they are unlikely to change suppliers unless they have to.
- PMS is a niche market involving considerable expertise and investment, which is unlikely to be attractive to new entrants. Some of the eight developers that failed to gain accreditation before might again become candidate suppliers in a more relaxed accreditation regime ... (but) no relaxation of accreditation should be countenanced.
- Developers already offer various enhancements to the basic UKPMS. (However) they will only consider new developments that are required from firm policy, translated into local authority requirements. They will not take the initiative by engaging in speculative developments.
- As with question 3, the developers need to see a clear market before they will undertake development. They will only develop on the basis of research converted into clear and firm policy and associated requirements.
- The document "Intelligent Transport Systems(ITS) – The policy framework for the roads sector, DfT, November 2006) does not provide guidance on which of the two approaches to adopt. In principle UKPMS impacts – by varying degrees – upon all seven ITS Policy Themes, notably theme 1: Improved Road Network Management.
- Developers are already bundling PMS with other products, and are guided by the business needs identified by the users. Other functions, such as Asset Management functions, should be articulated in policy, whereupon appropriate systems would be developed, either in UKPMS or the individual PMS.

In summary, it concluded that development of this revised system could not be delivered purely through commercial channels, and that a degree of central funding and direction would continue to be required.
Appendix B  Asset and pavement management systems

B.1 Introduction
As part of this project we reviewed some of the asset management systems with integrated pavement management systems or PMS modules currently available on the market. They were identified through searches within the TRL library knowledge base, relevant conference proceedings, the internet and discussions with experts. The review was carried out in the English language and therefore only identified systems that were described in English. There may be other systems that are only described in other languages.

The review identified twenty one different asset management systems with pavement management capabilities. Each of the system providers was invited to contribute their views to the project, although ONLY those with UKPMS accredited systems responded.

B.2 Asset management
The Institute of Asset Management describes asset management as a multi-functional discipline which is concerned with optimising the whole-life costs of an asset base such as roads, rail, airports and utilities. It requires the understanding and management of risk at all stages in the asset lifecycle, and the development and implementation of processes for the concept, design, installation, commissioning, operation, maintenance and disposal of assets which ensure the lowest whole-life cost outcomes for the business.

An asset management system/tool includes all the processes, tools, data and policies necessary for the effective management of the asset. It is involved in data collection, storage, analysis and interpretation. In general, an asset management system is composed of several modules including:

- Data repository – including data on asset type, location, condition, use and features, asset maintenance methods and management strategy.
- Analysis, prediction and decision aid tools including asset deterioration and lifecycle cost analysis/whole life costing models, risk analysis and trade off analysis procedures.
- Reporting and scheduling processes.

Asset management systems can typically integrate existing management systems for individual or several assets and work on both a network and project level. Taking into account the differing factors such as current asset condition, investment levels and maintenance standards, the asset management system can produce a measure of performance of each asset type. Use of such systems should enable better informed decisions on the allocation of resources across a range of infrastructure needs considering all the engineering, business and economic factors affecting the asset.

B.2.1 Data repository and asset inventory
Asset management systems make use of data from a wide range of sources including:

- Definition of the network.
- Asset type (pavement, structure, sign etc).
- Asset location.
- Condition of the assets.
- Levels of use (e.g. traffic flows).
- Policies and standards (e.g. maintenance standards).
- Budget information.

This range of data is normally loaded into and stored within a central database, namely a data repository, which can be easily accessed by the asset management system. The data repository is the foundation of any asset management system as it stores inventory information, condition measurements and a user-defined library of maintenance strategies.

The quality of the output from the asset management system depends on the quality of the data input to the system. Therefore, effective data administration of the system is crucial in order to ensure data integrity, accessibility and compatibility and facilitate periodic updating of information. The asset records can be kept up to date by regular inspections, good communication within the organisation and effective staff training such that they understand the data collection process and what the data means.

Databases used for storage of asset data, namely the data repository, are predominantly designed in Oracle, SQL and MS Access. The data repository stores a wide range of data. When comparing between systems, it is important to consider:

- How the asset locations are referenced i.e. linearly or by nodes or GPS.
- Whether the data fields can either be user-defined or fixed.
- How the data are viewed.

In general, the database might be fitted with a Visual Basic, Java, GIS (Geographical Information System) or a browser/web based interface as a means for the user to view the data.

**B.2.2 Analysis, prediction and decision aid tools**

The central database then feeds in data into the modelling and analysis component of the asset management systems. Based on the data available, asset management systems will carry out a number of different modelling and analysis procedures. These can be of a technical, financial or general nature and examples include:

- Condition modelling of the different asset types - Based on current condition data and maintenance policies through the use of asset deterioration models, forecasts of level of use etc.
- Life cycle/Whole life costing - Calculation of the whole life cost for maintaining the assets to a required standard are calculated for a given maintenance policy.
- Risk Analysis - Taking account of risk in a systematic way to aid decisions on prioritisation of projects.
- Trade Off Analysis - The investigation of trade offs between different asset categories or program areas (e.g. maintenance, capital expansion and capital renewal)

The data analysis and prediction tools are another important component of an asset management system. Typically, a pavement management system should be able to undertake all the data analyses which include:

- Current condition indicator and ratings - Interpretation of the condition data collected.
- Predictive analysis and condition projection - Use of deterioration models, road user models and level of use to forecast the degradation or remaining life of the asset.
• Analysis at either a project or network level.
• Identification of optimal future treatments.
• Calculation of life-cycle costs.
• Prioritisation of maintenance treatments according to available budgets.
• Capitalisation and financial valuation of the asset.

**B.2.3 Reporting and outputs**

The outputs of the asset management system, based on the data collection and analysis, are critical to enable effective decision making. They may include:

• Project prioritisation - Asset management systems may prioritise projects according to various criteria e.g. economic, environmental, risk.

• Valuation of the assets - There are a number of ways of valuing the assets, either based on the cost to society of the efficient movement of people and goods or the cost of repairing or replacing the asset. The value may depreciate according to the condition of the asset (typically where assets subject to vehicle loading) or at a constant rate over time.

• Performance monitoring - Measures progress towards achieving objectives. Performance can be measured in a variety of ways, both quantitative and qualitative, examples including condition, safety, environmental impact and public satisfaction.

• Reporting modules – facilitates presentation of inventory information and analysis results and they may be in the form of graphics, tables and maps.

The majority of the systems use GIS for data viewing and reporting.

**B.2.4 Standardisation and compatibility**

Some systems are designed specifically to be compatible with other asset management tools, for example HDM-4 and others comply with specific standards such as UKPMS and GASB 34.

**B.2.4.1 HDM-4**

HDM-4 (Highway Development and Management System) is a decision tool which provides a harmonized approach to road management with adaptable and user-friendly analysis tools, for investigating road investment choices. It can therefore be integrated within an asset management system in order to provide economic analysis capabilities.

HDM-4 is a primarily a tool for techno-economic analysis and is globally accepted as a road investment decision making analytical tool. HDM-4 is the outcome of extensive research for several decades in various parts of world. The research focused on mathematical modelling of road deterioration and performance predictions for all types of pavements falling under all terrains, climates, road conditions, treatments etc. HDM-4 generates multi-year road maintenance programmes with graphics showing the impact on road condition of the network under various budget scenarios.

HDM-4 software was developed as part of the International Study of Highway Development and Management Tools. Sponsored by the World Bank, Asian Development Bank, Swedish National Road Administration, DFID, as well as others, the project had three major outputs:

• Technical relationships for modelling pavement deterioration and vehicle operating costs.
- Procedures for applying the technical relationships for road asset management.
- The HDM-4 software for applying techniques and models.

HDM-4 is a globally accepted tool and a number of software products available in the market are compatible with HDM-4. The current version is HDM-4v2. HDM-4 is used in many countries and one third of users are in Europe.

**B.2.4.2 UKPMS**

The UK Pavement Management System (UKPMS) is the national standard for management systems for the assessment of local road network conditions and for the planning of investment and maintenance on paved areas of roads, kerbs, footways and cycle-tracks on local roads within the UK. UKPMS is described in greater detail in this Report, and particularly in Appendices A & F.

The primary use of UKPMS is to assist Local Authorities in the planning of maintenance on the local road network through the systematic collection and analysis of condition data. Use of a UKPMS accredited system is recommended as good practice and is a vital component of an effective Highway Asset Management regime. UKPMS supports local highway authorities’ maintenance management objectives by providing facilities to:

- Identify lengths of paved asset in need of maintenance, including treatment options and costs;
- Prioritise maintenance schemes to give best value for money;
- Identify network trends

Currently five companies have systems that are accredited to UKPMS.

**B.2.4.3 GASB 34**

The Governmental Accounting Standards Board (GASB) is responsible for setting the accounting principles for state and local governments in the USA. GASB Statement 34, Basic Financial Statements and Management’s Discussion and Analysis for State and Local Governments (GASB 34) requires that state and local governments (in the USA) report on the value of their infrastructure assets, including roads, bridges, water and sewer facilities and develop procedures and methods for asset management systems.

Physical infrastructure such as roads will continue to have value long after the initial cost of construction. Over a number of years, typically 20 to 50, this value or usefulness will decline. The aim of GASB 34 is to provide a more realistic picture of the existing value of an agency’s assets, with the cost, or loss in value, of each asset spread over its useful lifetime rather than accounted for in the first year.

This method of accounting for assets is generally the standard in the private sector. The aim of GASB 34 was therefore to bring the accounting of physical infrastructure by public agencies more in line with the private sector and provide a clearer picture of the overall financial condition of public agencies. So, in the United States, it is important for any asset management system to comply with the GASB 34 mandate. Some of the systems are specifically compatible with externally specified standards.
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Figure 9 List of Pavement Asset Management Systems
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Appendix C  Recent research and development

Over recent years there has been a considerable amount of other relevant research, summarised below. This includes:

- Highway Service Levels (Ramdas et al, 2007)
- Smaller, quicker, cheaper automated carriageway condition surveys for local roads (Gallagher et al, 2009), leading to a new specification for Surface Condition Assessment for Minor Roads (SCAMR) surveys.
- The Highways Agency Pavement Management System (HAPMS)
- Integrated Asset Management Systems (Highways Agency)
- Whole Life Cost models for all asset types (Highways Agency)
- Pavement stiffness from deflection measurements at traffic-speed (Highways Agency)

C.1 Highway Service Levels

Research on Highway Service Levels (Ramdas et al, 2007) explored public opinions of paved surfaces on the local authority road network and related their requirements from the highway network to engineering standards currently used to manage the network. The overall aim was to start the process of getting the public mindset into the prioritisation process so that the services provided are better aligned to customer needs. The scope of the work was limited to getting an improved understanding, in qualitative terms, of the levels of service the public expected for the surface of carriageways and footways. Some of the key findings of the research, relevant to carriageway condition and maintenance were:

- The type of road user is a key driver of perceptions of road surface condition. The elderly and disabled (whether pedestrians, private motorists or passengers) notice road surfaces more than any other group of users. Overall, public mindsets (recalled attitudes tended to be negative) about road condition are influenced by a number of factors, including experiences of a wider road network beyond the immediate locality and non-condition related factors.
- The two main condition drivers that influenced user opinions and satisfaction were ‘safety’ and ‘ride comfort’. Any condition aspect that caused them to react to the surface condition and took their attention away from driving was construed as unsafe and unacceptable. Users were generally willing to tolerate some level of deterioration and accept trade-offs.
- There was only limited alignment between the pedestrians’ perceptions of maintenance needs and engineering assessment (based mainly on Coarse Visual Inspection data) of the maintenance needs of the footways. The differences in measured and perceived data are probably due to the subjective nature of visual surveys.
- The available CVI data for cycle routes did not align with the unacceptable defects identified by the cyclists. More targeted surveys (e.g. focussed on the cycle paths) are needed to ensure that the requirements of this category of vulnerable road users are adequately addressed.
- The types of defects identified by the motor vehicle users on B and C class roads were:
  - Motorcyclists – Lack of grip, uneven/bumpy surfaces, overbanding, tramlines and the location and condition of ironworks and potholes;
Car drivers and passengers – Slippery surfaces, bumpiness and its effect on safety and ride comfort;

HGV drivers – lack of grip and edge deterioration; also, carriageway width and impact of the HGVs on carriageways and surfaces not designed to carry HGVs.

- Participants’ perceptions of condition were compared with the measured condition data represented by standard SCANNER parameters (except cracking) and 3 additional SCANNER parameters under development at the time. ‘Bumpiness’ and sudden, unexpected ‘jolts’ were identified as the main issues by the drivers of motorised vehicles:

  - In general, the lengths users believed had poor ride quality also had high values for 3m and 10m LPV, i.e. user perceptions of poor ride quality aligns well with 3m and 10m LPV;
  - The bump measure also aligned well with user perceptions and high LPV values;
  - There was no significant rutting on the route and therefore it was not possible to relate this parameter with user perceptions;
  - Lack of grip was an issue of concern for all users. Perceptions of poor grip are driven by factors such as visual appearance (e.g. shiny surface), type of treatment (e.g. overbanding) and debris (e.g. mud). On the study route, the locations of some of the comments on poor grip aligned with lengths where the measured texture was poor. It is not expected that users will always be able to easily judge lessening of grip;
  - The other parameters, transverse unevenness and Edge Deterioration Index do not align with user perceptions and may be appropriate only as engineering parameters.

- The RCI values calculated using SCANNER algorithms were compared with the qualitative opinions of the users regarding the lengths in need of maintenance. While lengths categorised by users as poor all had high RCI, the converse was not true. Users’ levels of acceptability of condition and the need for maintenance on longer lengths are related to more than just the condition. Condition that is deemed to be unacceptable in one location could be acceptable in another. For example, users expect and tolerate less smooth roads on speed restricted roads and urban environments.

- User hierarchy for roads and their expectations and requirements are influenced by their interpretation of where the road fits within that hierarchy. The users’ hierarchy appears to be different to the standard categorisation of roads on the network and is related to factors such traffic flow, speed, carriageway width, road geometry and the environment. Current BVPI and RCI do not appear to reflect user thresholds for further investigation or maintenance. A way forward would be the development of user BVPI taking account of user categorisation of road classes and expectations.

C.2 Smaller, quicker, cheaper automated carriageway condition surveys for local roads

Following the introduction of TRACS Type Surveys (TTS) on principal roads in 2004, the SCANNER (Surface Condition Assessment for the National NEtwork of Roads) machine survey was introduced on the whole of the local classified road network in England from 2005/06. Although it was originally envisaged that the surveys would extend to include unclassified roads, and hence cover the whole network, practical experience of machine surveys showed that productivity fell sharply on certain types of road, and it was
uncertain whether the data collected by these systems provided the information required to manage minor roads. Therefore research was required to establish what information local highways engineers need to manage these parts of their network and to develop a specification for machine surveys to deliver this information (Gallagher et al, 2009).

The requirements for surveys of minor roads and how these needs could be met using an automated road carriageway condition survey were investigated in phase 1. It was concluded that a planned, systematic approach should be taken to condition surveys on minor roads that would use all the data sources that engineers have for assessing their networks. Local authorities carry out safety inspections much more frequently than pavement condition surveys, and these could provide the basis for a systematic approach to condition surveys on the minor road network. It was therefore proposed that, rather than attempt to cover the whole of the minor road network over an extended period, detailed condition surveys could be targeted on those roads where there was already cause for concern about the condition of the road. Those minor roads that were in generally good condition, and where there was less reason for concern, could be monitored through regular safety inspections and occasional service inspections. Condition surveys could be targeted on those roads where the safety inspection identified a need, or where there had been complaints or concerns raised, where works orders had been raised and reactive maintenance had been carried out, or where there had been extensive excavation and reinstatement by utilities.

The practicality of the proposed regime was reviewed in phase 2, via further consultation and a more detailed investigation with an example local authority. It was concluded that, when selecting a condition survey (automated/ driven visual walked), automated surveys would be more appropriate for rural unclassified roads whereas, in urban areas, it would be less practical to undertake an automated machine survey to obtain carriageway condition data. Consultation with the machine survey industry reviewed the technical proposals for the survey specification, leading to a revised specification that could be used as the basis of the requirements for an automated condition survey targeted at rural unclassified roads. However, assessing further work has considered the practicality of applying this survey to an unclassified road network. This has lead to a number of concerns:

- Firstly it had not been demonstrated that such a survey would deliver the information required by authorities at a sufficient level of detail or accuracy. There was a need to undertake work to develop the required measures of condition that would be derived from an automated surveys of unclassified rural roads, and assess them in practice.

- Secondly, the efficiency of a survey dedicated to the measurement of rural unclassified roads is likely to be poor. This could make the survey very expensive. Furthermore the total length of unclassified roads to be covered each year is likely to be small, resulting in quite a small market. There may be little incentive for a contractor to build an automated survey machine to a new specification.

It was suggested that it might be more practical to extend current SCANNER surveys to (appropriate) unclassified roads, supplemented by driven visual surveys where SCANNER was not appropriate. As a minimum this would extend SCANNER to cover all category 2 and 3 unclassified roads. Survey contractors (in partnership with the local authority clients) would decide which of the category 4a (and perhaps 4b) roads it was safe to survey using their existing machines. This would provide an incentive for contractors to evolve their machine designs to smaller vehicles.

Because the proposed specification for automated surveys of unclassified roads (Surface Condition Assessment for Minor Roads, SCAMR) builds on SCANNER, it was recommended that contractors be encouraged to include the additional capability desired for unclassified roads on any new vehicles. This would lead, in the longer term, to survey vehicles capable of meeting the needs of both classified (SCANNER) and
unclassified (SCAMR) roads. This would not prevent new survey contractors joining the market with either a survey machine developed to survey minor roads (using specification proposed in this work) or a system meeting both the needs of minor roads and the SCANNER specification, thereby enabling them to survey the whole road network.

Finally, to make full use of the data provided by automated surveys of unclassified road there was a need for facilities to be available that assist in the planning and execution of the surveys (e.g. adequate geographical network referencing) and for making good use of the data. There was therefore a need to develop the appropriate tools, perhaps within UKPMS, or elsewhere.

C.3 HA Pavement Management System (HAPMS)

HAPMS is the management system for the carriageway pavements of the Agency’s network and consists of a series of computer applications to improve carriageway pavement management by providing:

- Improved data management by holding network, construction and condition data centrally on a single database,
- Enhanced analysis and reporting of the data both in map-based and textual formats,
- Tools for the optimisation, in terms of minimising whole life cost within the available budget, of pavement maintenance at both scheme and network levels,
- Accurate recording and management of lane closure information and the Delay Cost Model to calculate costs of delays at roadworks.

Managing Agents maintain up to date HAPMS information records about the current condition of the network, including technical information about carriageway composition. HAPMS helps prioritise schemes at the Continuous Value Management workshops.

There is little published information about HAPMS currently available in the public domain.


The HA is currently developing an assessment strategy covering its 5-year vision for the performance of the network. The new strategy will focus on managing the network to achieve the right balance between whole life cost, journey reliability, safety, affordability, risk, environmental impact and asset preservation. The objectives of the revised asset management strategy have been identified to be:

- Gaining an ability to forecast future funding requirements consistently across the various asset types,
- Strengthening prioritisation processes between asset types for authorisation of identified schemes,
- Providing a framework for raising awareness, culture and practice of asset management across the Agency and its suppliers.

The aim is to develop a methodology based on a whole life cost/whole life value approach, applied consistently across all the asset types making up the road infrastructure with the aim of having fewer but better targeted road works. This will require examination of current Standards for maintenance based on engineering parameters and take better account of issues related to congestion and disruption, impact on environment and safety of users and workers.
The aim of the Integrated Asset Management System (IAMS) is to enable the HA ‘to optimise the operation of the network by taking a long-term strategic approach to the management and monitoring of its asset performance’. Some key activities to achieve this are:

- Developing an approach centred on whole life cost/value,
- Introducing consistency of approach across asset types,
- Examining existing engineering standards,
- Taking account of maintenance impacts on disruption and congestion,
- Having intelligence led decision-making.

The aim is to have a single repository for information on all asset categories (e.g. pavements, structures, geotechnics and drainage) providing comparable measures for condition, performance and assessment of maintenance requirements. Part of the development of IAMS is the development of tools to enable top-down budget estimations and bottom-up scheme assessments based on the principle of minimising whole life cost of network maintenance.

The first phase of the development is focussing on the development of network-level models for use at the strategic level and scheme level models to support the value management process for the 4 main asset categories. The network and scheme level models are all standalone versions but a key aspect is the use of a common whole life costing approach across the asset categories. The next phase of the developments of the IAMS is expected to integrate the approaches to enable greater consistency in the management of the different asset types and deliver improved value for money.

There is little published information about IAMS currently available in the public domain.

**C.5 Whole Life Cost models for all asset types (Highways Agency)**

The HA has developed, over several years, whole life cost approaches for road pavements, bridges, tunnels, earthworks slopes, vehicle restraints, drainage, and lighting columns. The development of models for the different asset types have progressed at different rates.

Whole life cost analysis has been in use since 1999 for the appraisal of pavement schemes, both at the scheme level and the network level. The Scheme Analysis System (SAS) for Pavements (between 1999 and 2004) and the Software for the Whole life Economic Evaluation of Pavements (SWEEP.S), since 2004, as a module of the Highways Agency Pavement Management System (HAPMS), have been used to evaluate pavement maintenance schemes over £100k as part of the Value Management process. The prototype HA Network Whole Life Cost Model (NWLCM) has been used since1999 to carry out analyses to support the annual pavement maintenance programme development and annual condition target setting, as well as the analyses to support Spending Review submissions from 2000 to 2007.

Following Spending Review 2007, the need to deliver a set of whole life cost models for the top-down budget analyses and bottom-up scheme analyses for all asset features was recognised. Whole life cost models, with a consistent approach across all asset types are current being developed as part of the development of the Integrated Asset Management:

- Network level models for the strategic analysis of budget requirements for submission to the Government’s Spending Review. The models have in-built deterioration relationships and treatment selection rules based on current engineering practice for the identification of current and future maintenance requirements.
• Scheme level models (SAS-Structures, SAS-Geotechnics and SAS-Drainage) for the analysis of alternative maintenance options for renewal schemes. These are spreadsheet based applications developed to examine the whole life costs of maintenance schemes. The scheme level models and training in their use have been provided to the Service Providers responsible for delivering the maintenance programme on the HA network. The aim is to provide information for use in the assessment of the value for money component within the Value Management process.

Cost components in the models consist of:

• Works costs made up of the costs of treatments and traffic management. Default unit costs representative of national rates are included in the models for the standard types of treatments and traffic management arrangements used on the trunk road network.

• User costs made up of the costs of increased delays and accidents at roadwork sites. Traffic delay curves based on the HA Delay Cost Model are used to estimate the delay costs associated with different types of closures and time of working.

• In the SAS Models, Residual value at the end of the analysis period representing the value of the ‘unused’ part of any applied maintenance treatments.

C.6 Deflection measurement at traffic speed

The Traffic Speed Deflectometer (TSD) has been developed on behalf of the Highways Agency by TRL based on a Danish prototype to replace the Deflectograph which carried out surveys at low speeds (about 3mph) resulting in the need for traffic management and disruption to users. The TSD is designed to enable structural assessment of road pavements while travelling at traffic-speed (about 50mph) without disrupting traffic. The TSD is an articulated HGV with laser instrumentation and recording equipment and measures the vertical velocity of a road surface using non-contact laser sensors. It can detect early signs of structural deterioration of pavements and help the Agency in making the right decisions when planning maintenance (Ferne et al, 2009).
Appendix D  Pavement condition survey costs

D.1 Estimated annual SCANNER survey costs

In 2008-09 over 134,000 lane kilometres of SCANNER surveys were carried out in the UK through a number of different contracts. Information on survey prices is commercially confidential, but research carried out on the development of automated surveys for minor roads (Gallagher et al, 2009) reported the likely range of prices for SCANNER surveys in the UK (Table 11).

<table>
<thead>
<tr>
<th>SCANNER survey costs</th>
<th>Length weighted average (£/km)</th>
<th>Range (Mean ± one standard deviation) (£/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal (A) roads</td>
<td>24</td>
<td>21 to 48</td>
</tr>
<tr>
<td>B class roads</td>
<td>28</td>
<td>24 to 50</td>
</tr>
<tr>
<td>C class roads</td>
<td>30</td>
<td>25 to 56</td>
</tr>
<tr>
<td>Unclassified roads</td>
<td>35</td>
<td>30 to 60</td>
</tr>
</tbody>
</table>

1Calculated from responses to the consultation
2007/08 quoted prices, based on 16 contracts covering 103 authorities

From this, it is possible to estimate the annual cost of SCANNER surveys. The approximate proportions of principal, B class and C class roads may be estimated from information published in the annual report on SCANNER accreditation, QA and Audit (Werrio et al, 2009). Combining this with the length weighted survey price, it is possible to estimate the overall cost of surveys in England in 2006/07, and to scale that up, pro rata, to the cost of SCANNER surveys in the UK in 2008/09 (Table 12).

<table>
<thead>
<tr>
<th></th>
<th>Length (km)</th>
<th>Average price (£/km)</th>
<th>Cost (£k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal (A) roads</td>
<td>34,000</td>
<td>24</td>
<td>816</td>
</tr>
<tr>
<td>B class roads</td>
<td>25,000</td>
<td>28</td>
<td>700</td>
</tr>
<tr>
<td>C class roads</td>
<td>39,000</td>
<td>30</td>
<td>1,170</td>
</tr>
<tr>
<td>Total England (2006/07)</td>
<td>98,000</td>
<td></td>
<td>2,686</td>
</tr>
<tr>
<td>Pro rata UK (2008/09)</td>
<td>134,000</td>
<td></td>
<td>3,673</td>
</tr>
</tbody>
</table>

D.2 Estimated annual CVI survey costs

As well as SCANNER surveys on classified roads, some authorities are continuing to carry out visual condition surveys, either UKPMS detailed visual inspections (DVI) or coarse visual inspections (CVI) on classified roads, and many are continuing to carry out CVI surveys on unclassified roads. Information on survey prices is commercially confidential, but research carried out on the development of automated surveys for minor roads...
(Gallagher et al, 2009) reported the likely range of prices for CVI surveys in England (Table 13)

Table 13 Indicative CVI survey costs 2007-08 (Gallagher et al, 2009)

<table>
<thead>
<tr>
<th>CVI survey costs</th>
<th>Average (€/km)</th>
<th>Range$^1$ (€/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Built-up unclassified roads</td>
<td>35</td>
<td>14 to £59</td>
</tr>
<tr>
<td>Non built-up unclassified roads</td>
<td>29</td>
<td>14 to 55</td>
</tr>
</tbody>
</table>

$^1$Calculated from the 20 responses to the consultation
2007/08 costs based on limited sample of more than 20 contracts

The Code of Practice “Well Maintained Highways” (Roads Liaison Group, 2005b) recommends that the highway condition survey regime should reflect the different requirements of the network based on the defined hierarchy. Research carried out on the development of automated surveys for minor roads (Gallagher et al, 2009) reported typical frequencies of condition inspection on minor roads (Table 14)

Table 14 Frequency of carriageway condition surveys on unclassified roads

<table>
<thead>
<tr>
<th>Type of road</th>
<th>Each year</th>
<th>Every 2 years</th>
<th>Every 3 years</th>
<th>Every 4 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country lanes</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Older town roads</td>
<td>2</td>
<td>5½</td>
<td>3½</td>
<td>9</td>
</tr>
<tr>
<td>Mid-aged town roads</td>
<td>2</td>
<td>5½</td>
<td>4½</td>
<td>9</td>
</tr>
<tr>
<td>Newer estate roads</td>
<td>2</td>
<td>5½</td>
<td>3½</td>
<td>10</td>
</tr>
<tr>
<td>Town average</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>9</td>
</tr>
</tbody>
</table>

The $½$ symbol indicates that some authorities choose to carry out the carriageway inspections with different frequencies on different parts of the network – for example where the footway hierarchy requires a higher frequency of inspection.

From the information in Table 13 and Table 14 it is possible to estimate the annual cost of CVI surveys on unclassified roads in England (Table 15)

Table 15 Estimated annual cost of CVI surveys on unclassified roads in England

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Each year</th>
<th>Every 2 years</th>
<th>Every 3 years</th>
<th>Every 4 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country (Rural)</td>
<td>Length (km)</td>
<td>83,887</td>
<td>0</td>
<td>16,777</td>
<td>22,370</td>
</tr>
<tr>
<td></td>
<td>Cost per km (£)</td>
<td>29</td>
<td>29</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Per year (£k)</td>
<td>£784k</td>
<td>0</td>
<td>243</td>
<td>216</td>
</tr>
<tr>
<td>Town (Urban)</td>
<td>Length (km)</td>
<td>98,096</td>
<td>9,810</td>
<td>24,524</td>
<td>19,619</td>
</tr>
<tr>
<td></td>
<td>Cost per km (£)</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Per year (£k)</td>
<td>£1,388k</td>
<td>343</td>
<td>429</td>
<td>229</td>
</tr>
<tr>
<td>Total</td>
<td>£2,172k</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Thus, in summary, English local authorities are spending a minimum of about £4.86 million on road condition surveying data each year (£2.69 on SCANNER and £2.17 on CVI).
Appendix E  Issues with UKPMS performance

Both the previous reviews and the current project have identified a number of issues with UKPMS performance. These are described in more detail in this Appendix.

E.1 Issues previously identified with UKPMS functionality

E.1.1 The Strategic Plan

The UKPMS Strategic Plan (Robinson, 2004) identified some shortcomings with the existing UKPMS system, its documentation, and the way that it was often used.

These included

- Some algorithmic modelling deficiencies in the existing design of UKPMS, particularly in the areas of condition projection and prioritization, leading to a lack of confidence in results and the recommendations produced. There were also some coding problems in the same areas, which exacerbated the modelling problems.
- Inadequate reliability of input survey data leading to a lack of confidence in the reliability of data being processed by UKPMS.
- The level of detail at which UKPMS operates being significantly greater than that of pavement management systems in use in other countries, which highlights data problems, increases the complexity of processing and interpretation of results, and is perhaps inappropriate for network-level analysis.
- The high costs of operation perceived by local authorities of data collection and resources necessary to operate UKPMS, although survey data costs dwarf those of system operation.
- A lack of awareness and understanding among senior staff in local authorities of the main objectives of UKPMS and the potential benefits that could be derived from its use.
- The general lack of a proactive approach to pavement management by some local authorities, which only undertake the minimum to meet statutory obligations or to respond to initiatives from national Government.
- The limited availability of resources to finance enhancements to the design of UKPMS.

The UKPMS Strategic Plan (Robinson, 2004) proposed a number of tasks and initiatives including research programmes and user testing to

1. Resolve problems with condition projection;
2. Improve economics-based prioritization methods;
3. Improve treatment selection rules, including treatment history; and
4. Improve data collection methods including machine and visual surveys.

E.1.2 The Strategic Development Study

The UKPMS Strategic Development Study (Halcrow, 2006) and research into the use of TTS (or SCANNER) data for maintenance management (Schupke and Zohrabi, 2006a, 2006b) identified that many local highway authorities make little or no use of UKPMS. There were several reasons for this, but three main groups of criticism are relevant to the development of the specification:
1. The usefulness and relevance of UKPMS to the regular business of local road maintenance management. Many claimed that it did not provide useful information or outputs to support their normal business processes in the way that they wanted to fulfil their responsibilities and deliver their objectives. The previous reports (Halcrow, 2006, Ebert, 2006) stressed the importance of designing the new specification for UKPMS to meet local authority business requirements.

2. The ease of use of UKPMS. It was perceived as a difficult tool to use, and one that required considerable investment of time and other resources to learn to use it properly. The length of time taken to load machine survey data to the system and to run the programme (the Automatic Pass) with machine survey data were causes of concern to many people. It was perceived as being old fashioned, compared with other more modern software tools, and somewhat out of step with current approaches.

3. The reliability of the results. The reliability is influenced by the quality of survey data provided to the system. However there were also some concerns expressed about the data processing and analysis routines within UKPMS (the underlying algorithms). If these are only approximate, or contain inconsistencies or errors, the results may be inconsistent or unreliable. The limitations of repeatability and reproducibility in the survey data should be identified and expressed in terms of the consistency and reliability of the output results. Similarly any limitations inherent in the algorithms within UKPMS should be minimised, wherever possible, and explicitly recognised in the output results, in terms of confidence intervals or ranges.

E.1.3 Other technical issues

There are a number of other technical issues surrounding the implementation and use of UKPMS.

- The UKPMS documentation has not been kept fully up to date and information on the changes and change process is not readily accessible. Changes have been well controlled, but the documents that supported the original development and the changes during the original development process have not always been updated or maintained as a publicly accessible record. Consequently it is not immediately apparent what detailed functionality is now required, nor how it is specified and provided. This makes it difficult for “new” providers to implement and deliver competitive UKPMS products.

- UKPMS network referencing is defined around a simple model of the road network as a list of linear features (sections). This is a simple, logical approach which supports the recording and reporting of information gathered by traditional visual surveys. However, there is an inherent problem with achieving accurate position referencing when using this approach (especially when surveying at traffic-speed) that could be alleviated using modern approaches such as geographical referencing and the use of Global Positioning Systems (GPS) for data collection. [Note that the original UKPMS specification was developed when traffic-speed machine surveys provided a minor part of the data used by local authorities, as opposed to the current situation where SCANNER surveys provide a considerable quantity of the data populating authorities UKPMS databases.]

- The rule set for rating defects, providing condition indices and for selecting treatments has been developed over time, based on engineers’ appreciation of the different defect types, depending on their severity and extent. This has mainly been based on the type of data collected and results of visual surveys. The indicative treatments provided by UKPMS sometimes differ from those that an engineer might judge to be suitable in a particular instance. The rule sets for
rating defects do not encompass the majority of the parameters provided by machine surveys such as SCANNER, and hence do not exploit the very considerable potential of this information, which now covers a large part of the network.

- The rules for modelling the deterioration of roads, for predicting the future condition of the carriageway and for estimating the point at which different types of treatment are required are based on relatively little experimental or practical evidence. Neither have they been calibrated using practical experience on the full range of UK local roads. The results (from UKPMS) have not met engineers’ expectations in practice. The deterioration models do not encompass the majority of SCANNER parameters.

E.2 Impact of machine survey data (SCANNER) on UKPMS

E.2.1 Machine survey data

In 2003, following the report of the TTS Scoping Study (Ebert & Hawker, 2003), the Department for Transport decided to introduce automated surveys (machine surveys) as an alternative method of reporting the condition of principal road carriageways in England. Previously two other approaches had been approved, one based on the residual life of the pavement calculated from a Deflectograph survey, the other based on UKPMS condition indices derived from visual inspections. Machine surveys record the condition of the pavement in a fundamentally different way from visual inspections.

In essence a machine survey consists of a nearly continuous measurement of parameters along the pavement. For the purposes of reporting, the measurements are combined into characteristic values and reported at intervals. In the case of SCANNER surveys, values are reported at 10m intervals along the road. For example, rut depth is typically measured every 100mm along the road, the values are averaged over 10m lengths and reported as average values in each wheel path. The values reported from a machine survey have to be “interpreted” to give a measure of condition. For example, for a serviceable carriageway 20mm might be considered the maximum acceptable value of average rut depth over the 10m length. However, in determining treatments a number of different condition parameters may be combined and have an effect on the treatment required independently of the service level.

In essence a manual visual survey consists of a discontinuous set of “observations” about the condition of the carriageway. The inspector is looking for observable “defects”, against a list of predetermined defect definitions. For example “wheel track cracking” in a CVI survey is defined as “wide single cracking or multiple cracking/coarse crazing with visible crack width >2mm within the wheel tracks”, would be recorded as the length affected in metres and the number of lanes, and a “wearing course deterioration” defect would also be recorded for this defect.

A machine survey can report a very large number of values (which may have little significance in terms of carriageway deterioration) say for every 10m sub section over a carriageway section, whereas a visual inspection might produce no defects at all over the same carriageway sub section length.

This has two main consequences for the current UKPMS (discussed further below):

1. The volume of data from a (SCANNER type) machine survey is always vastly greater than the volume of data from a visual inspection.

2. The measurements from a machine survey first have to be “interpreted” in terms of carriageway defectiveness, whereas the observations recorded in a visual inspection only have to be combined to give an overall condition for the carriageway.
E.2.2 Use of machine survey (SCANNER) parameters

In total, a SCANNER survey reports thirty nine parameters to the current specification. These are:

- The position of the vehicle (LCOO) in three dimensions, easting, northing and altitude.
- Road geometry parameters; (radius of) curvature (LCRV), crossfall (LFAL) and gradient (LGRD).
- Eight longitudinal profile parameters; 3m and 10m moving average variance in the nearside wheel track, (LV3 and LV10), 3m and 10m enhanced profile variance in both wheel tracks (LL03, LL10, LR03 and LR10) and bump intensity in both wheel tracks (LLBI and LRBI).
- Five transverse profile parameters; rut depth in each wheel path (LLRT and LRRT) rut depth from the “cleaned” transverse profile in each wheel path (LLRD and LRRD), and transverse profile unevenness (LTAD).
- Five edge condition parameters; edge coverage (LEDC), edge steps medium depth (LES1) and larger depth (LES2), edge roughness (LEDR) and transverse variance (LTRV).
- Two measures of texture depth in the nearside wheel path; SMTD (LLTX) and MPD (LLTD).
- Nine measures of texture depth variability; RMS texture depth in each wheel path and midway between them (LLTM, LRTM and LCTM), variance of RMS texture depth in each wheel path and midway between them (LLTV, LRTV and LCTV), overall variance of texture depth (LTVV) and the 5th and 95th percentile values of RMST texture depth (LT05 and LT95)
- The crack map (LMAP) recording the crack length, offset position, angle and type code of each crack detected
- The cracking intensity parameters; whole carriageway cracking intensity (LTRC), cracking intensity in each wheel path (LWCL and LWCR), the transverse / reflection cracking intensity (LRCR) and the surface deterioration parameter (LSUR).

The SCANNER Road Condition Indicator was developed, over a number of years, as a way of combining a number of different SCANNER measurements into a single figure. This began with the initial development of the TTS “defects index” (Cartwright & Pickett, 2004), development and calibration of the SCANNER RCI (McRobbie, 2007), and a subsequent revision (McRobbie et al, 2007). The SCANNER RCI is currently calculated using the approach described in Appendix I, based on six of the measurements: nearside ride quality (LV3 and LV10), rut depth (LLRT and LRRT), nearside texture depth (LLTX), and whole carriageway cracking intensity (LRTC).

It is notable that there are many SCANNER measures that are not used in the SCANNER RCI. This stems from the fact that the SCANNER research programme introduced a number of new measurements with potential to be used as part of local authority asset management, but without developing the tools to enable local authorities to use them effectively, and with little practical guidance on how they could be used, to enable system developers to develop the tools.

However, a SCANNER Edge Condition Indicator is available (ECI) based on four of the measurements, edge steps (LES1 and LES2), edge roughness (LEDR) and transverse variance (LTRV), but this has not been highly tested on the network. Also, preliminary practical investigations with local authorities have shown the potential of the texture variability measurements as an indicator of surface distress and the need for surface treatment. There is also potential to reduce the duplication of reporting of...
measurements of rut depth and ride quality, by substituting the revised methods of reporting for the original methods.

There is hence a clear need to develop processes that would turn the wealth of data provide by SCANNER into information that local highway authorities can use to manage their pavement assets more effectively. Furthermore there is a potential for future machine surveys to measure structural and other parameters such as the Traffic Speed Deflectograph (TSD) currently being developed on behalf of the Highways Agency. Other traffic speed techniques such as ground penetrating radar (GPR) may also be able to provide useful data to UKPMS in the future. This would again be likely to create large amounts of data for processing.

As part of the introduction of automated surveys, a method of calculating treatment requirements from SCANNER data was developed and subsequently refined (Cartwright, 2007). This uses the “automatic pass” approach in UKPMS, summarised in Appendix I, section 5, with treatment rules based on a limited subset of SCANNER parameters (rut depth (LLRT and LRRT), whole carriageway cracking intensity (LRTC), wheel track cracking intensity (LWCL and LWCR), nearside texture depth (LLTX) and nearside ride quality (LV3)). Although it is possible to calculate indicative treatments from these SCANNER parameters, the rules were developed through informed discussion in workshops and have not been calibrated against results on local roads. In practice, it appears that the very few authorities have attempted to use UKPMS to develop indicative treatments and budgets using SCANNER data.

### E.2.3 Using machine survey data in UKPMS

During this review of UKPMS core functionality we have learnt that many authorities are unable to process SCANNER data to provide treatments (via the standard UKPMS processing routine – the Automatic Pass) because this simply takes too long (typically many days). There are several reasons for this unacceptable performance including:

- **Larger volumes of data.** The quantities of SCANNER data are very much larger than the other data sources (visual and machine) for which UKPMS was originally designed. Evidence suggests that SCANNER data volumes are well over 100 times greater than the data volumes for CVI data over the same network length. Although processing times do not necessarily scale up in a linear fashion it can be seen that a process which takes 1 hour for CVI data might well take 100 hours or more (i.e. over 4 days) for SCANNER data.

- **The complexity of the Automatic Pass processing.** While this is a powerful and flexible tool for processing many types of data together, it can be argued that firstly it is over complicated, and secondly, due to its generic nature, it cannot directly exploit the more structured nature of SCANNER data. It was designed to deal with all types of data (including the more sporadic defects recorded during visual surveys), and not just the continuous measurements provided by SCANNER surveys (e.g. a "new" measurement every 10m).

- **Inadequate computing resources.** Performance is clearly dependent on the type and level of computing resources and these will vary considerably from one authority to another. For example, stand-alone systems will often perform better than those which are part of a network. However, the full benefits of a pavement management system such as UKPMS can only be realised when linked in such a way as to allow easy access to other systems and sources of data within the local authority (routine maintenance, works ordering, accident data etc). Furthermore it would be unreasonable to expect authorities or users to upgrade their IT systems to a much higher level of network and processing capacity just to process UKPMS.
- **Lack of expertise.** Many authorities lack the expertise, resources, or time to use UKPMS effectively. When this is coupled with the above it is understandable why many authorities are not processing SCANNER data other than to satisfy national requirements to produce indicators.

The severity of this performance problem has been concealed to some extent by the fact that the Road Condition Indicator (RCI), which is used to calculate the results for national reporting, is a simpler, faster algorithm specifically designed for SCANNER data. The limitation of the RCI is that it only scores the condition of each subsection length on a scale and does not provide any indicative treatments or costs; these functions are only available currently via the full UKPMS Automatic Pass.

There is a deeper question about the way in which UKPMS was originally specified, which we have not investigated in depth. UKPMS was created to be a flexible and adaptable tool which readily allowed for updating and modification of the underlying algorithms using rules and parameters provided as data to the software system. Such flexibility may affect the practicality of achieving a fast working (i.e. processing) system. This issue overlaps between the “functional specification” and the “technical specification” and will be an important question to be resolved in taking forward our proposals.
Appendix F  Components of a pavement management system

F.1 Summary
The pavement management system consists of two main sub-systems; an information management system and a decision support system, both of which are required for an effective pavement management system. The relationship between some of the elements of a pavement management system is illustrated in Figure 10.

![Figure 10: Elements of a Pavement Management System](image)

F.2 Inventory (what we have)
In its simplest form, an inventory is just a list of elements. However a road pavement is a three dimensional structure which forms part of a network of such elements. Therefore a pavement asset management system needs some way of breaking the road network down into a series of discrete elements.

The simplest approach would be to characterise the network as a series of linear elements which connect at points. These points could be at road junctions, or intermediate section start and end points. Once a series of elements has been defined, values can be attached to each element – simple values like the length of the element, or the classification of the element within a hierarchy, or more complex values, like the statistical distribution of a measured value within the element, or the computed cost of replacing the element.

At the next level of complexity, each section length could be subdivided into shorter sections, giving a framework for distributing values within the section, and each section or sub-section could have a second dimension as an attribute (such as width). Similarly, each section could be sub-divided laterally as well as longitudinally, to create a series of parallel lanes (carriageway, footway, etc).

At the greatest level of complexity, each section or sub-section could also be divided vertically, into a series of layers, giving a framework for distributing values by depth within sections or sub-sections.
UKPMS currently specifies a network referencing system based on linear elements (i.e. elements without specific geographic position information) which can be linked at nodes (although UKPMS does not use connectivity at nodes in subsequent calculations). The sections have width as an attribute, specified by the number and type of lanes, and as a measured or estimated value.

Over the past 30 years geographic information systems (GIS) and global positioning systems (GPS) have been developed and widely adopted, using information and communications technology.

A road network is a three dimensional structure in space and, as such, can be characterised in a GPS and GIS environment. Individual elements of a road network, such as lighting columns or gully pots, can be positioned in three dimensions within the GPS and GIS environment. However the pavement is an extensive feature and, as such, has to be broken down into a series of smaller elements for its position to be described.

There is also an issue about the scale or “granularity” of the elements. Ideally each element should be small enough to have consistent properties throughout the element. However road pavements are composed of assemblages of materials with varying properties, from the microscopic scale upwards. Although individual materials used in road construction and maintenance are specified to have uniform properties, they are applied in lengths, layers and patches in a way that leads to variation from point to point and place to place.

The amount of data to be measured and stored increases proportionally as the scale of the elements decrease. For example, if the minimum element length is 1m, there will 10 times more elements than with a 10m minimum element length, and 100 times more elements than with a 100m minimum element length.

Therefore the minimum size of a pavement element needs to be specified in some consistent way that relates to a practical scale for road maintenance. Although individual patches can be less than 1 m² in extent, planned maintenance is normally carried out on longer lengths and larger areas, and therefore a minimum length of 10m might be acceptable on local roads in the UK.

F.3 Condition data

When a new road pavement is constructed, it is usually built to a very detailed technical specification in terms of geometric layout, structure and materials. However, over time, the specified requirements have changed, so that a road specified and built 100 years ago is likely to be very different from one constructed recently.

Normally a new road pavement will meet a performance standard in terms of strength, shape, and surface properties such as skidding resistance. Over time the pavement will deteriorate, due to the effects of ageing in stiffening binders and weakening materials, to the effects of traffic loading and surface wear, and to interventions such as excavation and reinstatement for utility works.

As the pavement condition deteriorates, and as traffic requirements change, maintenance and improvement work is carried out. Whilst this is also specified and generally carried out to a defined standard in terms of materials, methods and, in some cases performance, this inevitably changes the structure and condition of the pavement. Over time pavements evolve into complex assemblages of a range of different materials, in layers of differing thickness and age, and in a widening range of conditions.

Historically engineers, surveyors and inspectors monitored the condition of the pavement using visual assessment methods, and made maintenance decisions based on knowledge and experience. The inspection methods have become formalised, the information gathered has been standardised, and ICT systems have been used to store and analyse the data.
More recently engineers, surveyors and inspectors have used a number of machine based condition surveys to measure properties of the pavement. These include methods of measuring surface friction (such as SCRIM and GripTester) methods of measuring deflection under load and hence transient stiffness (such as the Deflectograph and the FWD) and methods of measuring surface conditions such as texture depth, profile along and across the road and identifying feature such as surface cracks. Each of these methods has become standardised and some are used to calculate or estimate a number of other parameters.

Over recent years there have been substantial advances in the methods of collecting highway condition data. These include the use of instrumented vehicles (like SCANNER) to gather information:

- about the vehicle position in three dimensions using GPS, enabling condition data to be linked directly to geographic information systems,
- about road profile, leading to measures of ride quality, rut depth and general deformation,
- about surface texture depth and variation, leading to measures of surface deterioration, polishing, fretting and ravelling,
- the type and extent of cracking, leading to measures of cracking intensity, and
- the condition of the edge of carriageway, leading to measures of edge deterioration.

F.4 Data repository

Condition data need to be located on the network (the pavement asset) to an appropriate level of accuracy. They could be expressed as

- a length, or area of the pavement, or as a point value, and
- by length along the carriageway, or by length and offset (carriageway lane, footway etc.), or by length, offset and depth.

The amount of detail required in the data structure within the repository will depend on the granularity of the analysis to be carried out.

The location of the condition data in relation to the inventory data will also depend on the complexity of the methods of analysis.

F.5 Condition assessment

Each method of collecting data about pavement condition has to be turned into information about pavement condition. For example:

i. A measurement of the average depth of a rut has to be rated for its importance in terms of the level of service of the road, and hence turned into an assessment of the need for treatment, and the relative priority of that treatment.

ii. A measurement of the transient deflection of a pavement surface under a rolling wheel (in the Deflectograph), which is a measure of stiffness, has to be interpreted as an indication of the strength and hence the longevity of a pavement structure.

UKPMS visual condition surveys collect a number of identified and named defects as “observations”. These are rated and combined in a number of ways to provide “indices” of the condition of the pavement and to identify indicative treatments, as described in more detail in Appendix I.
Measured SCANNER parameters have to be rated and scored to be used to provide a condition indicator and indicative treatments.

Ideally, a pavement management system would combine all the condition data from a number of different sources, including inventory data, to describe the condition of the pavement relative to some desired service level.

In practice, each of the different condition measurement tools has been developed independently, with its own condition assessment methodology, so that the results from each method are independent and may (or may not) be comparable. An area of pavement with visible defects may be stiff enough to be acceptable using a Deflectograph (or vice versa). An area of pavement with defects observed through a visual survey methodology may appear to be free from defects using a machine survey (or vice versa).

Different visual survey methodologies describe pavement condition in different ways, and the descriptions are not readily convertible from one system to another. Therefore a pavement management system that has been designed to use one methodology may not be able to use a different set of condition (or defect) definitions.

In order to provide a comprehensive assessment of the condition of each element of the pavement, there has to be

- a consistent method of combining results from disparate systems
- a defined standard of what is acceptable condition, and what is not acceptable, possibly including some sort of acceptability scale
- a way of comparing sections with differing quantities and qualities of data

F.6 Need for treatment

Just as each method of collecting condition data has an associated method of assessing pavement condition, so each method also has an associated method of identifying or assessing the need for treatment.

In some systems the need for treatment at the network level is a fairly “broad brush” assessment, leaving the detailed design of the scheme to be carried out at the project level. This can lead to conflict, especially where the network level assessment (and the associated prioritisation) indicates one option, and the detailed scheme design indicates a different approach, and possibly a different priority for schemes.

In order to provide a comprehensive assessment of the need for treatment, and the appropriate treatment option, for of each element of the pavement, there has to be:

- a consistent method of combining results from disparate systems
- a defined range of treatment options, criteria for selecting each of them, and for choosing between them
- a way of comparing treatment options on sections with differing quantities and qualities of data

Whilst the condition assessment is carried out at a point in time, usually relying on the most recent condition data, the treatment selection process may need other sorts of information:

- about the pavement construction and materials,
- about the maintenance history (including street works), and
- about the change in condition over time.

This is likely to be needed at the project level, but may also be useful at the network level.
F.7 Prioritisation of projects for treatment

Having assessed the condition of the pavement, and identified the need for treatment, there is the question of the best treatment option, and the best time to apply it.

If schemes are simply to be prioritised on condition, then the system needs some way of assembling elements of the pavement into large enough projects or schemes to be worth carrying out.

This may be an interactive process – there will be some small isolated areas of very poor condition that hardly justify a scheme, when combined with intervening lengths in better condition. So the area to be included within the scheme, and the average improvement in condition, will be relevant in prioritising between projects or schemes simply on condition.

However, if projects or schemes are to be prioritised on economic principles, assuming that there is an “optimum” time for each level of intervention, and that some treatments can be delayed, in order to get better value for money when they are applied, then the system needs to have some way of predicting the change in the condition of the pavement over time.

This also implies the importance of being able to track the condition of the pavement over time, to be able to model the future condition trajectory from knowledge of the past trajectory (of either the individual pavement element, or of the type of pavement element).

Having identified the need for treatment, and the viable projects or schemes, the system will need to ascribe a cost to each scheme. The cost may not simply be the cost of the indicative treatment, but also the cost of traffic management, and prices may be related to the method of procurement, either different rates within a term contract, or different rates from different contractors.

Either the “worst first” or the “economic” prioritisation of projects and schemes will lead to a future programme of work, which will have to be profiled over a number of years, taking account of available funding, of the effect of different projects and schemes on traffic management requirements, other resource constraints and other network management factors.

F.8 Determining the impact of funding decisions

Once a forward programme of work has been assembled, with indicative costs for each project or scheme, the overall level of funding can be estimated, and profiled over a number of years.

If a different level of funding is applied, projects or schemes may have to be re-profiled over a different period, or alternative treatment options may have to be considered.

If schemes are delayed, there is a risk that the work, when eventually done, will be more extensive or intensive, and cost more than it would have, if carried out sooner.

The overall condition of the network would also be expected to deteriorate, due to the reduction in maintenance activity.

Both of these calculations require a model of the deterioration of the pavement (or the network) so that the condition of the network can be projected forward.

They also require a measure of the “efficiency” of the treatment options in improving the condition of the carriageway, depending on the method of assessing condition.

As a simple example, a surface dressing treatment could seal the surface (reducing future deterioration) and restore surface properties, without directly affecting the structural stiffness or the implied strength. So a measure of condition based on the surface properties might be improved, whereas a measure of condition based on
structural properties might be (relatively) unaffected. Even though the surface dressing might seal the surface, control water penetration, and hence indirectly improve the stiffness and strength of hydraulically bound foundation layers.

F.9 A feedback process

Pavement management systems have been developed with treatment selection processes, condition projection techniques and costs based on relatively little information. The whole approach is based on the concept of regularly gathering detailed information about pavement condition. A feedback process would enable observed values to be compared with predicted values, and provide information to improve future estimates and calculations.

Software systems are increasingly being designed as self learning systems, with heuristics and algorithms to improve future predictions based on past experience.

In principle, a pavement management system should be designed to incorporate a self learning feedback process to enable the system to learn by experience.

F.10 Integration with other systems

Information from a pavement management system is often integrated with other, wider asset management or enterprise resource management systems.

The pavement management system should be able to share data with a number of other systems:

F.10.1 Safety Inspections

Most local highway authorities will have a system for managing the regular inspection of their highways (carriageways and footways) for safety defects, and for ordering and managing the responsive or reactive maintenance that ensues. The pavement management system should be linked with these systems, so that relevant data may be exported from one to the other, and combined for analysis.

F.10.2 Customer complaints and response

Most local highway authorities will have a system for receiving, recording and responding to customer feedback (complaints), possibly including third party claims. There will be a system for managing the reactive or responsive maintenance that ensues from customer feedback. The pavement management system should be linked with these systems, so that relevant data may be exported from one to the other, and combined for analysis.

F.10.3 Work management systems

Most local highway authorities will have a system for managing the work carried out on their behalf on their highways – both regular or routine maintenance, and planned maintenance projects or schemes. The pavement management system should be linked with these systems, so that relevant data may be exported from one to the other, and combined for analysis. In particular, records of work carried out on the pavements – location, type, extent, timing, and associated costs.

F.10.4 Streetworks management
Most local highway authorities will have a system for managing street works (works by contractors on behalf of third parties, mainly utilities) on their highways, which includes excavation and reinstatement of pavements. The pavement management system should be linked with these systems, so that relevant data may be exported from one to the other, and combined for analysis.

F.10.5 Integrated Highway Management Systems
Many local highway authorities will have a system or systems that combine the various aspects of highway management (above) into an integrated highway management system. A pavement management system could be one component part of an integrated highway management system.

F.10.6 Integrated Asset Management Systems
Many local highway authorities will have a system or systems to manage their various transport and highway assets. A pavement management system could be one component of an integrated asset management system. If the pavement management system is not part of an integrated asset management system, it should be linked to it, so that relevant data may be exported from one to the other, and combined for analysis.

F.10.7 Traffic Information Management Systems
Many local authorities will have a system or systems to manage information about traffic – volumes, speeds, composition, and changes from time to time. The pavement management system should be linked with these systems, so that relevant data may be exported from one to the other, and combined for analysis.

F.10.8 Road classification and management
Many local authorities will have a number of different ways of classifying their road networks, based on a range of differing requirements. For example in relation to spatial planning and development objectives, in relation to traffic management objectives and requirements, public transport, cycling and pedestrian routes, emergency routes, diversion routes, road safety, safe routes to schools, heavy load routes, etc. The pavement management system should be linked with these systems, so that relevant data may be exported from one to the other, and combined for analysis.

F.10.9 Geographic Information Systems
Most local highway authorities will have a corporate geographic information system for displaying all the spatially referenced data that they own, or have available. The pavement management system should be linked to that system, so that relevant data may be exported from one to the other, and compared for analysis.

F.10.10 Financial information management systems
Most local highway authorities will have financial information management systems, or enterprise resource management systems, to manage their financial and business responsibilities. The pavement management system should be linked to those systems, so that relevant data may be exported from one to the other, and compared for analysis.

F.10.11 Data requirements
One major issue of linking to some of these other systems, and sharing data, will be the level of detail, or granularity, of the data. For a pavement management system, the key requirement is to be able to locate the information on the road network – to associate a customer complaint with a specific section or sub-section, to associate expenditure with a particular project or scheme of work, and to be able to associate it with a part of the project. If data have to be “smeared” as average values over wider areas, the ability to precisely relate pavement condition, treatment work and expenditure will be reduced.

But there will be significant costs (as well as organisation and management issues) in trying to change systems to provide data or information in different ways, or structured to meet the arcane requirements of a pavement management system.

Therefore there will be practical limitations on the quality, quantity and suitability of data available and therefore significant limitations on the ability of a pavement management system to deliver the precision and accuracy of computation that would enable it to meet some of the wishes and expectations of engineers, their managers, and local highway authorities.

Consequently there will be practical limits to what can be achieved within realistic budgets and time frames. It may be more cost effective to concentrate on improving the amount of detail and the consistency and reliability in some parts of the pavement management system than in others.

**F.11 Reporting**

Information from a pavement management system is potentially useful in a number of different ways within a local highway authority.

At one extreme, summary information could be of interest to local residents, and some local highway authorities have experimented with making summarised information available over the internet, displayed on a map background.

At the other extreme, detailed information is likely to be of interest to those responsible for managing the network (perhaps in a central team) and to those responsible for managing specific sections of the road network (perhaps in an area team).

Each local highway authority will have its own way of doing business, from standing orders down to detailed business processes, and its own specific set of procedures and systems to support its responsibilities and deliver its services.

The pavement management system will need to be integrated into those business processes, procedures and systems, and reporting from the pavement management system will need to be tailored to the individual authority’s requirements.

Where there are legal or public administration requirements for a report (for example, to provide a national indicator) there may be a need for consistency between local highway authorities.
Appendix G  National reporting requirements

Currently the national administrations in England, Wales and Scotland have specified the use of SCANNER survey data, processed through a UKPMS compliant system, to report the condition of their classified road carriageways.

In Northern Ireland CVI surveys are used on all roads except motorways, trunk A roads and other A roads. The results are processed using a UKPMS compliant system, and used to inform the depreciation charge in the Annual Report and Accounts.

These requirements are described in more detail in the following sections.

G.1.1 National Road Maintenance Condition Survey (NRMCS)

The Department for Transport previously produced statistical reports on road condition in England, Scotland and Wales. Until 2008 results from the so called National Road Maintenance Condition Survey (NRMCS) were published in an eponymous publication. With a change of focus to England, the report was renamed Road Conditions in England: 2007 (DfT, 2008c). This publication reports on the condition of public roads, footways, kerbs and verges in England. Results are derived from a range of surveys of road condition which are collectively referred to as the National Road Maintenance Condition Survey (NRMCS). In 2008 the DfT reported that:

"Future publications of RCS are likely to differ significantly in form. From 2008, will be using the SCANNER machine-collected data to report on the condition of classified local roads in England. This reporting will be based around the SCANNER Road Condition Indicator, developed for reporting Best Value Performance Indicators on local roads. DfT will work with the UK Roads Board to scope the requirements for data on unclassified roads and to design a collection accordingly.

"The UK Roads Board will continue to work towards the production of a UK-wide road condition report. It has a standing objective to develop consistent surveying methods across England, Scotland, Wales and Northern Ireland, with the eventual aim of producing both UK estimates of road condition and comparisons between the countries." (DfT, 2008c).

Recently the Department for Transport has commissioned a contract to develop a national road condition database that will be populated with the annual provisions of SCANNER and TRACS data. Two “task and finish” groups have also been established to consult and decide on an approach to the use of this data for reporting condition at the national level.

G.1.2 England

In England the requirement is specified by the Department for Communities and Local Government (CLG). A single set of 198 national indicators was announced as part of the Comprehensive Spending Review 2007. The national indicators:

- Will be the only measures on which central Government will performance manage outcomes delivered by local government working alone or in partnership
- Replace all other existing sets of indicators including Best Value Performance Indicators and Performance Assessment Framework indicators and
- Will be reported by all areas from April 2008.

Two national indicators have been specified for road carriageways (CLG, 2008), NI168, Principal roads where maintenance should be considered and NI169, Non-principal classified roads where maintenance should be considered. The requirements are essentially the same as the former Best Value Performance Indicators (BVPI) BV223 and
BV224a, except that NI168 includes the small number of principal motorways (i.e. motorways where a local authority is the highway authority).

The detailed requirements for gathering the indicators (for reporting in 2009) have been published by the Department for Transport (DfT, 2009).

"The condition of local authority principal roads (NI168) and of non principal classified roads (NI169) reported in 2009 will be based on the results of SCANNER surveys carried out between 1st April 2007 and 31st March 2009. The condition of principal roads will be reported on the same basis in 2009 (NI168) as in 2008 (BV223). The condition of other classified roads will be reported on the same basis in 2009 (NI169) as in 2008 (BV224a). The SCANNER Road Condition Indicator (RCI) will be used with the “revised” set of parameters, thresholds and weightings, first used for reporting in 2008.

"In 2009, local highway authorities in England are required to use SCANNER accredited surveys and a UKPMS accredited pavement management system to produce their NI168 and NI169 reports."

G.1.3 Wales

In Wales, the Performance Measurement Framework was initially introduced in 2005/06, and included a revised set of nationally agreed and defined performance measures for local authorities. Developed in collaboration with local and central government representatives and regulatory bodies, the framework provides a mixture of strategic and operational measures across a range of local authority service/policy areas.

The framework gives local authorities the autonomy to use performance information, which best serves their local needs, and provides the ability to compare performance across Wales. The framework consists of a number of National Strategic Indicators and a range of service specific Core Indicator sets. These are reviewed annually to ensure that the framework remains “fit for purpose”. The guidance provides a detailed explanation of the measures contained within the 2009-10 framework.

The National Strategic Indicators focus on key strategic priorities whilst the Core Indicator Sets aim to provide a balanced picture of performance both corporately and at a service/policy area level. Under Environment and Transport – Transport and Highways, the framework defines THS/010 (NS16) as “Percentage of (a) Principal (A) roads; and (b) Non-principal/classified roads; that are in overall poor condition”. The guidance defines the condition as:

"The figures for both parts of this indicator represent the percentage of the road network length that is equal to or above the RED threshold, i.e. that is in poor overall condition and will require planned maintenance soon, i.e. within a year or so on a ‘worst first’ basis.

"Only data collected using survey equipment possessing a valid Scanner Acceptance Certificate, which explicitly states that the survey vehicle has been approved for use in the production of Best Value Performance Indicators, may be used in the calculation of this indicator.

"Detailed guidance on how to produce the information required to report this indicator can be found in the relevant UKPMS Technical note.” (UKPMS Technical Note 43, UKPMS 2009)

By implication the indicators have to be produced using a UKPMS accredited system.

G.1.4 Scotland

In Scotland the Accounts Commission’s role is to:
• Examine how Scotland’s 32 councils and 34 joint boards manage their finances.
• Help these bodies manage their resources efficiently and effectively promote Best Value.
• Publish information every year about how they perform.

Audit Scotland helps the Accounts Commission by investigating on its behalf, various aspects of how public bodies work. It was set up in 1975, is independent of local councils and of government and can make recommendations and reports to Scottish ministers.

The Accounts Commission has a statutory responsibility to specify information that councils must publish about their performance, in the form of statutory performance indicators (SPIs). The information is collected and published locally by each council after being checked by its auditor. The Commission then publishes information about the comparative performance of councils across Scotland.

The current requirements are specified in a direction under the Local Government Act 1992, The Publication of Information (Standards of Performance) Direction 2006. These include:

"Carriageway condition RL 1: The percentage of the road network that should be considered for maintenance treatment."

Further information on the indicator is given in the published compendium of all the data (Audit Scotland, 2008):

"Carriageway condition: 1: The percentage of the road network that should be considered for maintenance treatment.

"What the indicator reports

"This indicator shows the percentage of the road network that should be considered for maintenance treatment.

"The indicator is based on agreed United Kingdom current best practice derived to suit Scottish conditions. In particular it considers road texture, rutting cracks and road profile, measured against nationally applied quality thresholds."

More detailed information is published by the Society of Chief Officers of Transportation Scotland (SCOTS, 2009).

"The statutory performance indicator for the condition of the Scottish local authority road network, is defined as "the percentage of the road network which should be considered for maintenance treatment", i.e. has reached a condition where more detailed monitoring or investigation is appropriate, to establish if and when remedial measures are required.

"In 2007-08, the construction of the indicator changed from the former Scottish SPI, which included data on longitudinal profile, rutting and texture, to a new UK standard Road Condition Indicator (RCI), which in addition includes data on carriageway cracking and also takes account of the severity of each defect and its relative importance for road users.

"The data is collected by a machine-based survey, which is subject to independent audit and quality assurance with the survey vehicles being subjected to rigorous annual validation checks.

"In Scotland, "A" roads are surveyed in both directions every two years, all "B" and "C" roads in both direction over a four year period, and a 10% sample of the unclassified network being undertaken in one direction each year. In order to minimise the effect of sampling errors on the results, the RCI is derived from the survey data collected over the past two years. In order to present the results graphically, the following colour coding convention has been adopted:
"Green  A section score less than 40 – While minor defects may still be present, the road is considered to be in an acceptable condition.

"Amber  A section score greater than 40 but less than 100 – further investigation required.

"Red  A section score of 100 or greater – The road has deteriorated to the point where repairs are likely to preserve serviceability and to prolong its future life

"The Scottish RCI figure includes both the “red” and “amber” categories, unlike in England, where the RCI includes only the “Red“ category. An increase in the figure indicates deterioration, while a decrease would indicate improvement. Caution is required in interpreting the results, as minor changes may not be statistically significant and undue emphasis should not be placed on a single years’ data, with greater reliance being placed on the longer term trends in the data.”

G.1.5 Northern Ireland

The Roads Service is an Executive Agency within the Department for Regional Development (DRD) and operates within the context of the Department’s overall vision and strategic objectives. It is the sole road authority in Northern Ireland, responsible for building and maintaining roads and minor road improvements.

The most recent Annual Report and Accounts for the Roads Service for 2007/08 (DRD, 2008) reports on network maintenance, with a key objective: “Maintain the road infrastructure to keep it safe, effective and reliable”. Under “Condition of the network” it reports:

"Monitoring the condition of our road network is an essential part of planning maintenance work and, in order to detect deterioration at an early stage, we undertake a number of annual road condition surveys. These surveys are carried out using specialist vehicles, which measure the strength, surface condition, skidding resistance and bumpiness of the network. We monitor the residual life of the motorway network and the main strategic roads, known as the Trunk Road Network. The 2007 Deflectograph survey, which measures the life expectancy of the strategic road network, shows that:

- "84% of the motorway network has a residual life of more than 5 years (target: 81%). This compares with 85.5% in 2006, 89% in 2005, 91% in 2004, 91% in 2003 and 89.5% in 2002 and shows that the motorway network has remained in a fairly stable condition in recent years.

- "70% of the Trunk Road Network has a residual life of more than 5 years (target: 70%). This compares with 71.8% in 2006, 73.5% in 2005, 73% in 2004, 74% in 2003 and 72.5% in 2002. In 2006–07 the target was reduced, commensurate with a reduction in the overall funding available for structural maintenance.

"All other roads are monitored using Coarse Visual Inspection (CVI) Surveys in accordance with the United Kingdom Pavement Management System, which is carried out over a 4-year period on all roads apart from motorways, trunk roads and non-trunk A roads. We have just commenced the second cycle of the CVI survey programme.

"The funding made available to us means that we can treat our local road network at around 46% of that recommended in National Good Practice Guidelines. Much of this delivery has been achieved against a backdrop of increased unit costs, partly reflecting higher than general inflation within the construction industry.”

The Notes to the Accounts set out Roads Service policy on valuing infrastructure assets.
"Renewals Accounting for Infrastructure Assets

"The application of Renewals Accounting for infrastructure assets means that conventional depreciation methodology is not applied. Instead, the Income and Expenditure Account is charged with the full value of the maintenance expenditure each year required to maintain the network in a “steady state”.

“This charge should approximate to a conventional depreciation charge. It is arrived at by charging to the Income and Expenditure Account the expenditure on maintaining the roads, and then either charging an additional amount if the condition of the road has deteriorated, or crediting an amount if the condition has improved.”

However the Notes to the Accounts also set out the difficulties the Roads Service has experienced with data from pavement condition surveys:

"8.3 Condition Surveys for the Road Network

"Renewals accounting as outlined in the statement of Accounting Policies 1.2 requires that an annual condition survey be undertaken to inform the decision on whether depreciation should be charged and whether any adjustment is necessary in respect of the condition of the network.

"On the motorway and trunk road network and the rest of the "A" class roads this condition survey is a machine based survey (Deflectograph) carried out as a three year rolling programme. On the non-trunk roads, the condition survey is a visual survey (Coarse Visual Inspection (CVI)) carried out as a rolling programme over two years on the "B" and "C" class roads and every four years on the "Unclassified" roads. An independent consulting engineer’s opinion is sought on the output from the survey and on the methodology used to calculate the condition assessment.

"The CVI is the only physical survey currently suitable for the majority of non-trunk roads. However CVI is a visual as opposed to a machine based survey and is therefore subjective and has limited repeatability. To overcome this problem the results of each year’s survey are aggregated; 2 years for “B” and “C” class roads and 4 years for unclassified roads. CVI surveys commenced in 2002/03 and previously produced results which show a condition improvement of the non-trunk network. These condition improvements are contrary to engineering expectations given that structural maintenance for the non-trunk network has been under funded during these years. However until a machine based survey is fully developed, tested and implemented post 2009/10 the CVI survey remains the only physical assessment of condition on this class of road, therefore we have continued to use these results.

"The survey results for the 2006/07 programme showed that an unreasonably large condition improvement had taken place despite a reduction in structural maintenance activity in the same period. To resolve this disparity the results for 2006/07 were replaced with an estimate of £26million improvement derived from the previous years’ survey results adjusted for the shortfall which occurred on structural maintenance funding in year. This estimate as opposed to the actual outturn has been aggregated with the 2007/08 results as part of the rolling programme and so will continue to influence the condition figure for the non-trunk roads shown in the accounts.

"The 2007/08 results however showed a significant reversal in the trend of condition improvement in that for the first time a condition reduction of £48million was shown. This is more in line with engineering expectations and is likely to be due to the impact of improved training of survey staff, enhanced quality assurance processes, and independent quality control of data collection. In these circumstances the trend towards survey results showing a condition reduction is likely to continue, despite the subjectivity and limited repeatability of the CVI survey process."
Therefore a UKPMS accredited system is required to produce the condition assessment of B, C and unclassified roads to support the Northern Ireland Road Service Annual Report and Accounts.
Appendix H  Development and further research

Three previous studies have identified research and development requirements for UKPMS:

1. The UKPMS Strategic Plan (2004)
2. The UKPMS Strategic Development Study (2006) and

Each of these studies has identified problems with the UKPMS, unfulfilled requirements of local authorities for various types of functionality, and opportunities to make better use of data and systems. Relatively few of the recommendations have been taken forward so far. There are a number of reasons for this:

- In general, local authorities do not have the funds to develop systems individually, and this is particularly the case for specialist software tools, such as pavement management systems.
- In general, system developers will only develop systems where there is a clear commercial market opportunity, and the market for pavement management systems within the UK is quite limited.
- National government requirements of pavement management systems are relatively limited, compared with local highway authority requirements.

The report on developing a commercial development environment (Ebert, 2006) concluded that the UKPMS developers would only consider new developments that are required from firm policy, translated into local authority requirements. They would not take the initiative by engaging in speculative developments. They would only develop on the basis of research converted into clear and firm policy and associated requirements.

The development projects identified below are based on the need to deliver the local authority requirements, articulated through the questionnaires and workshops carried out within this project. Whilst no local authority would have the resources to commission this work on its own account, the benefits to all local authorities would justify the investment in centrally funded development, and there would be considerable efficiencies if local authority requirements could be procured collectively on their behalf by national governments.

They have been designed to enable UKPMS to deliver the core requirements of local authorities.

H.1 Using GPS and GIS for network referencing

Within local authority road networks the traditional method of location referencing has been to acquire survey data in relation to a network defined in terms of the physical location of referencing points (section start and end points), and in relation to the distance travelled (lane and chainage) from those points. For traffic-speed surveys, such as SCANNER, these points are identified manually by the survey operator as they are passed, using a device such as a push button. Following the survey the collected data is delivered in relation to the pre-defined network, employing appropriate stretching or compression to force the data to fit the network. For surveys carried out at traffic-speed this approach can introduce significant error into the location referencing due to the difficulties in identifying the section change points when travelling at speed, thereby reducing the value of the data. If data are located inaccurately, subsequent analysis of changes from year to year becomes unreliable, as readings from different locations are being compared.

Since its introduction SCANNER has provided accurate measurements of geographical position, acquired using GPS. This data offers the potential for use as the primary
source of location referencing via the approach of geographically referenced networks. In this approach the local authority network definition is provided in terms of geographical (OSGR) co-ordinates, which are used in combination with the position data collected in the survey in order to fit the survey to the network. However, this approach is currently only applied to a small proportion of SCANNER survey data in the UK.

Difficulties in realising the benefits that may be brought by fitting survey data to a geographically referenced network arise from a number of sources, including concerns over the capability of the technology (e.g. in delivering data with a sufficient level of accuracy), and its use (in particular in surveys other than SCANNER), difficulties in establishing the geographically referenced network required by survey contractors, and the suitability of current highways engineering software systems (such as UKPMS) to accommodate this approach to network referencing.

However, in recent years there has been an expansion in the capability, practicality and affordability of technology that could be used for the collection of position data, and hence assist the implementation of geographically referenced surveys. This has been particularly embraced in the SCANNER surveys, and is beginning to be introduced in other surveys of the highway asset.

The objective of the project is to propose a methodology for the implementation of geographical referencing in surveys of the local road network. This methodology would feed the development of specifications for survey data collection and for highways engineering software systems (PMS).

There are three elements to the project:

- Identifying the technical issues and barriers relating to the use of geographical referencing in surveys of the local road network, and proposing how these could be resolved.
- Identifying the organisational and data handling issues and concerns that would affect the implementation of geographical referencing for surveys of the local road network, and proposing how these could be resolved.
- Hence proposing a functional specification for the application of geographical referencing in surveys of the local road network.

A requirement of the commission is the delivery of an appropriate methodology for the implementation of geographical referencing that will accommodate the delivery and processing of SCANNER data. However, there may be further future benefit in applying this approach to other survey data, and therefore other surveys should be considered, with a view to suggest a future direction for these surveys.

The final element of this commission will be to deliver a functional specification for the employment of geographical referencing for the location of survey data within local authorities. This would be used to provide technical input to the requirements for each type of survey considered (e.g. input to the SCANNER specification). The functional specification would also be used to provide technical input to the requirements for highways engineering software systems used for processing the data.

The results from this work are needed urgently for the new core technical specification.

### H.2 Input and output data file formats

One of the regular complaints about loading SCANNER data into UKPMS accredited systems concerns the data file format currently specified in UKPMS, the HMDIF (Highways Maintenance Data Interchange Format). The HMDIF was designed to load visual survey results, which consist of “observations” at intervals along the road, with a start and end position, and which may also have a defined lateral extent and intensity. Whereas SCANNER data consists of a number of measured or calculated values, all at
nominally the same position along the carriageway, which characterise an area of the pavement.

Visual survey data are “sparse” in the sense that, in the absence of an observation, there are no data, and this does not generate a line in the HMDIF. Therefore long lengths of the network do not generate any data to be loaded to UKPMS.

Whereas machine survey data are “dense” in the sense that values are reported at frequent and regular intervals whether or not they relate to a defective condition. In the HMDIF file, each of these individual values is characterised as a separate observation, leading to a large number of separate observations every 10m along the road. Each observation generates a couple of lines within the HMDIF, so that a machine survey produces a very long HMDIF file, compared to a visual survey.

An alternative way of presenting machine survey data would be as a series of values associated with each position along the road, so that each subsection could be reported as a single line in the file. In practice, reading a different file format into the database might be much quicker than reading an HMDIF file, although there would be a need to ensure the validity of the data being entered, so different validity checking rules might be required.

As well as specifying different approaches to input data file format, at present there are no specifications for output data file formats from UKPMS. Now that there are a number of industry standard file formats for data transfer between systems, such as financial information systems, geographic information systems, and business management systems, there would be an advantage in requiring future pavement management systems to demonstrate the capability to deliver results consistently using widely accepted standard industry formats. This would enable pavement management systems to be used in a modular fashion as part of wider information management systems within local authorities and their service providers.

The results from this work are needed urgently for the new technical specification.

H.3 Treatment selection, indicative scheme and programme building

Currently UKPMS has quite complex rules for indicative treatment selection and very limited facilities for indicative scheme building, using visual inspection data (and to a limited extent Deflectograph and SCRIM data). There are also rules for using a limited selection of SCANNER parameters to generate indicative treatments, but no rules for combining SCANNER survey data and visual inspection data in treatment selection and scheme building.

There are therefore several areas that require further research and development:

- To check the validity of the existing rules for developing indicative treatments from SCANNER data,
- To extend the rules to include other SCANNER parameters (in particular edge condition and surface deterioration measure by texture variability)
- To develop an approach and the rules for combining information from both machine and visual surveys.
- To develop a simple approach to indicative scheme building from either (or both) machine survey data and visual inspection data.

The rules for using SCANNER data should be relatively straightforward to develop and test, because of the quantity of SCANNER data that has been gathered since TTS was first introduced. In Scotland there have been regular surveys (for SRMCS) since 2002 and in England there have been regular surveys since 2004, gradually extending from the principal roads to all classified roads.
In principle, the method would be to gather large, representative samples of SCANNER survey data, develop algorithms or rules (from expertise and pre-existing knowledge) and test them against the data and in the light of local authority engineers’ experience, knowledge and opinions. This approach was used to develop and calibrate the original SCANNER RCI (McRobbie, 2007) and subsequently the revised SCANNER RCI (McRobbie et al 2007).

In practice, gathering suitable survey data for detailed investigation and checking data quality is far from straightforward and this part of the task must not be underestimated. The process of developing initial algorithms, checking them against survey data and conditions on the ground, refining them and rechecking them is essentially iterative and can also be time consuming. It also requires a considerable input from experienced engineers in local authorities and their service providers.

A simple, consistent approach to scheme building would be based on combining information on current pavement condition and indicative treatment requirements, to generate lengths, possibly spanning across sections, where schemes might be considered, or to assemble lengths where similar treatments may be required into programmes (such as edge treatment programmes or surface dressing programmes). This would not be a scheme or project level analysis (for which additional information would be required), but it would provide the basis for local authorities to plan and carry out more detailed analysis of potential schemes.

The results from this work are needed urgently for the new technical specification.

**H.4 Deterioration modelling and condition projection**

Understanding how the condition of an asset changes over time is an essential component of asset management, so that effective maintenance treatments can be applied in a timely manner.

The deterioration of local road carriageways is due to a combination of quite well understood processes, such as the effect of traffic loading on structural integrity and surface shape, the effect of excavation and reinstatement on structural integrity and surface shape, the effect of environmental exposure and time on binder strength and stiffness and hence on surface condition and structural integrity, the effect of water penetration on foundation stiffness and strength, the effect of traffic wear on surface roughness and skidding resistance.

The essential problem is that local road networks consist of pavements with a very diverse range of construction and present condition, subject to a very wide range of different loading and environmental conditions. Therefore it is practically difficult to predict how individual sections of the network will deteriorate over time, without very detailed information on many aspects of construction, past and present condition, loading and maintenance history and likely future conditions. Whereas, at a network level it may be possible to predict the overall deterioration through an ensemble averaging approach.

The requirement for condition projection is to be able to predict the future condition of the pavement or the network from readily available or affordable information. In the case of local road pavements this will mainly be records from standardised visual inspections (such as CVI and DVI) or from routine machine surveys. The future condition (and hence the future need for treatment) will be expressed in the same terms as the measurement of condition, be it visual inspection or machine survey.

Thus the research question is how to model the future condition of either an element of the network, or the whole of the network, from current and past measurements of condition, and to identify what other data would be required to enable reliable predictions over the short, medium and longer term (which might, for example, include construction type, traffic levels and maintenance history).
Data gathered over past years, including visual inspection and machine survey data, could be investigated to identify the basic rules for a simple mathematical modelling approach to deterioration modelling and condition projection that could then be used at either (or both) network level and section level. However the amount of information for reliable prediction may be quite different at the two levels.

This work would provide the foundation for whole life costing and life cycle analysis.

**H.5 Whole life costing and life cycle analysis**

Whole life costing and life cycle analysis requires information on current and future treatment requirements and costs, as well as the effect of changing pavement condition on the extent and type of maintenance.

Whilst the principles are relatively easy to set out, there is relatively little published information on the precise relationships to be used to predict how the deterioration of the pavement leads to the requirement for more extensive or more intensive maintenance treatment on local roads. In the first instance, it may be more effective to use a generalised function approach, rather than trying to define specific treatment steps.

There are a number of asset management systems that currently include whole life costing and life cycle analysis functionality, some designed for use on roads (but none specifically designed for use on local roads in the UK) and some designed for use on other types of infrastructure asset.

The approach would be to identify the benefits and constraints offered by existing systems and, from that to develop a simple basic approach that would enable local authorities to carry out whole life costing and life cycle analysis, with functionality enabling them to enter different assumptions (based on local knowledge and experience) and see how they would affect investment decisions.

Initially there would be two parallel approaches, using visual survey data, and using machine survey data, with the overall objective of developing a combined approach.

**H.6 Scenario modelling and optimisation**

From a local authority perspective, one of the most important functions of a pavement management system as a network level (strategic analysis) management tool is the ability to do “what if” modelling. Rather than working from condition measurements to develop treatment requirements, maintenance schemes and programmes, and budget requirements, to be able to work backwards from budget allocations to prioritise expenditure according to predefined criteria and calculate the effect on the overall condition of the network in future years (impairment of the asset), and the consequent requirements for investment in maintenance (investment optimisation).

Whilst there are a number of systems that purport to carry out scenario modelling and investment optimisation for infrastructure assets, this is perhaps the hardest and most testing application for a pavement management system. It requires the underlying information on deterioration modelling and condition projection, treatment selection and scheme building and whole life costing and life cycle analysis to be sufficiently detailed and reliable (robust) as an input to the scenario modelling functionality.

The approach would be to review the capabilities and limitations of currently available systems, and estimate the level of detail and reliability required from the input information to be able to make valid and useful predictions of the overall condition of the network in future years (impairment of the asset), and the consequent requirements for investment in maintenance (investment optimisation).
This would then define the performance requirements for the system, leading to a detailed technical specification for a basic level of scenario modelling and optimisation capability, based initially on using visual survey data, and using machine survey data, with the overall objective of developing a combined approach.
Appendix I  Current UKPMS functional requirements

This Appendix summarises the functional requirements in the current UKPMS specification. It is structured as follows:

- Location referencing: How data is located and identified in UKPMS
- Loading and maintaining data
  - Inputs: Loading data and the structure of the associated files
  - Types of data
  - Maintaining the network
- Processing
  - The Automatic Pass
  - The Road Condition Indicator
  - Parameters used when processing
- Reporting
  - National reports
  - UKPMS reports

Inevitably, for reasons of brevity, it does not provide a full specification of the requirements. For further information, reference should be made to the UKPMS technical documentation identified in each section.

I.1 Location referencing

Location referencing is the means by which the physical network is represented within the UKPMS database. A specific location in the network is identified using a combination of the following:

- Section Label: This identifies a physical length of the highway network.
- Feature: This is used to distinguish between functionally distinct parts of the highway, such as carriageway, footway, verge, kerb, etc.
- Chainage: The chainage provides the longitudinal position, measured in metres from the start of the section. In UKPMS each section has an associated direction (the reference direction) against which ‘forward’ and ‘reverse’ are defined, so that chainage runs from the ‘start’ to the ‘end’ of each section.
- XSP: The cross sectional position (XSP) describes the transverse location. UKPMS supports two different levels of granularity: Minimal and Full XSPs. Minimal XSPs allocate all carriageway items to the code ‘C’ and all off-carriageway items to either ‘L’ (left) or ‘R’ (right). The Full XSP approach distinguishes between different lanes of the carriageway and also between different off-carriageway transverse locations identified by the feature.

Taken together this information provides a precise location for the inventory and condition data collected. So for instance, the location of a defect (condition) might be described as lying on section A0001/123, on the left footway, from chainage 40 to 60.

The network referencing system upon which UKPMS is based is therefore a linear system, with limited (or no) connectivity between the sections. All processing, in fact, treats each section as an entirely separate entity and does not join treatments, for instance, across sections. Also note that lateral relationships between data (e.g. from lane to lane, or from the carriageway to the adjoining footway) are not considered during processing.
In addition to the location referencing approach described above, UKPMS also "optionally" uses nodes. These are used to denote the start and end of a section, and also may be used for junctions along the section. Nodes are required when machine data is collected as they are used to determine whether the data has been collected in a 'forward' direction or a 'reverse' direction. Therefore the option to not use nodes is only practical where machine survey data are not collected.

There is more information about location referencing in the UKPMS User Manual Volume 1 Chapter 4 and Volume 2 Chapter 4.

I.2 Loading and maintaining data

At the heart of UKPMS is a data repository which stores all the data used for UKPMS processing. These data are categorised as shown in Table 16.

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network</td>
<td>Sections, nodes and their attributes</td>
</tr>
<tr>
<td>Inventory</td>
<td>Location, width and construction for each feature</td>
</tr>
<tr>
<td>Condition</td>
<td>Condition surveys carried out</td>
</tr>
<tr>
<td>Works Record</td>
<td>Maintenance work carried out</td>
</tr>
<tr>
<td>Pavement Sample</td>
<td>Samples (i.e. cores)</td>
</tr>
<tr>
<td>Radar</td>
<td>Ground penetrating radar</td>
</tr>
</tbody>
</table>

Condition data are subdivided into a number of different survey types as listed in Table 17.

Before loading any of the other data types the network data for the relevant section(s) must be set up. This then allows various attributes of the incoming data to be checked against the network data. For instance, the incoming section length (which accompanies inventory and condition data) is checked against the section length already stored as part of the network data. This results in one of three actions:

- If the section length already stored on the database has the status 'estimated' then the incoming inventory or condition data overwrites the section length (and sets the length status to 'measured').
- Else, the incoming section length is checked with the existing section length.
  - If the two are sufficiently close (i.e. within tolerance) then the incoming data is shrunk or stretched (using prescribed rules) to match the existing section length
  - Else, the incoming data are rejected

Note that it is not required to set up the entire network initially – sections can be added to the network at any time or, conversely, deleted from the network. (Sections may be modified but this is essentially a process of adding and deleting along with automatic processes for allocating historical information).

<table>
<thead>
<tr>
<th>Survey Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVI</td>
<td>Coarse Visual Inspection</td>
</tr>
<tr>
<td>DVI</td>
<td>Detailed Visual Inspection</td>
</tr>
<tr>
<td>CRUT</td>
<td>Machine collected rutting (coarse)</td>
</tr>
<tr>
<td>DRUT</td>
<td>Machine collected rutting (detailed)</td>
</tr>
<tr>
<td>TTS</td>
<td>SCANNER or TTS data</td>
</tr>
<tr>
<td>DEF</td>
<td>Deflectograph</td>
</tr>
</tbody>
</table>
The standard method for loading data into UKPMS is via an HMDIF (Highway Maintenance Data Interchange Format) file. This file format has certain generic characteristics but the specifics vary from one type of data to another. Details of the specification are given in Technical Note 3 (for all type of data except SCANNER) and in the SCANNER HMDIF Specification (UKPMS document 71).

All UKPMS systems must be able to load data presented in an HMDIF file, but UKPMS systems may also allow data to be loaded using other formats; these may be based on either a widespread file format (Excel, XML etc) or a native format unique to an individual system. Only HMDIF files are included in the UKPMS functionality/comparability testing regime. Although the original logical design included functionality to export UKPMS data as an HMDIF file, this was not included in the requirements for comparability or in subsequent annual health checks.

In keeping with the spirit of comparability rather than compliance, each UKPMS system varies in its approach to validation. All UKPMS systems carry out basic validation of the data but the details of what constitutes valid and invalid data vary from system to system, as do the actions taken when invalid data is encountered. The fundamental philosophy behind UKPMS was originally that if an HMDIF file contains any invalid data whatsoever then the entire HMDIF file is rejected. However, particularly with the advent of SCANNER data which generates very large HMDIF files which may take a long time to load (potentially hours) other more innovative approaches have been developed by individual system developers.

UKPMS specifies information which must be stored for UKPMS purposes but individual systems are free to store additional information if they wish. This is typical of those systems for which UKPMS is merely part of a much larger database.

All UKPMS systems provide functions to allow data to be maintained (added, edited or deleted). The functionality offered and the interface by which it is delivered varies widely from system to system. However, certain basic functions are required by all systems. For instance, it must be possible to split a section (and all its associated data – inventory, condition etc) into two new sections and similarly it must be possible to merge two sections to form a single new section, to enable the network to be “edited” to allow for physical change.

There is no requirement in UKPMS to retain a history of changes to the network. Instead only the current network and inventory data is required. This is one of the major ways in which the original UKPMS logical design was simplified for comparability testing. Because condition data is stored as surveys, then all historical condition data is retained, and is maintained so that it can be used in conjunction with the current network.

I.3 Processing data

UKPMS contains two methods for processing data, the Automatic Pass and the Weighting Set approach, used for the Road Condition Indicator (RCI). The Automatic Pass has always been part of UKPMS but the Weighting Set approach was added more recently (via the 2005 Annual Health Check). Parameters are required to control how the processing is carried out; these are referred to as Rules & Parameters (aka Rule Sets) and Weighting Sets.

I.3.1 The Automatic Pass
The Automatic Pass provides a way of processing UKPMS condition data to provide condition indices and suggested treatments. The Automatic Pass in UKPMS has been designed to offer flexibility (in what data is processed and how it is processed) and consistency (via the accreditation process).

A full description of Automatic Pass processing is provided in the UKPMS User Manual Volume 4 and in various documents intended for system developers (such as the Tranche2 Implementation Guidelines and the Tranche3 Scope Definition and Implementation Guidelines). A brief summary of the process follows, based on the UKPMS User Manual, to explain the key characteristics of processing.

UKPMS can store many sets of processed results, in different Automatic Passes. Each is distinguished by an Automatic Pass identifier which is set up when that particular Automatic Pass is first run. This allows the results of different Automatic Passes (perhaps using different data) to be compared with each other.

The Automatic Pass may be explained using the following five stages:

- Setting up the Automatic Pass
- Calculating Condition Indices
- Treatment Selection
- Ranking
- Budgeting

### I.3.1.1 Setting up the Automatic Pass

When setting up the Automatic Pass the user is required to select what data is processed and to decide how that data is processed. In choosing what data to process the user can select parts of the network by filtering on Section Attributes (just unclassified roads, for instance) and can select particular surveys (by survey type, or by date for instance).

**Notes:**

The Automatic Pass can be used to process any type of survey data including SCANNER data.

The data to be processed consists of ‘defects’. These are observations or measurements of road condition characteristics (cracking, rutting etc.) collected during a survey and which differ from one survey type to another.

The options for data processing include:

- Selecting a set of Rules & Parameters,
- Choosing whether or not to use condition projection and
- Choosing how to merge the data.
- The user may also select which budget to use during the budgeting stage of the Automatic Pass.

**Notes:**

Some UKPMS systems only offer the current Rules & Parameters.

The condition projection algorithm currently used in UKPMS is not considered to be sufficiently robust and so this option should be used with caution.

If condition projection is used then the user may choose to use either condition ranking or economic ranking; without condition projection only condition ranking is available.

If condition projection is used then the user may choose the ‘network trends’ option which processes the data through a number of budget cycles.
The methods for merging data are discussed below in ‘Calculating Condition Indices’.

I.3.1.2 Calculating Condition Indices

The key output from the Automatic Pass processing is termed a ‘defect length’. This is a part of a section, feature and XSP which is notionally homogeneous and which therefore has uniform condition characteristics and treatment requirements. Defect lengths do not necessarily cover all of the section as generally they are only produced where some defects are present.

Note: There is a fundamental difference between visual survey data, in which defects are identified where they occur, and many lengths of carriageway are reported to be free of visible defects, and machine survey data, in which measured values are recorded at regular intervals, typically every 5m, 10m or 20m, and the whole of a surveyed length or surveyed network has reported values.

UKPMS can process condition data from many different sources, both visual and machine-based. In the Automatic Pass the visual survey defects recorded are combined together, using the Rules & Parameters and UKPMS processing algorithms, to form condition indices. A condition index (CI) is a measure of the condition of a particular aspect of the defect length. So, for example, the Edge CI provides information about the condition of the edge of the carriageway, and is calculated from observed defects which report the deterioration of the edge. Other condition indices include Structural, Wearing Course, Surface Properties and Overall.

Notes: There is a fundamental difference in the way visual survey data and machine survey data are treated. The classic UKPMS condition indices are based on visual survey data, whereas machine survey data are treated differently, and measured values are used directly to generate treatments, rather than being used to generate intermediate Condition Indices.

Certain condition indices only apply to particular types of pavement. For example, the Reflective Cracking CI is only calculated for Leanmix and Covered Concrete pavement types.

If condition projection has been used for the Automatic Pass then the condition data are projected from values at the date of collection to values at the date used for processing. This projection is in accordance with prescribed algorithms and is controlled by the Rules & Parameters.

There are four key steps which together create the defect lengths and calculate the condition indices. These steps are described briefly below.

Chopping to form Rating Lengths

In this step each section included in the Automatic Pass is chopped into small temporary subsections referred to as Rating Lengths. These rating lengths are produced so that the defectiveness and other attributes (e.g. feature hierarchy) are constant. The rating lengths are formed separately for each feature and XSP within the section.

Calculating Defect Ratings

Once the rating lengths have been established then each defect present on a rating length is assigned a rating value. The defect ratings are obtained from look up tables or curves in the Rules & Parameters. For CVI defects there is a different rating for each extent code. For other defects the rating is obtained from a rating curve which relates the quantity of the defect to a rating value.

The purpose of rating is to place all of the observed or measured defects from different surveys on a common scale so that they can be combined together subsequently to form condition indices.

Calculating Condition Indices
The rated defects are combined together to provide condition indices for each rating length.

For footways, cycletracks, verges and kerbs only one condition index is calculated, the Overall CI, whereas for carriageways a number of different condition indices are calculated depending on the pavement type (bituminous, covered concrete etc).

This process is governed by the Rules & Parameters, which determine which defects contribute to which condition index, and the precise way in which they are combined together. Note that observed or measured defects from a number of different types of survey can be combined together when calculating a condition index.

**Merging to form Defect Lengths**

The final stage in the calculation of condition indices is to merge the rating lengths to form defect lengths. This process is controlled by the parameters set up at the start of the Automatic Pass.

If the Automatic Pass has been set up to use a fixed interval merge, then a defect length is formed for the fixed interval. The condition indices for the defect length are calculated from the length weighted average of all the rating lengths which lie within the defect length.

If the pre-defined interval merge has been selected then the defect lengths will be formed in accordance with the chainages entered for each section.

If the variable merge has been selected then the defect lengths are formed based on a complex algorithm which joins together parts of each section where the condition is similar. There are two variations on this merge method; the standard variable merge and the enhanced variable merge.

Once the defect lengths have been merged, then the Overall CI is calculated for defect lengths on carriageways. The Overall CI is obtained by combining together the other condition indices for the defect length, and once again the Rules & Parameters determine exactly how this is done.

At the end of this stage of the Automatic Pass, defect lengths have been formed and condition indices have been calculated for each of these.

### I.3.1.3 Treatment Selection

The condition indices are used, together with other information about the defect length (e.g. pavement and hierarchy), to provide a suggested treatment for the defect length. The Rules & Parameters compare the condition index values for the defect length with intervention levels in order to determine the most appropriate treatment. These intervention levels vary depending on the feature hierarchy for the defect length. Other factors are also taken into account:

- whether the defect length has a step level set (which would prevent the carriageway being raised);
- whether the off-carriageway is tied to the carriageway (which leads to a requirement for associated works if the suggested treatment raises the carriageway);
- or whether there is SCRIM or GripTester failure. (denoting insufficient skidding resistance)

In some situations multiple treatments may be suggested, for example edge work in conjunction with surface treatment.

In addition to suggesting a treatment, the Automatic Pass calculates the quantity of treatment required and the cost (based on a table of unit costs for each treatment). These quantities and costs are necessarily broad-brush, since they are based on typical
unit costs for that treatment, rather than the particular circumstances pertinent to the site in question. The unit costs are supplied by the user of the UKPMS system, and will therefore differ from one authority to another.

### I.3.1.4 Ranking

The Automatic Pass provides two types of ranking of defect lengths.

**Condition Ranking**

This gives a simple ‘worst first’ list and is controlled by a table in the Rules & Parameters, which assigns a ranking based on the treatment, the feature hierarchy and the Overall CI.

**Economic Ranking**

This compares the cost of treatment in the current year with the cost of the projected treatment in one year’s time and uses this to assign a priority to the work. The factors used in this calculation are obtained from the Rules & Parameters.

### I.3.1.5 Budgeting

UKPMS Budgets are set up by the user of the system; each budget is made up of a number of budget headings, and each of these budget headings has a definition and a monetary limit. So for example, the user might set up a budget called ‘2008 Budget’ which has three budget headings:

- ‘Edge works’,
- ‘Surface improvements’ and
- ‘Resurfacing’.

The definitions for each of these budget headings would be set up to assign defect lengths according to treatment.

Any budgets set up are available to any Automatic Pass and the particular budget(s) used for an Automatic Pass are selected by the user when setting up the Automatic Pass.

During the budgeting process the defect lengths are assigned to one of the budget headings, or to the ‘Unassigned’ heading. The budget heading is then ‘top-sliced’ to fund any defect lengths which require treatment for SCRIM or GripTester failure. After this, all remaining defect lengths are sorted into descending ranking order within each budget heading, and then designated as ‘funded’ or ‘not funded’ depending on whether the cumulative treatment costs exceed the limit for that budget heading.

### I.3.2 The Weighting set approach used for the Road Condition Indicator

The Weighting Set approach provides an alternative method for processing data. It is a much simpler method than the Automatic Pass, but it is not as powerful or flexible. A full description of the process is given in SCANNER Road Condition Indicator Implementation Guidelines (UKPMS document 070v0104). What follows here is a brief summary of the process based on that document.

UKPMS can store many sets of RCI results. Each is distinguished by an identifier which is set up when that particular weighting set is first run. This allows the results of different RCI runs (perhaps using different data) to be compared with each other.

The Weighting Set approach was primarily designed for use with SCANNER data. However, it has been set up so that it could readily be extended for use with other types of data if required. The key requirement is that the data processed by this method must be available on consistent subsections. So if, for instance, rutting had been collected on a section on the following subsections 0-5, 5-15, 15-25 etc and cracking had been
collected on 0-10, 10-20, 20-30 etc, this data would not be eligible for processing using the Weighting Set approach; whereas it could of course be processed by the Automatic Pass.

The Weighting Set approach may be explained using the following four stages:

- Setting up the Weighting Set Run
- Weighting SCANNER Values for the RCI
- Combining the Weighting Values
- Producing Summary Results

I.3.2.1 Setting up the Weighting Set Run
When setting up Weighting Set run the user simply selects what data (sections and surveys) to process. Although UKPMS systems must offer the ability to select sections (e.g. the principal network) and surveys (e.g. by survey date), there is some flexibility as to precisely what functionality each UKPMS system offers and how that functionality is delivered.

The user also selects which Weighting Set to use for the run. The Weighting Set is a set of parameters which control some of the details of the processing. More information is given below in the section on Processing Parameters.

I.3.2.2 Weighting SCANNER Values for the RCI
Each SCANNER value is given a score in the range 0 to 100. The scores are obtained from weighting curves provided by the Weighting Set for each SCANNER measured parameter. The weighting curves may differ depending on various section attributes (road hierarchy, DfT classification etc). The weighted value is further adjusted by multiplicative factors to reflect the importance and reliability of each SCANNER measured parameter.

I.3.2.3 Combining the Weighted Values
The weighted values are grouped into families (cracking, rutting etc) and for each family the highest value is taken as a representative value for that family. The values for all families are then combined together to give a single numerical value for each subsection. The Weighting Set determines to which family each SCANNER measured parameter belongs and also how the subsection value is calculated (as the sum, average, maximum or weighted average of the family values).

I.3.2.4 Producing Summary Results
The final step is to produce summary results for groups of subsections. This process is also controlled by the Weighting Set; this determines whether the summary is produced using the ‘Bin’ approach or the ‘Probability’ approach.

- The Bin approach divides the subsections into bins and reports the length of subsections in each bin as a percentage of the total length of subsections in that group. The number of bins and the thresholds between the bins are controlled by the Weighting Set. The most familiar example of this is the ‘Red’, ‘Amber’ and ‘Green’ bins currently used for national reporting.

- The Probability approach calculates the summary result using a proportion of the subsection length. Typically, this notional length is based on the length of all the subsections above an upper threshold plus a proportion of those between the upper and lower thresholds; the proportion will be based on a linear function which interpolates between the lower threshold and the upper threshold. Each subsection between the thresholds will therefore contribute according to where it...
lies within the range. Note that, in the general case, there may be more than two thresholds.

### I.3.3 Processing Parameters

The precise way in which many of the algorithms are applied in UKPMS is controlled by parameters. For instance, there is a list of defect codes which is used when data is loaded to determine whether the defect code for the incoming data is valid (i.e. recognised by UKPMS) or not. These parameters are stored in two separate sets of tables:

- The Rules & Parameters
- The Weighting Set

#### I.3.3.1 Rules & Parameters

The Rules & Parameters contain two different types of tables;

- those which contain parameters to control processing, and
- empty tables which convey information about the underlying data model for UKPMS.

The parameter tables are listed below in Table 18:

<table>
<thead>
<tr>
<th>Rules &amp; Parameter table name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents at Works</td>
<td>Used for Economic ranking</td>
</tr>
<tr>
<td>Age Weighting</td>
<td>Used during condition projection</td>
</tr>
<tr>
<td>Analysis Period</td>
<td>Used for Economic ranking</td>
</tr>
<tr>
<td>Attributes Used in Projection Relationship</td>
<td>Used during condition projection</td>
</tr>
<tr>
<td>Basic Defect</td>
<td>Lists the basic defects</td>
</tr>
<tr>
<td>Closure Due to Works</td>
<td>Used for Economic ranking</td>
</tr>
<tr>
<td>Closure Type</td>
<td>Lists the closure types</td>
</tr>
<tr>
<td>Condition Index and Pavement Type for Feature</td>
<td>Lists the condition indices for each combination of feature and pavement type</td>
</tr>
<tr>
<td>Condition Index Type</td>
<td>Lists the condition indices</td>
</tr>
<tr>
<td>Consequent Cost Percentage</td>
<td>Used for Economic ranking</td>
</tr>
<tr>
<td>Construction Type</td>
<td>Lists the construction types</td>
</tr>
<tr>
<td>Cost of Accidents At Works</td>
<td>Used for Economic ranking</td>
</tr>
<tr>
<td>Cross Sectional Position</td>
<td>Lists the cross sectional positions</td>
</tr>
<tr>
<td>Default Feature Widths</td>
<td>Gives a default width for each feature</td>
</tr>
<tr>
<td>Defect</td>
<td>Lists the defects recognised by UKPMS</td>
</tr>
<tr>
<td>Defect Base Date Group</td>
<td>Lists the defect base date groups</td>
</tr>
<tr>
<td>Defect Category</td>
<td>Lists the defect categories</td>
</tr>
<tr>
<td>Defect Composition</td>
<td>Controls how composite defects are formed from collected defects</td>
</tr>
<tr>
<td>Defect Length Overall CI Calculation</td>
<td>Together these determine how the Overall CI is calculated</td>
</tr>
<tr>
<td>Defect Length Overall CI Calculation Detail</td>
<td></td>
</tr>
<tr>
<td>Defect Parameter</td>
<td>Lists the parameters for each survey type</td>
</tr>
<tr>
<td>Defect Parameter Option</td>
<td>Lists the option codes for each defect parameter</td>
</tr>
<tr>
<td>Defect Transformation</td>
<td>Controls how defects are refined depending on inventory construction type</td>
</tr>
<tr>
<td>Defectiveness Calculation</td>
<td>Lists the defectiveness calculation codes</td>
</tr>
<tr>
<td>Delay Due to Works</td>
<td>Used for Economic ranking</td>
</tr>
<tr>
<td>Rules &amp; Parameter table name</td>
<td>Purpose</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Diversion Quality</td>
<td>Lists the diversion quality codes</td>
</tr>
<tr>
<td>DOT Classification</td>
<td>Lists the DfT classification codes</td>
</tr>
<tr>
<td>Drainage Status</td>
<td>Lists the drainage status codes</td>
</tr>
<tr>
<td>Duration of Works</td>
<td>Used for Economic ranking</td>
</tr>
<tr>
<td>Effect of Treatment</td>
<td>Gives the effect of the treatment on pavement life</td>
</tr>
<tr>
<td>Feature</td>
<td>Lists the features used by UKPMS</td>
</tr>
<tr>
<td>Feature Attribute</td>
<td>Lists the attributes for each feature</td>
</tr>
<tr>
<td>Feature Attribute Option Code</td>
<td>Lists the option codes for each feature attribute</td>
</tr>
<tr>
<td>Feature Hierarchy</td>
<td>Lists valid hierarchies for each feature</td>
</tr>
<tr>
<td>Footway Opening Frequency</td>
<td>Lists the footway opening frequency codes</td>
</tr>
<tr>
<td>Footway Status</td>
<td>Lists the footway opening codes</td>
</tr>
<tr>
<td>Generic Treatment</td>
<td>Lists the generic treatments produced by UKPMS</td>
</tr>
<tr>
<td>Intervention Levels for Hierarchy</td>
<td>Gives the intervention level values for each feature hierarchy</td>
</tr>
<tr>
<td>Method 1 Rating Coordinate</td>
<td>Gives defect rating curves</td>
</tr>
<tr>
<td>Method 2 Rating Lookup</td>
<td>Gives defect rating lookups (typically for CVI data)</td>
</tr>
<tr>
<td>Node Type</td>
<td>Lists the types of node recognised by UKPMS</td>
</tr>
<tr>
<td>Pavement Type</td>
<td>Lists the types of pavement recognised by UKPMS</td>
</tr>
<tr>
<td>Pavement Type after Treatment</td>
<td>Gives the pavement type after a treatment</td>
</tr>
<tr>
<td>Projection Curve</td>
<td>Lists the types of projection curve</td>
</tr>
<tr>
<td>Projection Curve Point</td>
<td>Gives the standard projection curve points</td>
</tr>
<tr>
<td>Projection Parameters</td>
<td>Used for condition projection</td>
</tr>
<tr>
<td>Projection Relationship</td>
<td>Used for condition projection</td>
</tr>
<tr>
<td>Ranking Curve</td>
<td>Gives the condition ranking curves</td>
</tr>
<tr>
<td>Rating Length CI Calculation</td>
<td>Together these determine how the condition indices are calculated</td>
</tr>
<tr>
<td>Rating Length CI Calculation Detail</td>
<td></td>
</tr>
<tr>
<td>Rating Length Pavement Type for Construction Type</td>
<td>Links pavement type and construction type</td>
</tr>
<tr>
<td>Road Hierarchy</td>
<td>Lists the road hierarchies recognised by UKPMS</td>
</tr>
<tr>
<td>Road Type</td>
<td>Lists the road types recognised by UKPMS</td>
</tr>
<tr>
<td>Routine Maintenance Cost</td>
<td>Used for economic ranking</td>
</tr>
<tr>
<td>Rule Set</td>
<td>Lists the rule sets in the database</td>
</tr>
<tr>
<td>Speed Limit</td>
<td>Lists the speed limit codes recognised by UKPMS</td>
</tr>
<tr>
<td>Surface Type</td>
<td>Lists the surface types recognised by UKPMS</td>
</tr>
<tr>
<td>Survey Type</td>
<td>Lists the survey types recognised by UKPMS</td>
</tr>
<tr>
<td>Traffic Level</td>
<td>Lists the traffic levels</td>
</tr>
<tr>
<td>Treatment</td>
<td>Lists the specific treatments produced by UKPMS</td>
</tr>
<tr>
<td>Treatment Composition</td>
<td>Groups together generic treatment, treatment and treatment type to give a complete treatment</td>
</tr>
<tr>
<td>Treatment for Functional Defect</td>
<td>Gives treatments for functional defects (SCRIM or GripTester)</td>
</tr>
<tr>
<td>Treatment Selection Intervention Levels</td>
<td>Lists the intervention levels</td>
</tr>
<tr>
<td>Rules &amp; Parameter table name</td>
<td>Purpose</td>
</tr>
<tr>
<td>------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Treatment Selection Rule Cell</td>
<td>Together these determine which treatment rule line applies</td>
</tr>
<tr>
<td>Treatment Selection Rule Line</td>
<td></td>
</tr>
<tr>
<td>Treatment Type</td>
<td>Lists the treatment types produced by UKPMS</td>
</tr>
<tr>
<td>Treatments for Rule Line</td>
<td>This gives the treatment corresponding to the treatment rule line.</td>
</tr>
<tr>
<td>Valid Defect</td>
<td>Lists the defects which are valid for a survey type</td>
</tr>
<tr>
<td>Valid Defect Parameter</td>
<td>Lists the parameter(s) for each valid defect</td>
</tr>
<tr>
<td>Valid Defect Parameter Option</td>
<td>Lists the option codes for each valid defect parameter</td>
</tr>
<tr>
<td>Valid Defect Parameter Option Combination</td>
<td>Assigns a VDPO code to each valid defect parameter option combination</td>
</tr>
<tr>
<td>Value of Time</td>
<td>Used for economic ranking</td>
</tr>
<tr>
<td>Vehicular Traffic</td>
<td>Lists the valid vehicular traffic codes</td>
</tr>
<tr>
<td>XSP for Feature</td>
<td>Lists the valid XSP codes for each feature</td>
</tr>
<tr>
<td>XSP Mapping</td>
<td>Provides a mapping between Full and Minimal XSPs</td>
</tr>
<tr>
<td>XSP Reversal</td>
<td>Lists the XSP code for each XSP when reversed</td>
</tr>
</tbody>
</table>

The data model tables are listed below in Table 19.

**Table 19 UKPMS Rules & Parameters – Data Model tables**

<table>
<thead>
<tr>
<th>Rules &amp; Parameter table name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUTOMATIC PASS</td>
<td></td>
</tr>
<tr>
<td>BUDGET</td>
<td></td>
</tr>
<tr>
<td>BUDGET HEAD</td>
<td></td>
</tr>
<tr>
<td>BUDGET HEAD INSTANCE</td>
<td></td>
</tr>
<tr>
<td>BUDGET INSTANCE</td>
<td></td>
</tr>
<tr>
<td>BUDGET INSTANCE IN AUTOMATIC PASS</td>
<td></td>
</tr>
<tr>
<td>DEFECT LENGTH</td>
<td></td>
</tr>
<tr>
<td>DEFECT LENGTH CONDITION INDEX</td>
<td></td>
</tr>
<tr>
<td>DEFECT LENGTH FUNCTIONAL DEFECT</td>
<td></td>
</tr>
<tr>
<td>DISTRICT</td>
<td></td>
</tr>
<tr>
<td>ESTIMATING TREATMENT UNIT COSTS</td>
<td></td>
</tr>
<tr>
<td>FUNCTIONAL THRESHOLD</td>
<td></td>
</tr>
<tr>
<td>FUNDING ORGANISATION</td>
<td></td>
</tr>
<tr>
<td>INVENTORY ITEM</td>
<td></td>
</tr>
<tr>
<td>ITEM ATTRIBUTE</td>
<td></td>
</tr>
<tr>
<td>NODE</td>
<td></td>
</tr>
<tr>
<td>NODE WITHIN SECTION</td>
<td></td>
</tr>
<tr>
<td>OBSERVATION</td>
<td></td>
</tr>
<tr>
<td>OBSERVATION VALUE</td>
<td></td>
</tr>
<tr>
<td>PAVEMENT SAMPLE</td>
<td></td>
</tr>
<tr>
<td>PAVEMENT SAMPLE LAYER</td>
<td></td>
</tr>
<tr>
<td>PROJECTION BASE DATE</td>
<td></td>
</tr>
<tr>
<td>SECTION</td>
<td></td>
</tr>
<tr>
<td>SECTION WITHIN SURVEY</td>
<td></td>
</tr>
<tr>
<td>SITE CATEGORY</td>
<td></td>
</tr>
<tr>
<td>SURVEY</td>
<td></td>
</tr>
<tr>
<td>WORKS RECORD</td>
<td>These are empty tables. They convey information about the underlying data model for UKPMS</td>
</tr>
</tbody>
</table>
Each UKPMS system developer has flexibility in how they set up their UKPMS data model, and in the data structures used when loading, storing and processing the data. Each therefore incorporates the Rules & Parameters into their system in accordance with their own data structure. Because of this, UKPMS users cannot plug the Rules & Parameters directly into some UKPMS systems themselves; they require their system developer to install them, often via a system upgrade.

I.3.3.2 Weighting Set

The processing of data for the SCANNER Road Condition Indicator is controlled by a simple smaller set of parameters called the Weighting Set. This contains the tables listed in Table 20.

<table>
<thead>
<tr>
<th>Weighting Set table name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>DefectConfidence</td>
<td>Gives the reliability and importance factors</td>
</tr>
<tr>
<td>DefectFamily</td>
<td>Gives the family for each defect</td>
</tr>
<tr>
<td>DefectWeightings</td>
<td>Gives the weighting curve for each defect</td>
</tr>
<tr>
<td>Family</td>
<td>Lists the valid families</td>
</tr>
<tr>
<td>Thresholds</td>
<td>Gives the thresholds for each bin or for the probability method</td>
</tr>
<tr>
<td>Weighted Average</td>
<td>Only used if the family values are combined using a weighted average</td>
</tr>
<tr>
<td>WeightingCurveList</td>
<td>Lists the weighting curves</td>
</tr>
<tr>
<td>WeightingCurvePoints</td>
<td>Gives the curve points for each weighting curve</td>
</tr>
<tr>
<td>WeightingSetList</td>
<td>Lists the weighting sets in the database</td>
</tr>
</tbody>
</table>

Each Weighting Set is associated with one or more sets of Rules & Parameters. This is to ensure that the defects, survey types and any section attributes used in the Weighting Set are valid. The link is provided by a simple WSRPlink database containing a single WeightingRuleSetLink table.

UKPMS systems are required to be able to store more than one Weighting Set and they are also required to provide functions so that their users can ‘plug-in’ new weighting sets directly rather than having them installed by the system developer. The Weighting Sets are made available on the UKPMS website (as Access database, Excel spreadsheet and CSV files). They are either loaded (by the user) into the UKPMS system or else the UKPMS system uses a link to the Weighting Set.

I.4 Reporting

The original UKPMS comparability tests were generally not prescriptive about report contents or layout. However, for many aspects of the tests, reports or screen shots were required as evidence, for example to show that data had been loaded correctly and to verify that calculations had been performed correctly. This inevitably led to a need for various listings (such as a section listing etc.). Over and above this pragmatic general requirement some specific reports were required for the comparability tests. These were:

- CVI Inconsistency report
- DVI Inconsistency report
Defect Length report

Budget reports:
- Summary analysis by budget head
- Detailed analysis by budget head
- Budget analysis by section

Audit Trail report
Monitor Network Condition report
Project Network Trends report

Since then, various reports have been added to UKPMS through the Annual Health Check process and are listed below:

- National Indicator (previously BVPI) reports for England
- SRMCS PI report for Scotland
- THS/010 reports for Wales
- PI reports for Northern Ireland
- Reports to support the SCANNER Road Condition Indicator
  - Main report
  - Detailed results
  - Coverage report
  - Weighting Set reports
- Defect Length sorted by Condition Index report

Note that the national performance reports for England, Scotland, Wales and Northern Ireland are each optional modules of the Annual Health Check. Systems only need submit reports for those countries for which they wish to be accredited. To date, all five UKPMS systems have so far opted to be accredited for all four countries.

The Annual Health Check also requires developers to produce defect length results in a standard spreadsheet format using a prescribed column layout. This report is simply part of the test mechanism, to facilitate checking of the results. System developers are not required to make this particular report available to their users, but their system is required to offer equivalent functionality for their users (i.e. the capability to see this information but not necessarily using precisely the same layout as required for test purposes).
Appendix J  Developing the new functional specification

J.1 General principles
There are a number of general principles governing the design of the specification and how it is implemented.

- The specification must be flexible enough to evolve as requirements change. An obvious example is the introduction of requirements connected with asset valuation.
- The specification must allow for radical change to UKPMS but within a framework which recognises the current position and evolves from that point.
- The specification must encourage (and not stifle) innovative functionality which is unique to an individual system and which forms part of their commercial advantage. Such functionality may well be more advanced than that already within UKPMS.
- The specification must facilitate accreditation of new UKPMS systems where these are able to provide the required functionality. At present new systems are inhibited from seeking accreditation because they are required to meet the original comparability tests plus the annual health checks. Much of the original functionality, as tested within the comparability tests, has subsequently evolved or even been superseded. Furthermore, the necessary documentation for comparability testing is not readily available.
- The specification must be set up in such a way that it is manageable to maintain both the specification itself and the accreditation required. This is a major failing of the existing specification for UKPMS which, due to the prohibitive expense of maintaining the original specification documents, has evolved as a series of stand-alone documents (Technical Notes, Advice Notes, User Guide) which update, clarify and refine the original specification, but which do not provide a complete replacement for the original specification.
- The ethos should be to describe the requirements as outputs wherever possible rather than be too prescriptive. There may be some exceptions to this philosophy (e.g. the Road Condition Indicator algorithm) where the simplest way of explaining the output required is to describe how the calculation is performed.

J.2 How the new approach would work
It has been shown that UKPMS requires fundamental change (as opposed to a few minor adjustments) in order to meet the future business requirements of the local road network owners. However, the problem with instigating a complete overhaul is that it is high risk and very expensive. Therefore, we propose a framework with the potential to deliver far-reaching changes but in a controlled and low-risk way. Our method for achieving this is to view the specification in a more modular way. This would place UKPMS on a new footing and would ultimately permit major changes, but within a well-controlled, affordable and low-risk context.

A more modular framework would provide a way of managing the transition of UKPMS from the existing specification to a new specification able to deliver the current requirements. This new specification for UKPMS using a modular design would then provide a sound platform on which future development of UKPMS can be based. It would provide the flexibility to accommodate future requirements – as yet unknown and unspecified. In summary, it would enable UKPMS to evolve into a system which is simple to maintain, flexible and adaptable.
The more modular approach does not remove the requirement for a sustained and committed approach to funding. Adequate funding will be required to transfer UKPMS over to the new modular framework and to re-cast the supporting materials and accreditation regime accordingly. This stage must be achieved as quickly as possible and without loss of the momentum gained under the current PCIS support project.

**J.2.1 The Modular Framework**

The modular framework would comprise a list of modules in the specification, referred to as the **core modules**. Each of these would be defined by a specification and be verified via accreditation. Alongside and supporting the core modules, UKPMS would require parameters to drive the processes and these **parameter modules** would also be organised using the modular approach.

In addition to the specification and accreditation regime, the modular framework would accommodate **guidance modules**. These would provide a way to offer good practice guidance on a range of topics and a way of disseminating research information. The guidance modules would not be subject to accreditation and therefore would allow innovation by system developers and others who may wish to develop tools for use with UKPMS. Some topics which are introduced to UKPMS as guidance could, in due course, form the basis for new specifications (i.e. the module would transfer over to the specification if required for consistency and comparability to meet new national standards).

This modular framework is illustrated in Figure 11. This gives the components of the modular framework, showing the parameters underpinning the framework and indicating that there is the potential to transfer modules between the ‘core’ and ‘guidance’.

![Figure 11: Modular Framework – Components](image)

The list of core modules would grow or shrink as UKPMS requirements change. Individual developers would be free to choose which modules to include in their system. For example, an individual system might be accredited to produce the performance indicators for Northern Ireland but not to produce the LAA National Indicators for England.

There will be relationships and dependencies between some of the modules. For example, the LAA National Indicators for England, the performance indicators THS/010 for Wales and the SRMCS PI for Scotland all rely on the SCANNER road condition indicator processing algorithm.

**J.3 The specification**
The functional specification has been provided in Appendix K, as a stand-alone document that can be extracted and used independently of the main body of the report. Here we summarise some of the characteristics of the proposed specification.

### J.3.1 UKPMS Catalogue

The UKPMS catalogue lies at the heart of the new system. It pulls together and controls all the various documents and files which collectively describe UKPMS. Defining the catalogue in detail should form one of the earliest tasks of implementing the new specification for UKPMS. However, the following list gives a flavour of how the catalogue would operate and the type of information it would contain for each module.

- Module version: A version number for the module.
- Module change control file: Details of changes to the module from one version to the next.
- Module type: Distinguishing between core modules, parameter modules and guidance modules. Some of the information provided in the catalogue would only relate to a particular module type.
- Module ownership: Who is responsible for updating and maintaining the module.
- Module files: Listing the files (documents, spreadsheets, databases etc.) which belong to the module. For core modules it may be helpful to subdivide this list into specification and accreditation files.
- Module relationships: Listing relationships between this module and others which depend on it, and between this module and others on which it depends.

An example to illustrate the type of information contained in the UKPMS catalogue is given in Table 21 for the LAA National Indicators for England (NI168 and NI169).

**Table 21: Illustrative example of a PMS catalogue entry**

<table>
<thead>
<tr>
<th>Reference:</th>
<th>M123</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version:</td>
<td>2.08</td>
</tr>
<tr>
<td>Change Control file:</td>
<td>ChangesC123v208.doc</td>
</tr>
<tr>
<td>Description:</td>
<td>NI168 and NI169 for 2009/10</td>
</tr>
<tr>
<td>Type:</td>
<td>Core</td>
</tr>
<tr>
<td>Ownership:</td>
<td>PCIS (for DfT)</td>
</tr>
<tr>
<td>Files:</td>
<td></td>
</tr>
<tr>
<td>Specification:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TN44_England_NI168_2009_10_v0102</td>
</tr>
<tr>
<td></td>
<td>TN45_England_NI169_2009_10_v0102</td>
</tr>
<tr>
<td>Accreditation:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2009AHC_Req_M123_v1_02</td>
</tr>
<tr>
<td></td>
<td>2009AHC_Instructions_M123_v1_01</td>
</tr>
<tr>
<td></td>
<td>2009AHC_TestData_M123_v1_01</td>
</tr>
<tr>
<td></td>
<td>2009AHC_Results_M123_v1_01</td>
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<tr>
<td></td>
<td>2009AHC_Checklist_M123_v1_01</td>
</tr>
</tbody>
</table>
The example given in Table 21 is fictitious; the specification files listed are reminiscent of those used to describe NI168 and NI169 in 2008/09 and the accreditation files listed imply that accreditation might be based on parts of the existing annual health check.

For practical reasons the catalogue would probably be implemented as a simple database, but with reports and queries to allow it to be used and interrogated in a straightforward fashion. The catalogue could if required also maintain information about those systems which are accredited for that module.

### J.3.2 Core Modules

The core modules would consist of **specifications** and **accreditation**. The core modules would form a flexible and adaptable list of requirements for UKPMS; able to grow or shrink as UKPMS evolves in the future. Modules could change status from core to guidance as requirements change, and new modules could also be added directly to the core if required.

The specification would describe the requirements for a particular core module; these may vary in level of detail depending of the purpose of that module. Wherever appropriate the specification would be expressed as an output requirement rather than being prescriptive about processing details.

PMS systems used in the UK would not be compelled to adhere to all the specifications but it would be clear, via the accreditation regime, when they have or have not worked to the specification for a particular module. Note that working outside the specification does not necessarily imply 'sub-standard'; it might be a sign of an innovative, improved approach.

This flexibility would also allow UKPMS to retain specifications for some modules for historical reasons. An obvious example is HRM data. When local authorities were asked (via the UKPMS Steering Group in 2005) if they wished to drop HRM data from UKPMS they were reluctant to do so as a few authorities still retained this type of data. Using the new modular approach local authorities that wished to continue to keep and use HRM data could ensure that the UKPMS system they use is able to store HRM data but other UKPMS systems would not be burdened unnecessarily by this requirement.

There may be cases where the specification is considered ‘self-policing’. Perhaps a candidate for this would be when exchanging data between systems (e.g. loading survey data or exporting data from the PMS). In these circumstances the specification would not necessarily form part of an accreditation scheme but would be used for reference when there are difficulties.

An initial list of core modules is given below in Table 22. This list also shows the likely impact on existing UKPMS systems based on the functionality tested by the 2008 Annual Health Check. More detailed information is given about the core modules in Appendix J. [Note that BV224b and BV187 are included in this list as some authorities may wish to produce these for local purposes even though they are no longer a national requirement.]

<table>
<thead>
<tr>
<th>Core Module</th>
<th>Notes</th>
<th>Offered by existing UKPMS systems?</th>
</tr>
</thead>
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**Relationships:**

<table>
<thead>
<tr>
<th>M459 (Road Condition Indicator)</th>
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<tbody>
<tr>
<td>M223, M512 (various parameter modules)</td>
</tr>
<tr>
<td>Feature</td>
</tr>
<tr>
<td>-------------------------</td>
</tr>
<tr>
<td>Network referencing</td>
</tr>
<tr>
<td>Location referencing</td>
</tr>
<tr>
<td>Section attributes</td>
</tr>
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<td>Importing data</td>
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<tr>
<td>Exporting data</td>
</tr>
<tr>
<td>RCI processing</td>
</tr>
<tr>
<td>Automatic Pass</td>
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<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>NI168 &amp; NI169</td>
</tr>
<tr>
<td>SRMCS PI</td>
</tr>
<tr>
<td>THS/010</td>
</tr>
<tr>
<td>PI (Northern Ireland)</td>
</tr>
<tr>
<td>Asset valuation/Financial information</td>
</tr>
<tr>
<td>BV224b</td>
</tr>
<tr>
<td>BV187</td>
</tr>
</tbody>
</table>

Some of the modules that will require additional technical development work are listed below.

- **Data management:**
  - Network referencing & location referencing.
  - Data interchange file format for importing and exporting UKPMS data.
  - Archiving data.
  - Implementing new survey types.
- **Processing algorithms:**
  - Schemes and programmes of work.
  - Deterioration modelling and/or condition projection.
  - Life cycle planning.
  - Scenario modelling (i.e. ‘what-if modelling’).
  - Financial information to support asset management.

In Figure 12 the prerequisites for the module for NI168 & NI169 are sketched out, to illustrate how relationships may exist between modules.
J.3.3 Parameter Modules

Many existing UKPMS processes are controlled by parameters. These provide flexibility by allowing the same processes to be used in different ways. They also provide ‘future-proofing’ so that data and algorithms can be configured differently in the future. An example is the Weighting Set used for RCI processing.

Currently UKPMS has a large Rule Set plus a much more compact Weighting Set. These are described more fully in Appendix I. There would be advantages in stripping these back to essentials and dividing them up into modules so that it is possible for users of UKPMS systems to:

- See the dependencies and links between the different parameters more easily.
- Understand the parameters and their role in loading, processing and reporting.
- Customise some of the parameters for local use in an easy, transparent way without compromising those parameters used as the basis for national comparisons.

An additional benefit is that a modular approach will also allow the parameters to be maintained and updated more easily.

Note that some parameter modules will be fundamental to the whole system (e.g. the list of valid defects), while others will only be used by an individual core module (e.g. the Weighting Set used by RCI processing).

An indicative breakdown of the parameters is given in Appendix K. This part of the transfer of UKPMS from the existing system to the proposed new system is not trivial. It will require more detailed technical work and is likely to have an impact on the existing UKPMS systems. However, it is considered an important step in moving UKPMS to the more flexible, modular approach.

J.3.4 Guidance Modules
In addition to the core modules, the new UKPMS framework would contain more general guidance modules. These would provide good practice guidance on a range of topics and would also be a way of disseminating research information. Note that some topics introduced to UKPMS as guidance could, in due course, form the basis for new core modules subject to the requirement for national consistency.

The advantage of the guidance module approach is that this would provide a central, easily accessed source of information – a ‘one-stop shop’ for all interested parties. Increasingly with so many sources of information it is difficult for local authority engineers (and others) to be aware of what work has already been carried out and how it might help them.

A second benefit is that this would provide a mechanism to improve those areas of UKPMS which, although not core, would benefit from development and which no individual system developer would be motivated to initiate. Once some groundwork has been established (and disseminated via the guidance module) then individual system developers may find it commercially attractive to carry out subsequent development work to incorporate the new ideas within their systems.

This would allow flexibility in how (or if) the guidance is implemented within UKPMS so that developers could adapt the approach to suit their system design.

In the short term some guidance modules could be produced using existing material (such as parts of the UKPMS User Guide). Typically these would offer ‘good practice’ guidance.

### J.3.5 Accreditation

The new accreditation scheme would be open to all systems as a complete replacement to the existing approach of comparability tests plus annual health checks.

It would recognise the dependencies between modules and these could be expressed as pre-requisites. So, for instance, a system could not be accredited for NI168 and NI169 without prior or simultaneous accreditation for the RCI calculation.

Although there would be a need for a central coordinator to oversee the accreditation as a whole, the accreditation of individual modules could lie with various different bodies. These may be groups of local authorities or commercial organisations which have a particular interest and expertise in the detailed technical requirements for that module. They might provide material for the specification and accreditation of the module, and might even conduct the accreditation tests. However, there would still need to be some sort of central management (see below).

The approach used for accreditation could vary from module to module. For some modules the approach could be to produce prescribed results within a tightly controlled test environment, for others the system might need to demonstrate capability in a ‘real-world’ environment – for example, via user testimonies. The latter approach might well be valid when a key requirement for a module is its usability by the engineer, rather than a more theoretical assessment. An example is when a system may be able to produce the correct answers when processing data but cannot process large volumes of data sufficiently quickly with typical local authority IT equipment.

### J.3.6 Administration of the modular framework

The modular framework would require careful organisation of all the various documents and files which collectively form the description of the new UKPMS system. This necessary organisation of documents would be achieved via a catalogue listing all the modules forming UKPMS (that is, the core modules, the parameter modules and the guidance modules).
The UKPMS catalogue would show the dependencies between modules and provide a cross reference to the more detailed files describing requirements. It would also show who is responsible for administering each of the modules. The detailed technical requirements for an individual module could be provided (and maintained) by relevant interested parties such as groups of local authorities or commercial organisations who have specialist knowledge of a particular topic. In addition to specifying a module, they might also arrange and/or provide materials for the accreditation of the proposed module.

The coordination of the process, including the maintenance of the catalogue, would need to be handled centrally. We suggest that an appropriate mechanism to use for this would be a central support contract (e.g. similar to the current Pavement Condition Information Systems (PCIS) contract), with suitable agreed terms of reference. Likewise the governance of the new system could be accommodated within the existing Roads Board framework (including the Roads Board subgroups and the Roads Board Advisory Group) albeit with due recognition of this new role.

Funding would be required to support the transition over to the new modular framework. This would be a one-off cost to establish the new regime.

Thereafter funding would be required in a sustained and ongoing way for:

- Ongoing administration of the modular framework – to coordinate and liaise with all those contributing to the modules and to maintain the UKPMS catalogue.
- Ongoing maintenance of the modules – regular updating of all components including specifications and accreditation materials for core modules, parameters, guidance documents, etc.
- Carrying out accreditation tests – both for new systems entering the market and for existing systems requiring regular re-accreditation.
- Development of specifications and accreditation for new core modules.
- Development of parameter modules to support new core modules.
- Development of new guidance modules.

Some central funding would undoubtedly be required, in particular for the first task listed – ongoing administration of the modular framework. Continuity of funding for this task is vital as it provides the pivot connecting all other parts of the UKPMS system and without this many of the benefits of new developments and research will not be realised. However, funding for the other tasks listed may be spread amongst various organisations and groupings – led by whoever is the champion of the individual module.
Appendix K  The new functional specification

This Appendix has been written as a self-contained document so that it can be extracted from the full report as required. It does, therefore, repeat some of the material in the main report but note that it does not repeat the arguments or justifications for the design of the new functional specification.

It describes the recasting of the EXISTING UKPMS system to the new modular framework. As such, it intentionally describes very similar functionality to that in the existing UKPMS system.

The KEY POINT is that the existing functionality has been RECONFIGURED in a way that makes future evolutionary change possible.

The breakdown of the parameters into modules is intended to illustrate the first step (during the transition phase). This is an indicative breakdown of the parameters – more detailed technical work would be required to determine which, if any, could be simplified or dropped. Many of these parameters may become redundant as UKPMS evolves but, equally, they may still be needed during an interim stage before new algorithms have been designed and tested.

Several aspects of the current UKPMS approach have been criticised.

For example, CVI data are loaded using pre-processing to obtain local, partial and general extents, which are threshold based categories. Consequently a small change in the data collected can generate a much larger change in the data loaded to UKPMS. In future, if the CVI type of survey is retained, we recommend that the data should be processed using the level of detail at which is gathered.

For example, the existing Condition Index method has been widely criticised. This also tends to coarsen the results and would need to be examined very carefully as part of the re-design of UKPMS. The treatment rules are included below because this is how the current system works and the initial transition would be to re-cast the current system into the modular framework. During the process some parameters may be simplified or omitted.

The treatment rule cell (Table 32) is required to support the current Automatic Pass processing. When the Automatic Pass is replaced by something else, then the treatment rules could be retained in a module to continue to support Automatic Pass processing (as a “non core” module) for historic compatibility, for those users and system designers that choose to continue to use the Automatic Pass approach for some purposes.

If a different approach to processing visual survey information is developed, this could be designed to avoid condition indices and use survey data in a much more direct manner.

For example, the Condition Projection and Economic Ranking approach has also been widely criticised, and it has been recognised that the current approach has limitations. Table 33 and Table 34 have been included for completeness, pending the results of research and development to introduce a new approach to delivering this functionality.

K.1 Outline of the Functional Specification

The functional specification of UKPMS is based on a modular framework which is organised via a catalogue. Those modules in the specification are referred to as the core modules. Each of these is defined by a specification and verified via accreditation. Alongside and supporting the core modules are parameters which drive the processes and which are also organised using a modular approach. In addition to the core modules, the framework also accommodates guidance modules. These are more general in nature and capture good practice and research information.
The list of core modules is not static; it grows or shrinks to reflect changes to UKPMS requirements. In particular, some of the guidance modules may in due course form the basis for new specifications (i.e. the module would transfer over to the core).

Developers providing UKPMS systems are free to choose which modules to include in their systems, and their accreditation status reflects which modules have been provided in accordance with the UKPMS requirements.

There are dependencies between some of the modules and these are taken account of during the accreditation process. For example, the LAA National Indicators for England, the performance indicators THS/010 for Wales and the SRMCS PI for Scotland all rely on the road condition indicator processing algorithm.

K.2 The Functional Specification for UKPMS

K.2.1 UKPMS Catalogue

The UKPMS catalogue lies at the heart of the new system. It pulls together and controls all the various documents and files which collectively describe UKPMS. Designing the catalogue in detail should form one of the earliest tasks of implementing the new specification for UKPMS. The following list is intended to give a flavour of how the catalogue will operate and the type of information it will contain for each module.

- Module version: A version number for the module.
- Module change control file: This is the file which provides details of changes to the module from one version to the next.
- Module type: This will distinguish between core modules, parameter modules and guidance modules. Some of the information provided in the catalogue will only relate to a particular module type.
- Module ownership: This will show who is responsible for updating and maintaining the module.
- Module files: This will list the files (documents, spreadsheets, databases etc) which belong to the module. For core modules it may be helpful to subdivide this list into specification and accreditation files.
- Module relationships: This will list relationships between this module and others which depend on it, and between this module and others on which it depends.

An example extract to illustrate the type of information contained in the UKPMS catalogue is given in Table 23 for the LAA National Indicators for England (NI168 and NI169).

<table>
<thead>
<tr>
<th>Table 23 Illustrative example of catalogue entry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reference:</strong></td>
</tr>
<tr>
<td><strong>Version:</strong></td>
</tr>
<tr>
<td><strong>Change Control file:</strong></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
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<tr>
<td><strong>Type:</strong></td>
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<td><strong>Ownership:</strong></td>
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</table>
The example given in Table 23 is fictitious; the specification files listed are reminiscent of those used to describe NI168 and NI169 in 2008/09 and the accreditation files listed imply that accreditation might be based on parts of the existing annual health check.

For practical reasons the catalogue would probably be implemented as a simple database, but with reports and queries to allow it to be used and interrogated in a straightforward fashion.

The catalogue could if required also maintain information about those systems which are accredited for that module.

### K.2.2 Core Modules

The core modules consist of specifications and accreditation.

The specification describes the requirements for a particular core module; these may vary in level of detail depending of the purpose of that module. Wherever appropriate the specification is expressed as an output requirement rather than being prescriptive about processing details.

PMS systems used in the UK would not be compelled to adhere to all the specifications but it would be clear, via the accreditation regime, when they have or have not worked to the specification for a particular module. Note that working outside the specification does not necessarily imply ‘sub-standard’; it might be a sign of an innovative, improved approach.

The new accreditation scheme is open to all systems as a complete replacement to the previous UKPMS approach of comparability tests plus annual health checks.

Dependencies between modules are expressed as pre-requisites. So, for instance, a system would not be permitted to seek accreditation for NI168 and NI169 without accreditation for the RCI calculation.

Although the central coordinator oversees the accreditation as a whole, the accreditation of individual modules can lie with various different bodies. These may be groups of local authorities or commercial organisations who have a particular interest and expertise in the detailed technical requirements for that module. They may provide material for the specification and accreditation of their module, and they may even conduct the accreditation tests.

The approach used for accreditation may vary from module to module. For some modules the approach may be to produce prescribed results within a tightly controlled...
test environment, for others the system may need to prove itself in a ‘real-world’ environment – for example, via user testimonies. The latter approach may well be valid when a key requirement for a module is its usability for the engineer, rather than a more theoretical assessment. An example is when a system might well be able to produce the correct answers when processing data but cannot process large volumes of data sufficiently quickly with typical local authority IT equipment.

There may be cases where the specification is considered ‘self-policing’. Perhaps a candidate for this would be when exchanging data between systems (e.g. loading survey data or exporting data from the PMS). In these circumstances the specification would not necessarily form part of an accreditation scheme but would be used to adjudicate when there are difficulties.

The current Annual Health Check approach ensures that those elements that are tested each year (which can and does vary from year to year) do comply with the current specification. The proposed new approach to accreditation, QA and audit is summarised in section 5.6. Whilst accreditation describes a “one off” process for acceptance testing, the QA and audit processes must be designed to ensure that the systems remain compliant. This might, for example, be by having a time limited accreditation for each element, requiring re-testing at intervals.

The initial list of core modules is given below in Table 24. This list indicates where existing materials could provide the basis for the specification and accreditation of the module.
<table>
<thead>
<tr>
<th>Ref</th>
<th>Core Module</th>
<th>Existing documents available as a basis for specification</th>
<th>Existing Annual Health Check tests (2008) available as a basis for accreditation</th>
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<td>UKPMS_Manual_01_04v03.pdf</td>
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<td>UKPMS_Manual_01_04v03.pdf</td>
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<th>Not tested in 2008 AHC</th>
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</tr>
</thead>
<tbody>
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</thead>
<tbody>
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</table>

<table>
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<th>Not tested in 2008 AHC</th>
</tr>
</thead>
<tbody>
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<th>Not tested in 2008 AHC</th>
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<tbody>
<tr>
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### Table 1: Existing Documents Available for Specification and Accreditation

<table>
<thead>
<tr>
<th>Ref</th>
<th>Core Module</th>
<th>Existing documents available as a basis for specification</th>
<th>Existing Annual Health Check tests (2008) available as a basis for accreditation</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>Automatic Pass processing – BV224b</td>
<td>Tranche 2 Implementation Guidelines - Version 1.4.6.pdf, UKPMS_Manual_04_01v03.pdf</td>
<td>Test 5c, Test 5f</td>
</tr>
<tr>
<td>40</td>
<td>SRMCS PI</td>
<td>TN41_Scotland_SRMCS_PI_2008_09_v0102.pdf</td>
<td>Test 8</td>
</tr>
<tr>
<td>41</td>
<td>THS/010</td>
<td>TN43_Wales_THS010_2008_09_v0102.pdf</td>
<td>Test 10</td>
</tr>
<tr>
<td>42</td>
<td>PI (Northern Ireland)</td>
<td>TN42_NorthernIreland_PI_2008_09_v0102.pdf</td>
<td>Test 9</td>
</tr>
<tr>
<td>43</td>
<td>Asset valuation</td>
<td>No existing document</td>
<td>Not tested in 2008 AHC</td>
</tr>
<tr>
<td>44</td>
<td>BV224b</td>
<td>TN38 - BV224b Unclassified Roads (2007-2008) v0104.pdf</td>
<td>Test 7c</td>
</tr>
</tbody>
</table>

**NOTES:**

1. The documents listed as source material for the specifications for importing data also include information about survey methodology. Under this specification, survey methodology lies outside the boundaries of UKPMS. Only the interface between UKPMS and the surveys is covered by UKPMS so that the way in which data is imported into (or exported from) UKPMS is controlled. However, in specifying the transfer of data it may be necessary to include some contextual information about the attributes so that they can be interpreted appropriately within UKPMS.

2. The file format currently used for importing data is HMDIF (Highway Maintenance Data Interchange Format). Although it is envisaged that this will be replaced by some other format in due course, in order to transfer over to the specification from the previous UKPMS system, it is proposed to retain HMDIF files in the first instance.
3. BV224b and BV187 are included in the list of core modules and some authorities may wish to produce these for local purposes even though they are no longer a national requirement.

4. These are four modules for the automatic Pass. The first is the full automatic Pass able to deal with all different types of survey data and different settings (merge methods etc) to give condition indices, treatments and costs. The other three Automatic modules have reduced functionality geared towards PI (Northern Ireland), BV224b and BV187 respectively.

In Table 25 the pre-requisites for each module are given, to show the relationships between modules.

### Table 25 Initial List of Core Modules – Pre-requisites

<table>
<thead>
<tr>
<th>Ref</th>
<th>Core Module</th>
<th>Pre-requisites</th>
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<td>1</td>
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<td>Location referencing</td>
</tr>
<tr>
<td>2</td>
<td>Location referencing</td>
<td>Network referencing</td>
</tr>
<tr>
<td>3</td>
<td>Section attributes</td>
<td>Location referencing</td>
</tr>
<tr>
<td>4</td>
<td>Network referencing</td>
<td>Location referencing</td>
</tr>
<tr>
<td>5</td>
<td>Importing data - Inventory</td>
<td>Location referencing</td>
</tr>
<tr>
<td>6</td>
<td>Importing data - CVI</td>
<td>Location referencing</td>
</tr>
<tr>
<td>7</td>
<td>Importing data - CVT</td>
<td>Location referencing</td>
</tr>
<tr>
<td>8</td>
<td>Importing data - CRUT</td>
<td>Location referencing</td>
</tr>
<tr>
<td>9</td>
<td>Importing data - HRM</td>
<td>Location referencing</td>
</tr>
<tr>
<td>10</td>
<td>Importing data - DVI</td>
<td>Location referencing</td>
</tr>
<tr>
<td>11</td>
<td>Importing data - Deflectograph</td>
<td>Location referencing</td>
</tr>
<tr>
<td>12</td>
<td>Importing data - SCRIM</td>
<td>Location referencing</td>
</tr>
<tr>
<td>13</td>
<td>Importing data - GPR</td>
<td>Location referencing</td>
</tr>
<tr>
<td>14</td>
<td>Importing data - SCANNER</td>
<td>Location referencing</td>
</tr>
<tr>
<td>15</td>
<td>Importing data - GRIP</td>
<td>Location referencing</td>
</tr>
<tr>
<td>16</td>
<td>Importing data - Works Records</td>
<td>Location referencing</td>
</tr>
<tr>
<td>17</td>
<td>Importing data – Pavement Samples</td>
<td>Location referencing</td>
</tr>
<tr>
<td>18</td>
<td>Importing data – Treatment Unit Costs</td>
<td>Location referencing</td>
</tr>
<tr>
<td>19</td>
<td>Exporting data - Network</td>
<td>Importing data - Network</td>
</tr>
<tr>
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<td>Exporting data - Inventory</td>
<td>Importing data - Inventory</td>
</tr>
<tr>
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<td>Importing data - CVI</td>
</tr>
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<td>22</td>
<td>Exporting data - DVI</td>
<td>Importing data - DVI</td>
</tr>
<tr>
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<td>Exporting data - CRUT</td>
<td>Importing data - CRUT</td>
</tr>
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<td>24</td>
<td>Exporting data - DRUT</td>
<td>Importing data - DRUT</td>
</tr>
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<td>Exporting data - HRM</td>
<td>Importing data - HRM</td>
</tr>
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<td>26</td>
<td>Exporting data - Deflectograph</td>
<td>Importing data - Deflectograph</td>
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<td>27</td>
<td>Exporting data - SCRIM</td>
<td>Importing data - SCRIM</td>
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<tr>
<td>28</td>
<td>Exporting data - GRIP</td>
<td>Importing data - GRIP</td>
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<td>Exporting data - SCANNER</td>
<td>Importing data - SCANNER</td>
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<tr>
<td>30</td>
<td>Exporting data - GPR</td>
<td>Importing data - GPR</td>
</tr>
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<td>31</td>
<td>Exporting data – Works Records</td>
<td>Importing data – Works Records</td>
</tr>
<tr>
<td>32</td>
<td>Exporting data – Pavement Samples</td>
<td>Importing data – Pavement Samples</td>
</tr>
<tr>
<td>33</td>
<td>Exporting data – Treatment Unit Costs</td>
<td>Importing data – Treatment Unit Costs</td>
</tr>
<tr>
<td>34</td>
<td>RCI processing</td>
<td>Importing data - SCANNER</td>
</tr>
<tr>
<td>35</td>
<td>Automatic Pass processing – Full</td>
<td>Importing data – all types</td>
</tr>
<tr>
<td>36</td>
<td>Automatic Pass processing – PI (Northern Ireland)</td>
<td>Importing data – CVI, CRUT</td>
</tr>
<tr>
<td>37</td>
<td>Automatic Pass processing – BV224b</td>
<td>Importing data – CVI</td>
</tr>
<tr>
<td>Issue</td>
<td>Resolution</td>
<td>Page</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>---------------</td>
<td>------</td>
</tr>
<tr>
<td>Automatic Pass processing – BV187</td>
<td>BV187</td>
<td>45</td>
</tr>
<tr>
<td>Automatic Pass processing – BV224b</td>
<td>BV224b</td>
<td>44</td>
</tr>
<tr>
<td>Not Yet determined</td>
<td>N/A</td>
<td>43</td>
</tr>
<tr>
<td>Automatic Pass processing – PI (Northern Ireland)</td>
<td>N/A</td>
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</tr>
<tr>
<td>RCI processing</td>
<td>THS/010</td>
<td>41</td>
</tr>
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<td>SMCS/Pi</td>
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<tr>
<td>RCI processing</td>
<td>Nl68 &amp; Nl69</td>
<td>39</td>
</tr>
<tr>
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<td>N/A</td>
<td>38</td>
</tr>
<tr>
<td>Importing data – Inventory</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Section Attributes</td>
<td>BV187</td>
<td></td>
</tr>
</tbody>
</table>
K.2.3 Parameter Modules

Many UKPMS processes are controlled by parameters. These provide flexibility by allowing the same processes to be used in different ways. They also provide ‘future-proofing’ so that data and algorithms can be configured differently in the future. An indicative breakdown of the parameters is given in Table 26 and Table 27. This is based on the Rules & Parameters and Weighting Sets used already in UKPMS.

This part of the re-design of UKPMS to support the new modular approach is not trivial and it will require more detailed technical work. In particular it is advisable to review the existing parameter tables in more detail to determine if any can be simplified or dropped.

It is envisaged that the parameters are stored as a database file (with one file for each parameter module) and are accompanied by a text commentary file explaining the purpose of each table and attribute.

### Table 26 UKPMS Parameters – Modules

<table>
<thead>
<tr>
<th>Ref</th>
<th>Parameter Module</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Control</td>
<td>Lists valid combinations of parameter modules</td>
</tr>
<tr>
<td>2</td>
<td>Location referencing</td>
<td>Features, cross sectional positions and nodes</td>
</tr>
<tr>
<td>3</td>
<td>Section attributes</td>
<td>Codes for attributes stored on each section</td>
</tr>
<tr>
<td>4</td>
<td>Inventory data</td>
<td>Inventory data parameters</td>
</tr>
<tr>
<td>5</td>
<td>Survey data</td>
<td>Survey data parameters</td>
</tr>
<tr>
<td>6</td>
<td>Automatic Pass</td>
<td>Rules and parameters to control the Automatic Pass</td>
</tr>
<tr>
<td>7</td>
<td>Condition Projection</td>
<td>Rules and parameters for condition projection</td>
</tr>
<tr>
<td>8</td>
<td>Economic Ranking</td>
<td>Rules and parameters for economic ranking</td>
</tr>
<tr>
<td>9</td>
<td>Network Trends</td>
<td>Rules and parameters for network trends</td>
</tr>
<tr>
<td>10</td>
<td>Road Condition Indicator</td>
<td>Weightings for the Road Condition Indicator</td>
</tr>
<tr>
<td>11</td>
<td>Data Model</td>
<td>Empty tables giving the structure of the data model</td>
</tr>
</tbody>
</table>

### Table 27 UKPMS Parameters – Control Module

<table>
<thead>
<tr>
<th>Table name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>ParameterSetID</td>
<td>Lists parameter identifiers for each parameter module</td>
</tr>
<tr>
<td>ParameterSetLink</td>
<td>Links parameters modules using parameter identifiers</td>
</tr>
</tbody>
</table>

This Parameter Control module lists the discrete sets of parameters for each parameter module (using parameter identifiers’). It acts as a replacement for both the Rule Set table in the Rules & Parameters database. It also contains linking information to control which combinations of parameter modules are valid. In this respect it replaces the WeightingRuleSetLink table.

### Table 28 UKPMS Parameters – Location referencing

<table>
<thead>
<tr>
<th>Table name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross Sectional Position</td>
<td>Lists the cross sectional positions</td>
</tr>
<tr>
<td>Feature</td>
<td>Lists the features used by UKPMS</td>
</tr>
<tr>
<td>Node Type</td>
<td>Lists the types of node recognised by UKPMS</td>
</tr>
<tr>
<td>XSP for Feature</td>
<td>Lists the valid XSP codes for each feature</td>
</tr>
<tr>
<td>XSP Mapping</td>
<td>Provides a mapping between Full and Minimal XSPs</td>
</tr>
<tr>
<td>XSP Reversal</td>
<td>Lists the XSP code for each XSP when reversed</td>
</tr>
</tbody>
</table>

1 Analogous to the identifiers RP7.01, RP7.02, RP8.01 etc used for Rules & Parameters, and WSPinv0101 etc used for Weighting Sets.
### Table 29 UKPMS Parameters – Section attributes

<table>
<thead>
<tr>
<th>Table name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversion Quality</td>
<td>Lists the diversion quality codes</td>
</tr>
<tr>
<td>DOT Classification</td>
<td>Lists the DfT classification codes</td>
</tr>
<tr>
<td>Drainage Status</td>
<td>Lists the drainage status codes</td>
</tr>
<tr>
<td>Footway Opening Frequency</td>
<td>Lists the footway opening frequency codes</td>
</tr>
<tr>
<td>Footway Status</td>
<td>Lists the footway status codes</td>
</tr>
<tr>
<td>Road Hierarchy</td>
<td>Lists the road hierarchies recognised by UKPMS</td>
</tr>
<tr>
<td>Road Type</td>
<td>Lists the road types recognised by UKPMS</td>
</tr>
<tr>
<td>Speed Limit</td>
<td>Lists the speed limit codes recognised by UKPMS</td>
</tr>
<tr>
<td>Traffic Level</td>
<td>Lists the traffic levels</td>
</tr>
<tr>
<td>Vehicular Traffic</td>
<td>Lists the valid vehicular traffic codes</td>
</tr>
</tbody>
</table>

### Table 30 UKPMS Parameters – Inventory data

<table>
<thead>
<tr>
<th>Table name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction Type</td>
<td>Lists the construction types</td>
</tr>
<tr>
<td>Default Feature Widths</td>
<td>Gives a default width for each feature</td>
</tr>
<tr>
<td>Feature Attribute</td>
<td>Lists the attributes for each feature</td>
</tr>
<tr>
<td>Feature Attribute Option Code</td>
<td>Lists the option codes for each feature attribute</td>
</tr>
<tr>
<td>Feature Hierarchy</td>
<td>Lists valid hierarchies for each feature</td>
</tr>
<tr>
<td>Surface Type</td>
<td>Lists the surface types recognised by UKPMS</td>
</tr>
</tbody>
</table>

### Table 31 UKPMS Parameters – Survey data

<table>
<thead>
<tr>
<th>Table name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Defect</td>
<td>Lists the basic defects</td>
</tr>
<tr>
<td>Defect</td>
<td>Lists the defects recognised by UKPMS</td>
</tr>
<tr>
<td>Defect Base Date Group</td>
<td>Lists the defect base date groups</td>
</tr>
<tr>
<td>Defect Category</td>
<td>Lists the defect categories</td>
</tr>
<tr>
<td>Defect Parameter</td>
<td>Lists the parameters for each survey type</td>
</tr>
<tr>
<td>Defect Parameter Option Code</td>
<td>Lists the option codes for each defect parameter</td>
</tr>
<tr>
<td>Pavement Type</td>
<td>Lists the types of pavement recognised by UKPMS</td>
</tr>
<tr>
<td>Survey Type</td>
<td>Lists the survey types recognised by UKPMS</td>
</tr>
<tr>
<td>Valid Defect</td>
<td>Lists the defects which are valid for a survey type</td>
</tr>
<tr>
<td>Valid Defect Parameter</td>
<td>Lists the parameter(s) for each valid defect</td>
</tr>
<tr>
<td>Valid Defect Parameter Option</td>
<td>Lists the option codes for each valid defect</td>
</tr>
<tr>
<td>Valid Defect Parameter Option</td>
<td>Assigns a VDPO code to each valid defect parameter option combination</td>
</tr>
</tbody>
</table>

### Table 32 UKPMS Parameters – Automatic Pass

<table>
<thead>
<tr>
<th>Table name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition Index and Pavement Type</td>
<td>Lists the condition indices for each combination of feature and pavement type</td>
</tr>
<tr>
<td>Condition Index Type</td>
<td>Lists the condition indices</td>
</tr>
<tr>
<td>Defect Composition</td>
<td>Controls how composite defects are formed from collected defects</td>
</tr>
<tr>
<td>Defect Length Overall CI Calculation</td>
<td>Together these determine how the Overall CI is calculated</td>
</tr>
<tr>
<td>Defect Length Overall CI Calculation Detail</td>
<td></td>
</tr>
<tr>
<td>Defect Transformation</td>
<td>Controls how defects are refined depending</td>
</tr>
</tbody>
</table>
Defectiveness Calculation | Lists the defectiveness calculation codes
Generic Treatment | Lists the generic treatments produced by UKPMS
Intervention Levels for Hierarchy | Gives the intervention level values for each feature hierarchy
Method 1 Rating Coordinate | Gives defect rating curves
Method 2 Rating Lookup | Gives defect rating lookups (typically for CVI data)
Ranking Curve | Gives the condition ranking curves
Rating Length CI Calculation | Together these determine how the condition indices are calculated
Rating Length CI Calculation Detail | Links pavement type and construction type
Treatment | Lists the specific treatments produced by UKPMS
Treatment Composition | Groups together generic treatment, treatment and treatment type to give a complete treatment
Treatment for Functional Defect | Gives treatments for functional defects (SCRIM or GripTester)
Treatment Selection Intervention Levels | Lists the intervention levels
Treatment Selection Rule Cell | Together these determine which treatment rule line applies
Treatment Selection Rule Line | Lists the treatment types produced by UKPMS
Treatments for Rule Line | This gives the treatment corresponding to the treatment rule line.

**Table 33 UKPMS Parameters – Condition Projection**

<table>
<thead>
<tr>
<th>Table name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age Weighting</td>
<td>Used during condition projection</td>
</tr>
<tr>
<td>Attributes Used in Projection Relationship</td>
<td>Used during condition projection</td>
</tr>
<tr>
<td>Projection Curve</td>
<td>Lists the types of projection curve</td>
</tr>
<tr>
<td>Projection Curve Point</td>
<td>Gives the standard projection curve points</td>
</tr>
<tr>
<td>Projection Parameters</td>
<td>Used for condition projection</td>
</tr>
<tr>
<td>Projection Relationship</td>
<td>Used for condition projection</td>
</tr>
</tbody>
</table>

**Table 34 UKPMS Parameters – Economic Ranking**

<table>
<thead>
<tr>
<th>Table name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents at Works</td>
<td>Used for economic ranking</td>
</tr>
<tr>
<td>Analysis Period</td>
<td>Used for economic ranking</td>
</tr>
<tr>
<td>Closure Due to Works</td>
<td>Used for economic ranking</td>
</tr>
<tr>
<td>Closure Type</td>
<td>Lists the closure types</td>
</tr>
<tr>
<td>Consequent Cost Percentage</td>
<td>Used for economic ranking</td>
</tr>
<tr>
<td>Cost of Accidents At Works</td>
<td>Used for economic ranking</td>
</tr>
<tr>
<td>Delay Due to Works</td>
<td>Used for economic ranking</td>
</tr>
<tr>
<td>Duration of Works</td>
<td>Used for economic ranking</td>
</tr>
<tr>
<td>Routine Maintenance Cost</td>
<td>Used for economic ranking</td>
</tr>
<tr>
<td>Value of Time</td>
<td>Used for economic ranking</td>
</tr>
</tbody>
</table>
Table 35 UKPMS Parameters – Network Trends

<table>
<thead>
<tr>
<th>Table name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect of Treatment</td>
<td>Gives the effect of the treatment on pavement life</td>
</tr>
<tr>
<td>Pavement Type after Treatment</td>
<td>Gives the pavement type after a treatment</td>
</tr>
</tbody>
</table>

Table 36 UKPMS Parameters – Road Condition Indicator

<table>
<thead>
<tr>
<th>Table name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>DefectConfidence</td>
<td>Gives the reliability and importance factors</td>
</tr>
<tr>
<td>DefectFamily</td>
<td>Gives the family for each defect</td>
</tr>
<tr>
<td>DefectWeightings</td>
<td>Gives the weighting curve for each defect</td>
</tr>
<tr>
<td>Family</td>
<td>Lists the valid families</td>
</tr>
<tr>
<td>Thresholds</td>
<td>Gives the thresholds for each bin or for the probability method</td>
</tr>
<tr>
<td>Weighted Average</td>
<td>Only used if the family values are combined using a weighted average</td>
</tr>
<tr>
<td>WeightingCurveList</td>
<td>Lists the weighting curves</td>
</tr>
<tr>
<td>WeightingCurvePoints</td>
<td>Gives the curve points for each weighting curve</td>
</tr>
<tr>
<td>WeightingSetLists</td>
<td>Gives information describing the weighting set</td>
</tr>
</tbody>
</table>

Table 37 UKPMS Parameters – Data Model Module

<table>
<thead>
<tr>
<th>Table name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUTOMATIC PASS</td>
<td></td>
</tr>
<tr>
<td>BUDGET</td>
<td></td>
</tr>
<tr>
<td>BUDGET HEAD</td>
<td></td>
</tr>
<tr>
<td>BUDGET HEAD INSTANCE</td>
<td></td>
</tr>
<tr>
<td>BUDGET INSTANCE</td>
<td></td>
</tr>
<tr>
<td>BUDGET INSTANCE IN AUTOMATIC PASS</td>
<td></td>
</tr>
<tr>
<td>DEFECT LENGTH</td>
<td></td>
</tr>
<tr>
<td>DEFECT LENGTH CONDITION INDEX</td>
<td></td>
</tr>
<tr>
<td>DEFECT LENGTH FUNCTIONAL DEFECT</td>
<td></td>
</tr>
<tr>
<td>DISTRICT</td>
<td></td>
</tr>
<tr>
<td>ESTIMATING TREATMENT UNIT COSTS</td>
<td></td>
</tr>
<tr>
<td>FUNCTIONAL THRESHOLD</td>
<td></td>
</tr>
<tr>
<td>FUNDING ORGANISATION</td>
<td></td>
</tr>
<tr>
<td>INVENTORY ITEM</td>
<td></td>
</tr>
<tr>
<td>ITEM ATTRIBUTE</td>
<td></td>
</tr>
<tr>
<td>NODE</td>
<td></td>
</tr>
<tr>
<td>NODE WITHIN SECTION</td>
<td></td>
</tr>
<tr>
<td>OBSERVATION</td>
<td></td>
</tr>
<tr>
<td>OBSERVATION VALUE</td>
<td></td>
</tr>
<tr>
<td>PAVEMENT SAMPLE</td>
<td></td>
</tr>
<tr>
<td>PAVEMENT SAMPLE LAYER</td>
<td></td>
</tr>
<tr>
<td>PROJECTION BASE DATE</td>
<td></td>
</tr>
<tr>
<td>SECTION</td>
<td></td>
</tr>
<tr>
<td>SECTION WITHIN SURVEY</td>
<td></td>
</tr>
<tr>
<td>SITE CATEGORY</td>
<td></td>
</tr>
<tr>
<td>SURVEY</td>
<td></td>
</tr>
<tr>
<td>WORKS RECORD</td>
<td></td>
</tr>
<tr>
<td>WORKS RECORD LAYER</td>
<td></td>
</tr>
</tbody>
</table>

These are empty tables. They convey information about structure of the underlying data model for UKPMS

K.2.4 Guidance Modules
Guidance modules offer good practice guidance on a range of topics and are also a way of disseminating research information.

In situations where the guidance relates to topics which, although pertinent to UKPMS, lie outside the boundaries of UKPMS (e.g. survey methodology, asset management etc) the guidance module for that topic may simply offer links and references to source materials. For instance, a guidance module on SCANNER surveys could simply provide references to the SCANNER User Guide and Specifications and explain where these are to be found.

In other situations the guidance module may be a mechanism to introduce new ideas to UKPMS and air them for public debate before moving on to create new core modules based on the guidance.

There may also be areas of work where the guidance presents research on a topic (an example might be pavement deterioration), leaving flexibility in how to take the findings forward and apply them to UKPMS.

As this illustrates, by their very nature guidance modules will vary considerably. What unites them is that they provide a way of capturing and organising disparate information related to UKPMS and give a single ‘gateway’ for such information to be accessed. The list of guidance modules will never be static; it will evolve to reflect the ongoing development of UKPMS.

In the short-term some guidance modules could be produced using existing material (such as parts of the User Guide). Typically these would offer ‘good practice’ guidance.

Some of the guidance modules requiring additional work are summarised below:

- **Network referencing & location referencing** – A research project has been proposed for using GPS and GIS for network referencing. The perceived advantages of this are that data collection and loading of machine data (especially SCANNER) would be much more efficient. The results of this research could initially be made available to UKPMS as a guidance module, with a view to implementing it as a core module once a specification has been produced and accreditation has been developed.

- **Data interchange file format for importing and exporting UKPMS data** – It would be beneficial to review the data interchange file format in more detail to establish if it is possible to set up a file format more suited to the large volumes of data in SCANNER surveys, and more suited to exporting data. Consideration should also be given to the advantages of setting up a generic file format suitable for any type of data.

- **Archiving data** – It may be helpful to produce guidance for local authorities about how best to archive UKPMS data so that it can be retrieved in the future. It may not always be best just to store the original data files. Networks and parameters change over time and this can make it difficult and time-consuming to load old stored data. The preferred alternative may well be an archive function within (and controlled) by UKPMS.

- **Survey types** – The methodology for new survey types lies outside the remit for UKPMS. However, work is needed within UKPMS to establish how to load, process and interpret new sources of data. Two area where change may be required are:

  - The new footway survey: The methodology for this survey is being developed by the Footways and Cycletrack Management Group. Work will be required in UKPMS to handle this new data appropriately to provide useful information for engineers. Once a specification and accreditation approach have been produced then this could form a new core module, but prior to this it may be introduced to UKPMS as a guidance module.
Review the CVI survey: Currently CVI survey data is post-processed after it has been collected and before loading into UKPMS. This should be reviewed to determine if it would be better for UKPMS to load and process the data in a format closer to how it is collected (rather than as ‘local’, ‘partial’ and ‘general’ extent codes).

- **Processing algorithm** – A review is required of the processing of data to produce condition information and suggested treatments. Currently this functionality is provided in UKPMS by the Automatic Pass. The Automatic Pass is important for historical reasons (and currently to support the PI for Northern Ireland, and for local use via BV224b and BV187). However, it does have drawbacks and more suitable alternatives are required for processing data in UKPMS (particularly SCANNER data). A new processing approach need not necessarily be as prescriptive as the existing Automatic Pass and could possibly be expressed as basic principles which could be adapted to suit each system. Potentially it could enable treatments to be based directly on the defects themselves rather than via condition indices.

- **Schemes and programmes of work** – This is a potential research topic, the results of which could initially be introduced to UKPMS as a guidance module.

- **Deterioration modelling and/or condition projection** – This is a potential research topic, the results of which could initially be introduced to UKPMS as a guidance module.

- **Life cycle planning** – This is a potential research topic, the results of which could initially be introduced to UKPMS as a guidance module.

- **Scenario modelling (i.e. ‘what-if modelling’)** – This is a potential research topic, the results of which could initially be introduced to UKPMS as a guidance module.

- **Financial information to support asset management** – This area of functionality is progressing under various national initiatives, including the Highways Asset Management Financial Information Group (HAMFIG). Guidance produced by outside organisations could be captured within UKPMS via guidance modules giving references to external sources of information. In addition, extra information may be produced (as a guidance module) offering further interpretation of general guidelines for a UKPMS context.
Review of UKPMS core functionality – the minimum functionality all PMS should embody in the UK

Local highway authorities require pavement information and decisions systems to support the management of their transport infrastructure assets in the delivery of their transport objectives. The purpose of this study was to produce a specification to replace the existing UKPMS specification as the minimum functionality that all PMS should embody in future to meet the evolving needs of local highway authorities and national governments in the UK for local roads.

Local authorities need confidence that the systems they use for asset management store, analyse and report on the data consistently and accurately to ensure that asset management decisions and financial information reports are correct. They need a nationally consistent approach to pavement asset management systems wherever the results have to be compared between authorities, or combined across a wider area. Also wherever authorities are required to justify their recommendations, decisions or actions so that they can demonstrate they have applied professional judgement in the context of nationally agreed guidelines or approaches adapted to local needs, rather than in an arbitrary or idiosyncratic way. Furthermore, local authorities need to be confident that the systems they use for asset management consistently store, analyse and report on the data accurately. This is required to ensure that the asset management decisions made and financial information reported are correct.

This report determines the priorities and produces a rationale for the commonality of PMS functions across local authorities and systems, taking account of the increasing importance of an asset management approach. It sets out the proposed core functional specification and maps its implementation to an indicative timetable and budget, taking account of where the costs are likely to fall and the ability of the market to deliver. It identifies where there are gaps or techniques that would benefit from further research.

Other titles from this subject area

PPR253  Investigation of the effects of pavement stiffness on fuel consumption. E Benbow, J Iaquinta, R Lodge and A Wright. 2008
PPR299  Automated detection of fretting on HRA surfaces. S McRobbie and G Furness. 2008