OPTIMISING MAINTENANCE AND REHABILITATION OUTCOMES - STRATEGIES & KNOWLEDGE

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ABSTRACT

For most developed countries more and more use of allocated funds for roads will be spent on the maintenance of the road, as distinct from their construction. Limiting the deterioration rate of the road pavement is therefore an essential goal as typically pavement maintenance is the largest single component of a road agency's recurring costs.

The challenge then is to provide optimum maintenance strategies, to understand them and to ensure quality implementation of the most appropriate strategy.

Australia relies more on road transport than any other nation in the world, on a per capita basis and is challenged on critical fronts like few others, given its size, its climatic and geological diversity, and a low population base (but high road length km/head). An overview will be provided of the various pavement evaluation techniques used and the maintenance strategies performance.

Future improved performance is however threatened by the continuing loss of experienced road and pavement engineers, resulting in the evaluation of pavements and the selection of the most appropriate maintenance and rehabilitation being undertaken by less experienced and knowledgeable engineers. Today's roads and pavement engineers however need to be more skilled and knowledgeable, and this is a priority issue in Australia, and becoming more so globally.

How we achieve this is a major task and old paradigms are no longer valid as we continue to become a more global society and technology provides new opportunities.

To enhance the standing of roads and pavements sector for attracting engineers, and to provide improved education and training of our current engineers and technologist, systems and learning materials for personal and career development need to be improved, and readily accessible. The development in iPads and other mobile phone devices which can rapidly deliver high quality video, text and sound, just about anywhere, provides attractive options for improved learning.

Technology transfer, education and the optimisation of maintenance and rehabilitation are inextricability linked and success in enhancing each will play a big part in the sustainability of the asphalt road in the future.

Keywords: Technology Transfer, Education, Maintenance Strategies

INTRODUCTION AND THE AUSTRALIAN CONTEXT

The Australian road system is used for many purposes, including private and business trips by car, commercial trips in a range of types of small commercial vehicles, public transport (buses and taxis), and freight movement. A wide range of industry sectors rely on road transport, ranging from primary industries such as agriculture and mining, secondary industries such as and manufacturing, and service industries including tourism.

New pavements are designed to withstand the expected traffic loading and environmental conditions. For many pavements, the actual traffic loading and weather conditions over the design period are not the same as that allowed for in design. Pavement maintenance is concerned with ensuring the design requirements are suitably satisfied throughout the operating life of the pavement (i.e. the pavement fulfils it structural and functional requirements throughout its design life.)

People responsible for road maintenance are pivotal to a road agency's ability to manage its road network so that it will satisfy these requirements. The responsibilities of road maintenance people cover the whole network every year. By contrast, those responsible for road construction focus on a very small proportion of the network at any given time.

The maintenance of the road network has in recent times emerged as the most important aspect of the road management task. It is now clear that the single most sensitive influence on the annual road agency costs of maintenance and rehabilitation and their distribution across roads in the network is the rate of pavement deterioration.

Retardation of the deterioration rate of a road pavement has become the essential goal of pavement maintenance and rehabilitation.

The 1980s and 1990s was a time when the Australian road network began to reach a relatively 'mature' state and recognition that the road network was a major public asset that needed to be managed in a systematic, strategic manner.

Australia is a vast country of almost 7.7 million square kilometres and is the world's sixth largest country after Russia, Canada, China, the USA, and Brazil.1 In contrast to its vast size, the country is populated with less than twenty-three million inhabitants (about the population of Romania), of which about 80% reside along the eastern seaboard, this compares to a population of about 344 million for Canada and USA, which covers a similar area, and about 740 million for Europe.

The total length of roads in Australia is approximately 810,000 kilometres of which about 333,000 are sealed roads. 2 With a relatively low population, the proportion of road length (metres) per capita in Australia, is in the order of 39 compared to 22 for USA, 16 for France, 7 for Germany and 5.5 for Turkey.4 Thus, the proportionate burden of transport related expenditure per person in Australia is high relative to other developed countries. State spending on road maintenance, 2004-05 to 2009-10 averaged at about $275 per capita, representing about 2.7% of total State expenditures.3 In Australia approximately 14% of household income is spent on transport related expenditure with the total expenditure on roads in Australia nearing A$8 billion annually.

In respect of the Australian freight task, as well as having the second highest level of car ownership in the world and the third highest per capita rate of fuel consumption, Australia is critically dependent on land transport for the distribution of freight. Australian road freight operations are estimated to generate 2.8 per cent of GDP, employing 150,000 people directly and providing employment for a further 150,000 in supporting activities (ATA 2002a).7

Australia's land freight transport task is expected to double between 2000 and 2020 according to the Australian National Transport Commission.5 This will increase the already massive freight task currently calculated at 7,934 tonne-km per capita compared with 5,567 for USA, 2,537 for UK and 2,456 for Japan. The key influences on demand are increases in resource demand for minerals and agricultural production, and the substitution and growth of imports as both consumer goods and raw material inputs.9 The forecast increase in the freight task has stimulated the Australian government to undertake several transport reforms to underpin Australia's future economic competitiveness.

A significant component of the reforms is the introduction of Performance-Based Standards (PBS) for heavy vehicles and includes the introduction of safer and more productive SMART* heavy vehicles; vehicle tracking to ensure SMART
* Safer Management of Australian Road Transport (SMART) trucks remain on approved freight routes; and direct-user

charges linked to the level of road wear. These expected increases in the freight task, together with constrained economic circumstances following the Global Financial Crisis, and rising expectations of levels of service demanded by the community, means that the effectiveness and efficiency of road maintenance is even more critical to Australia's future prosperity than ever before.

2.0 WHAT DO WE MEAN BY PAVEMENT ?

Pavement is defined by Austroads (Australia's National body representing all State Road Authorities in Australia and New Zealand), as the portion of the road placed above the subgrade for the support of, and to form a running surface for, vehicular traffic. A pavement usually comprises subbase, base and wearing surface layers. Although at times there is a distinction made between pavement and surfacing (or wearing surface), it is noted that pavement is defined to include the surfacing.

Due to very large land area/road lengths relative to small population densities, road construction has been by necessity in a form that is the most economical to cover the vast distances at often very low traffic densities. Austroads describes the road systems in Australia and New Zealand as characterised by substantial lengths of pavements constructed from crushed rock or gravel materials (i.e. unbound materials) with a thin bituminous surfacing. This low cost technique was developed by the pioneer road builders and enabled the rapid expansion of all weather dust free roads in sparsely populated areas.

In rural areas the thin bituminous surfacing on many roads is a sprayed seal. This is an effective low cost treatment but has limited resistance to high shearing stresses, such as at sharp curves and with heavy traffic. High tyre pressures on trucks also place considerable strain on sprayed seals.

On more heavily trafficked roads and in urban areas, hot mix asphalt is commonly used because of its greater resistance to traffic effects and greater durability. Concrete also has these advantages, and the Australian road system has seen some growth in the amount of concrete pavements, partly as a result of improved efficiencies and quality made possible by modern paving equipment. However they remain only a small proportion overall.

Asphalt and concrete may be used both as structural layers within a pavement and as a surfacing.

The amount of stabilised material in road pavements is increasing, due largely to improved plant and equipment for stabilising, and to increasing environmental awareness which encourages recycling of material such as old pavement material and industry waste and by-products, and also the availability of a wider range of binders, particularly slow setting binders.

Road pavements have a number of particular features which should be kept in mind when planning, conducting and evaluating maintenance and rehabilitation strategies, programs and activity.

These include:

- Road pavements are long life assets many of which remain in service for periods of the order of 50 years and more.
- Road pavements, particularly wearing surfaces, are fully exposed to the weather.
- The foundations of road pavements are natural materials whether on an embankment, in a cutting or at natural ground level.
- Road pavements and wearing surfaces exist in large quantities.
- Deterioration rates of road pavements are not well enough understood to be easily predictable, and can vary markedly even in apparently similar circumstances.
- The costs of maintenance and rehabilitation of road pavements (including wearing surfaces) comprise a significant proportion of total life cycle costs
- Road maintenance activity is fully visible to the public.

3.0 WHAT DO WE MEAN BY MAINTENANCE ?

The Australian Standard glossary of terms for use in road and traffic engineering (AS 1348.1) does not specifically include a section on pavement maintenance and rehabilitation. However, AS 1348.1, Part 1 - Road Design and Construction gives the following definitions:

Maintenance is the work carried out on a construction to maintain its efficiency or quality.

Rehabilitation is the restoration of a distressed pavement so that it may be expected to function at a satisfactory level of serviceability for a further design period.

The Transportation Association of Canada defines pavement maintenance and rehabilitation as:

Pavement Maintenance: Well timed and executed activities to ensure or extend pavement life until deterioration of the pavement layer materials and subgrades is such that a minimum acceptable level of serviceability is reached, and/or it is more cost-effective to rehabilitate the pavement.

Pavement Rehabilitation: A term in pavement management involving the restoration of pavement serviceability through such action as overlays.

Austroads lists activities in maintenance, rehabilitation and construction as shown in Table 3.1:

Table 3.1 - Common Activities in Maintenance, Rehabilitation and Construction

Maintenance routine and periodic	**Rehabilitation** restoration to current standard	**Construction** enhancement, improved capacity
pothole repair, crack sealing, edge repair, shoulder grading, drainage maintenance, vegetation trimming, guide post replacement and repair, shoulder resheeting, linemarking, reseals, non-structural asphalt overlays	pavement structural overlays, shape correction, pavement strengthening, minor widening (< 300 mm)	major works overtaking lanes new works black spots, i.e. road safety improvements

The benefits of uniform definitions for maintenance and construction include allowing improved national and State reporting on road investment, and providing improved opportunities for inter-agency benchmarking. Austroads has adopted the following definitions:

Pavement Maintenance	Actions which are intended to preserve the pavement and are mainly directed to the surface, with no improvement in strength or capacity beyond that from original construction or design intention. Maintenance includes rehabilitation if, after rehabilitation, the pavement is no stronger or wider than when it was first constructed.
Pavement Construction	Action to provide a new pavement, or to increase either strength or capacity or both of an existing pavement, beyond the initial as-constructed values. Pavement construction includes rehabilitation if, after rehabilitation, the pavement is stronger or wider than the strength or width originally constructed. Pavement construction provides additional capacity or service potential, usually to carry increased axle loads (pavement strength) or traffic volumes (pavement or seal width), and sometimes to improve safety performance (eg, widening for turning traffic, sealing shoulders).
Pavement Rehabilitation	Major surfacing action or pavement treatment for the purpose of improving the structural condition of the pavement, either to reach original as constructed or design condition (when the cost would be regarded as a recurring expense for maintenance work), or to exceed the original as constructed condition (when the cost would be regarded as a capital investment for construction work), so that it may be expected to function at a satisfactory level of service for a further period of time.
Reconstruction	Construction of a new asset which replaces or upgrades an existing asset generally in the same location and essentially the same alignment as the asset being replaced – the existing asset will no longer be in service. Examples include formation or bridge widening, pavement or bridge strengthening, and local improvements such as at curves and intersections. The cost of reconstruction is a capital cost.

Costs attributable to an action include the costs of planning, design, supervision and acceptance, as well as the costs of the physical works. Overheads that relate to the implementation of the work (investigation, survey, design, testing, project, management, etc) should be included. Other more general corporate overheads (community relations, recruitment, etc.) should be excluded. Costs of providing funds (loan charges where applicable, or opportunity costs) should also be excluded.

The need for a clear distinction between construction and maintenance (capital expenditure and recurring expenditure) is partly influenced by accounting considerations, because of the commercial accounting framework of AAS 27 and AAS 29 in Australia.

In addition, in a private sector context (eg, Toll Roads in Australia, and proposals in New Zealand to commercialise road operation), it is important for tax purposes to distinguish clearly between capital and recurring expenditure.

In this context, rehabilitation may either be construction or maintenance, as described in the Austroads definitions.

4.0 TYPES OF MAINTENANCE

Pavement maintenance is conveniently broken into:

- routine maintenance
- periodic maintenance
- rehabilitation.

4.1 Routine Maintenance

Routine maintenance includes works which are intended to remedy minor defects. These works are normally planned with a short lead time and undertaken with light equipment and small quantities of materials, much of which could be carried on a single patrol vehicle, or with heavier plant where the work is well defined and undertaken regularly (such as the grading of shoulders, or cleaning of table drains).
Some of the main activities in routine pavement maintenance are:

- Surfacing repairs of minor localised areas of flushing, ravelling or stripping,
- Crack sealing of linear cracking (longitudinal, transverse, diagonal, meandering, etc),
- Repairs to edge breaks and edge drop-off,
- Emergency or expedient patching of minor potholes (with no or minimal pre-shaping),
- Shoulder grading or shoulder reshaping,
- Vegetation control,
- Table drain cleaning, and,
- Culvert cleaning.

4.2 Periodic Maintenance

Periodic maintenance involves correcting widespread defects in surface integrity, other than those which would be treated by routine maintenance. Periodic maintenance activities focus on wearing surfaces, and are carried out regularly at frequencies of one year or more over significant continuous lengths of road. These activities repair and preserve the pavement and wearing surface, while also improving travel safety.

Preservation includes structural preservation, but only to the extent that the wearing surface is protecting the structure. Periodic maintenance activities usually cost considerably more than routine maintenance activities on a per km or per lane-km basis.

The forms of distress justifying periodic pavement maintenance include bitumen oxidation, general block cracking, polishing, flushing, ravelling or stripping.

Some of the main activities in periodic pavement maintenance are:

- Resurfacing of significant areas or lengths of pavement (say, > 500m2) suffering from extensive defects caused by either localised problems (e.g., poor initial planning, design, construction, or materials), or by ageing or traffic wear.
- Treatments such as rejuvenation, reseals, slurry seals or semi/non-structural asphalt overlays (<40mm thickness).
- Special reseals using rubberised bitumen, polymer modified binders or geotextile reinforcement as holding treatments for extensive areas of structural fatigue cracking, and
- Gravel resheeting of unsealed pavements
- Re-gravelling of shoulders or, shoulder resealing.

4.3 Rehabilitation

Rehabilitation works do not involve major changes to horizontal or vertical alignment or width, but can include strengthening and sometimes minor widening works to meet the current cross-section standards, for the class of road and expected traffic loading. Rehabilitation works are much more expensive than periodic maintenance and are less frequent. Rehabilitation is usually chosen following an economic evaluation of alternative treatments.

- Major patching requiring deep structural base replacement of significant areas of pavement (> 500m2) suffering from extensive failure defects, usually due to localised problems or poor initial design/construction, materials etc. The forms of visual distress justifying this activity include widespread potholing, cracking or shoving; and,

- Structural reinstatement of pavement at or nearing the end of its 'life' with the appearance of extensive and general crocodile cracking, shoving or potholing. Treatments include overlays such as a granular re-sheet plus new surfacing (i.e. a new base, with the current base reclassified as subbase), structural asphalt overlay (>40mm thickness), or in-situ pavement rejuvenation by stabilisation (such as 'deep lift' work).

5.0 ISSUES IN ROAD MAINTENANCE & REHABILITATION

Among the challenges in road maintenance and rehabilitation are:

- To provide an apparently consistent standard for the road user even where different parts of the route may have been constructed at different times with different geometrical standards, different pavement designs and different materials. Consistent standards are regarded as beneficial in terms of road safety.

- To avoid surprises for drivers, again for the purposes of road safety.

- To ensure traffic control that is safe for road users and road maintenance personnel during road maintenance activities.

- To select a form of service delivery for road maintenance activity which best serves the community, e.g., in-house maintenance personnel, agency equipment, hired equipment, schedule of rates contract, lump sum contract, performance contract, or a mixture of all or some of these forms of service delivery.

- Planning over a long term consistent with the long life of the pavement asset, to minimise agency costs over a long period. This involves extending service life of the pavement and wearing service to remain within acceptable standards at minimum cost.

- Catering for increases in axle loads (legal increases as well as incidences of illegal overloading), and increases in volumes of heavy traffic over time. In Australia, long term rates of growth for heavy vehicles are typically at least twice the long term growth rates for lighter traffic. In addition, the long term history in Australia of increases in axle loads is expected to continue, as a result of the never-ending quest for improved transport productivity and the size of the freight task.

- Reaching an understanding with road users as to standards of maintenance which conform to community expectations and can be provided on a stable long term basis within a budget acceptable to the community. These standards would typically include driver comfort and road user costs (roughness), safety (potholes, edge and shoulder condition), and neighbourhood amenity (tyre noise, appearance), etc.

- Maintaining reliable records of pavement inventory, condition and maintenance history over long periods, e.g. in a manner sufficiently robust to survive changes of personnel.

- In some agencies, co-ordination between pavement maintenance planning and activity and related works by others is an issue. This could include matters such as utility and service installation and maintenance (trenches, pits, etc), provision and maintenance of transverse and longitudinal linemarking (e.g., pedestrian crossings, give way and stop lines, etc), detectors for traffic signals and other so-called "intelligent systems", the potential pavement damage resulting from watering systems for roadside beautification schemes, and so on.

The service lives of periodic maintenance and rehabilitation are key factors in determining the frequency of treatment required, particularly for surfacings.

Deterioration occurs as a combination of load associated damage and damage caused by environmental influences, in particular the oxidation of bituminous binders, and below in Table 5.1 are typical service lives adopted in the Australian environment.

Table 5.1 – Typical service lives

Surfacing type	Expected average service life (years)1
Sprayed seal (5 mm and 7 mm	5 - 7
Sprayed seal (> 10 mm)	8 – 15
Double application seal	8 - 15
Open graded asphalt2	7 – 10 (standard binder)
Thin open graded asphalt2	10 – 15 (modified binder)
Dense graded asphalt	8 - 20
Stone mastic asphalt	10 – 20
Fine gap graded asphalt	15 – 25
Slurry/micro surfacing	5 – 10
Cape seal	8 – 15
Concrete3	30 - 40

Notes:
1. The service lives in this table are for average conditions and assume that the pavements are structurally sound.
Service conditions that affect the expected life include:
Traffic volume. High traffic volumes and high stress areas where there is turning and braking traffic will tend to give a service life near the low end of the range whereas lesser traffic volumes will result in longer service life.
Climate. High service temperatures generally reduce service life. High rainfall may also reduce service life.
2. Clogging or reduction in voids of open graded and thin open graded asphalt may reduce effective life
3. Maintenance issues in concrete pavements are normally related to construction problems, joints and cracking

Considering the data in Table 5.1and the design lives usually chosen for rehabilitation treatments, for a mature road network, about 8 – 11% should be resurfaced annually and about 1 – 5% rehabilitated.

6.0 PAVEMENT CONDITION

All road pavements are damaged by the traffic they carry, and the environment they are situated in. The greater the number of heavy vehicles in the flow, the greater the distress caused. (Heavy vehicles play the most significant part in causing pavement distress – the passage of one fully loaded semi-trailer cause's at least 30,000 times more structural damage than the passage of a car). The condition of a pavement depends primarily on the number of heavy vehicles in the flow, axle weights, tyre pressures, travel speeds, turning movements, as well as temperature and moisture conditions. The rate of change of the various condition parameters is of as much concern to those responsible for pavement maintenance as the absolute value of each condition parameter.

Pavement condition can be influenced by an increase or decrease in the number of heavy vehicles using the facility. The result of the damage imposed over a period of time is visible as deterioration in the pavement surface. The surface shows signs of structural failure. As it deteriorates, a pavement may become uncomfortable to travel over, it may become unsafe, and the road agency's costs for routine maintenance may increase. Road agencies must assess the pavement's current condition and monitor its performance over time. The costs of such assessments are a necessary and legitimate part of a maintenance program.

It is usually not helpful for engineering purposes to combine a number of condition parameters into one index or all cracking into one cracking parameter. Pavement engineers are first and foremost concerned with the cause and effect of the condition—the diagnosis.

While responsibility for a whole road network (as distinct from isolated short lengths) is a feature of the duties of pavement maintenance engineers, close attention such as evaluation of a pavement section, is usually required only when:

a) The particular section is showing signs of distress; or

b) A higher traffic loading is being considered such as an increase in the traffic volume or the traffic mix (cars/trucks/buses), or a decrease in travel speeds.

The requirements for a pavement evaluation are:

Surface condition	Based on visual inspection supplemented by data from automated surveys of condition parameters such as roughness, rutting, cracking, and surface texture. Will the surface protect the pavement structure?
Structural capacity	Will the pavement carry the loads that are going to be placed on it now, and in the future?
Safety	Is the pavement providing a safe travelling surface, now and into the future?

7.0 PAVEMENT EVALUATION PROCEDURES

7.1 Purposes of pavement evaluation

Road agencies evaluate existing pavements for the following three main purposes, listed in order of increasing detail:

* Medium to long term planning (known as network level);
* Short term planning (project level); and
* Pavement technology research.

The purpose of the evaluation should be the main driver of the details of the evaluation process adopted.

"Network level" surveys are used in pavement management, enabling less precise and longer term predictions of maintenance needs for pavements throughout the whole of a road network by monitoring trends in pavement condition. Evaluations of existing pavements for the purpose of planning and designing maintenance and rehabilitation treatments are known as "project level" investigations or surveys.

In a maintenance context, the main aim of project level pavement evaluation is normally to identify the precise mode and cause of failure or excessive deterioration. The findings of evaluations are used to design and implement maintenance treatments so that they will be effective in eliminating or controlling the causes of failure and in retarding the rate of deterioration.

Pavement evaluations should be designed to provide the necessary inputs for the selection and design of maintenance treatments.

For example, the typical inputs needed to design an overlay for a flexible pavement are:

* Deflection (maximum and characteristic)
* Curvature
* Site temperature (characteristic)

* Seasonal moisture adjustment
* Design traffic loading
* Failure mode - cracking (cemented base) or fatigue.

7.2 Pavement evaluation methods

There are a number of different methods of assessing the condition and maintenance needs of an existing pavement, including:

* Sampling and laboratory or in-situ testing of existing subgrade and pavement materials;

* Visual inspections from a moving vehicle (observations made by trained inspectors, desirably in the front passenger's position, or by video for subsequent interpretation, or both);

* Visual inspections where the observations are made and recorded by trained inspectors on foot;

* Automated surveys of selected pavement condition parameters; and

* Combinations of the above

Until about 1990, all specialised devices for road pavement condition surveys in Australia were owned and operated by the major road agencies. In recent years there has been increasing private ownership of automated equipment for pavement condition surveys.

8.0 MAINTENANCE MANAGEMENT

The process of developing and managing annual budgets and programs of maintenance work is complex and involves a wide range of inputs. The process can be considered as comprising two main parts:

Pavement Management
and
Maintenance Management.

In maintenance management, the emphasis is mainly on efficiency within an annual program. In pavement management, the emphasis is more on effectiveness over many years in maintaining the road network in acceptable standards at the lowest whole-of-life cost.

The main differences between efficiency and effectiveness are that:-

Efficiency refers to activities being done well, with regard to time, cost and quality - this is the area of maintenance management.

Effectiveness refers to doing the right activities, that is dealing with the appropriate locations on the network at an appropriate time and using the appropriate treatment - this is the area of pavement management.

8.1 What are maintenance management and pavement management systems?

Definitions for the terms maintenance management and pavement management are :-

> Maintenance Management System (MMS) - *A systematic approach to maintenance planning, budgeting and work, usually supported by software to assist in organising and analysing data on pavement and surface inventory and condition as well as on maintenance activities (e.g., type, costs, productivity, location, history).*

Pavement Management System (PMS) - *A systematic method of information collection and decision making, necessary to permit the optimisation of the use of resources for the maintenance and rehabilitation of pavements.*

Maintenance Management Systems usually operate within one program year at a time, whereas Pavement Management Systems, other than the most basic types, examine analysis periods of 5 to 20 years before recommending works programs for year 1 and subsequent years.

The purposes of Maintenance Management include:

- Assisting the works delivery organisation to monitor and improve:
  - the efficiency of its maintenance operations with respect to time, cost and quality
  - the productivity of their resources

- Providing information that assists in matching maintenance standards with realistic budget expectations and where necessary, generating lists of deferred maintenance

- Providing information for use as inputs to pavement management analysis, especially:
  - unit costs for work activities
  - locations where expenditure on routine and reactive maintenance is high
- Providing progressive information on expenditure, for comparison with the budget.

The main purposes of a Pavement Management system are to answer the following questions:

- What level of investment needs to be made to bring the pavements on the network of roads to the target condition standard and then to maintain the pavements to satisfy those targets over a long period?

- With the budget that is available or can reasonably be expected, what is the highest overall condition that can be achieved for the network of road pavements?

For a given budget size and a set of long term targets for pavement condition, what is the recommended program of pavement treatments?

Maintenance Management usually covers all maintenance for which the unit or organisation is responsible (both routine and periodic), including for example verge mowing and maintenance of drainage and signs. Pavement Management relates only to pavement expenditure and mostly excludes routine maintenance.

8.2 Maintenance management philosophy

Road maintenance and in particular, routine maintenance, normally comprises are number of distinct activities conducted in small quantities in a large variety of locations.

A typical road maintenance organisation may be responsible for an average of between 1,000 and 2,000 lane-km and up to around 5,000 lane-km. Significant funding may be allocated to activities such as minor patching, shoulder grading, crack sealing, edge repairs, verge mowing, etc.

In a construction project, tight operational control would be expected for work of similar cost. However there has been a tendency to exert a lower degree of management control of costs and productivity in maintenance. MMS is a tool to improve this.

Maintenance management aims to define activities, estimate costs and productivity rates and monitor actual progress against the estimates. In other words, with a MMS, the principles and techniques of project management are applied to road maintenance, in order to improve control on costs, productivity and expenditure.

The maintenance management cycle is identical to other management cycles, viz:

- Plan
- Organise
- Direct
- Control and
- Evaluate.

An overall aim in maintenance management is to minimise reactive maintenance. Reactive maintenance, while essential if the need arises, is not as productive as preventive maintenance. Savings in reactive maintenance can be directed to more productive preventive maintenance or safety improvements.

Important drivers for reducing reactive maintenance include:

economics - much reactive maintenance expenditure is not productive
occupational health and safety - special care is needed to protect personnel during unplanned work on pavements
excessive reactive maintenance can detract from the public perception of the organisation

In this context, managers who are experienced in maintenance are in a strong position to influence designers of new works and reconstruction to adopt minimisation of maintenance as a design criterion (see Fig 8.1).

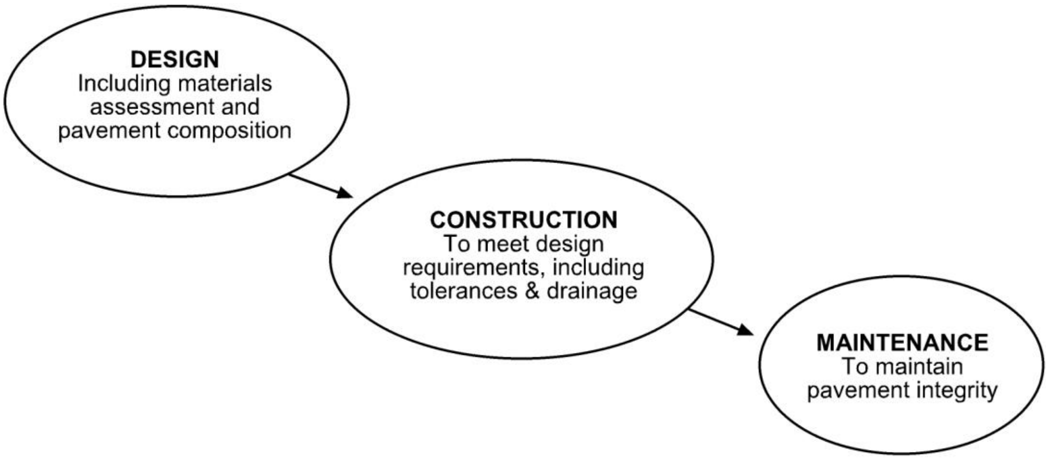

Fig 8.1 – A global approach is required to ensure good long term performance (Austroads 2004)

Potential areas for reducing maintenance include:

- Low risk pavement structures, particularly on strategic routes and where traffic volumes are high
- Carefully detailed subsurface drainage and stormwater outlets
- Maintenance free medians (e.g. low ground cover shrubs or concrete surfacing)
- Narrow shoulder areas sealed (e.g. between nominal edge of seal and safety barriers).

8.3 What benefits are expected from maintenance management?

Among the potential benefits of pro-active maintenance management are:

- Fostering a systematic and quality approach to the conduct of the maintenance works program
- Raising awareness of deferred maintenance as a quantifiable issue
- Ensuring that maintenance allocations are spent more transparently
- Improved job satisfaction and commitment among personnel.

8.4 Elements of a maintenance management system

MMSs, like all management systems, rely on inputs, conduct processes and produce outputs. Input information necessary for managing road maintenance includes:

- Road inventory and condition
- Defined work activities
- Levels of effort
- Available budget
- Other resources available and their costs (e.g., personnel, contractors, plant, materials)
- Seasonal constraints on work
- Work orders.

8.5 Planning in maintenance management

Planning is an essential aspect of both MMS and PMS. The usual boundary between planning at the maintenance management level and planning in a broader context is that **Maintenance Management begins with a fixed total maintenance budget**, with fixed programs for periodic maintenance and rehabilitation. The amount for routine maintenance is therefore also fixed. MMS is about planning, organising, directing, controlling and evaluating the use of the routine maintenance budget. The maintenance manager usually has considerable discretion as to the distribution of this amount among activities in the maintenance budget and locations for the work.

Planning in maintenance management relates to the distribution of available funding among routine maintenance activities such as pavement patching, rut correction, crack sealing, shoulder maintenance and maintenance of drainage and delineation.

8.6 Intervention levels (maintenance standards)

For sound maintenance management, intervention levels (also known as action levels, maintenance standards or trigger points) must be defined.

Intervention may be expressed in absolute numerical terms, (e.g. edge drop-off 50 mm), or as a range (e.g. cut grass when 300 mm high in normal circumstances, but not more than 500 mm high during summer growth period).

Response times are also necessary, particularly in a contract or service agreement. For example, “pot-holes are to be treated within 24 hours of being reported”, possibly in conjunction with something like “the National Highway is to be free of pot holes at 4.30pm every Friday”.
Successful administration of intervention levels relies on clear definitions (e.g. what is a pot-hole?) and repeatable measurement methods of measurement (e.g. how is grass height measured?).

Road authorities in Australia have gained benefit by subdividing their road systems into sub networks or road categories, on the basis of inputs such as travel speed, traffic volume, traffic mix and strategic importance. For each sub network, a set of pavement maintenance intervention levels are adopted. The sub networks formed for this purpose do not correspond to legal classifications such as National Highways. Higher maintenance standards are set for roads of greater importance, faster travel, higher traffic volumes and higher proportions of heavy vehicles.

To illustrate this, the intervention levels being considered by RTA NSW for cracking on flexible pavements are in Table 8.1

Table 8.1 - Examples of intervention levels for pavement cracking

Sub network	Intervention level	Response time
6, 5	* Any crack longer than 2m with an average width > 3mm * Crocodile cracking > 1 m2 with fines pumping	1 month
4, 3	* Any crack longer than 2m with an average width > 3mm * Crocodile cracking > 1 m2 with fines pumping	2 months
2, 1	* Any crack longer than 2m with an average width > 3mm * Crocodile cracking > 1m2 with fines pumping	3 months

Roads with the highest rank in terms of traffic volume, proportion of commercial traffic and travel speeds are in sub network 6, while those with lowest rank are in sub network 1.

8.7 Forms of service delivery for pavement maintenance

Traditionally in Australia, road pavement maintenance was conducted in-house by road organisations. However, in recent times, a strong trend has established towards contracting out of road maintenance generally, including pavement maintenance. In some cases, this has been accompanied by the formation of separate government business units or trading enterprises.

The trend towards contracting out is partly attributable to a wider trend to separate government responsibilities for policy from operational responsibilities, partly in response to the 1993 HORSCOTCI report Driving the Dollar Further and partly a consequence of early reports of considerable financial savings from contracting out. As well, some States have introduced Compulsory Competitive Tendering (CCT) requirements.

Contracting out has taken a number of broad forms, including:

- Service level agreements between separate divisions/branches of an organisation (with vertical and horizontal splits)
- Schedule of rates contracts for a comprehensive suite of road maintenance activity
- Bulk sum contracts for routine maintenance, with provision for the conduct of specific maintenance at scheduled rates
- Bulk sum long term “performance contracts”.

Schedule of rates contracts for maintenance typically have a large number of items and are expensive to administer. Contractors have found bulk sum contracts for routine maintenance difficult to price.

In performance contracts, which typically have a term of 10 years, the road owner specifies the condition that the network is to be in, when measured each year, including at the end of the Contract. Condition is normally measure in terms of skid resistance, deflections, roughness, rutting and cracking. Long time performance contracts carry the risk of loss of expertise within the road agency.

A central criterion in decisions about contracting out maintenance, including specification development, is the apportionment of risk. In general, risk should be attributed to the party best able to control it. A summary of some of the owner’s risks is in Table 8.2.

Table 8.2 Risk in delivery of road maintenance (road owner's perspective)

Nature of Risk	Direct Control (in-house)	Plant Hire	Schedule of Rates	Lump Sum/ Schedule of Rates	Performance
Financial risk	High	High	High	Medium	Low
Total costs	High	High	Medium	Medium	Low
Standards defined	Low	Low	Low	Medium	High
Contract document standards	Low	Low	Low	Medium	High
Contract administration skills	Low	Low	Low	Medium	High
Pavement management skills	High	High	High	Medium	Low
Emergency capability	Medium	Medium	Medium	High	High
Local knowledge	High	High	High	High	High
Technology	Low	Low	Medium	Medium	High

9.0 ASSET MANAGEMENT

A growing appreciation of the importance of Infrastructure Asset Management has been steadily progressing since about the mid-seventies in Australia with the parallel evolution of Pavement Management Systems across the country. This phenomenon is being stimulated by ongoing developments globally in the infrastructure asset management field with publications such as the 2011 edition of the International Infrastructure Management Manual (IIMM) published by the Institute of Public Works Engineering Australia (IPWEA) and the New Zealand National Asset Management Steering Group (NAMS)6, the British Standards Institution's (BSI) PAS 55 Asset Management specification for the optimal management of physical assets, and the start of preparations to produce an International Standard (ISO) standard for asset management.

"*There is now widespread recognition amongst infrastructure providers that it is not sustainable to focus on meeting infrastructure needs through investment in infrastructure creation, without recognising the long-term lifecycle costs associated with ongoing operation, maintenance and renewal of their networks*." IIMM (2011)

9.1 Historical Australian Context

Australia became an independent nation on 1 January 1901. The British Parliament passed legislation allowing the six Australian colonies to govern in their own right as part of the Commonwealth of Australia and the Commonwealth of Australia was established as a constitutional monarchy.

In Australia, power was divided between the then Commonwealth Government and the governments of the six colonies, which were renamed 'states' by the Constitution. 10

Specific areas of legislative power ("heads of power") were given to the then Commonwealth Government, including:

- taxation
- defence

- foreign affairs
- postal and telecommunications services

The states retained legislative power over all other matters that occurred within their borders, including:

- police
- hospitals
- education
- public transport

As a result of the formation of the states and territories, each with responsibility for transport infrastructure within their respective geographical boundaries, the development and management of the country's road transport infrastructure was fragmented and non-uniform across jurisdictions.

A conference of the Commonwealth and State Ministers for Transport in Melbourne in 1933 decided that there should be an annual conference of State road authority executives. As a result the NSW Commissioner for Main Roads instigated the First Annual Conference of State Road Authorities (COSRA) and wrote in his invitation that "it would be a good thing for us to meet as road men interested in the development of our states and transport facilities, and there are many problems which it is thought could be better dealt with jointly." (p. 84) 11

The first COSRA meeting took place in Melbourne over 3 days in February 1934. The agenda dealt with matters including the organisation of the conference, road finance and legislation, coordinating research and disseminating information, along with a number of technical issues.

The main benefit of COSRA is that it gave the State road authorities the opportunity to find out what other states were doing. Instead of each state trying to solve the same problems, they could make a separate but coordinated contribution to the solution.

9.2 Austroads

Following from those original meetings between representatives from the states and territories, the current day AUSTROADS has evolved. AUSTROADS, the association of Australian and New Zealand road transport and traffic authorities, purpose is to contribute to the achievement of improved road transport outcomes by:

- Undertaking nationally strategic research on behalf of Australian road agencies and communicating outcomes
- Promoting improved practice by Australian road agencies
- Facilitating collaboration between road agencies to avoid duplication
- Promoting harmonisation, consistency and uniformity in road and related operations
- Providing expert advice to the Australian Transport Council (ATC) and the Standing Committee on Transport (SCOT).

In 2010 Austroads launched a comprehensive suite of Guides covering all facets of road agency operations of the road network including:

- Planning and evaluation
- Design and construction
- Maintenance and management

The various Parts (totalling 96 in all) of the Guides include:

- Asset Management – 16 Parts
- Bridge Technology - 7
- Pavement Technology - 22
- Project Delivery - 4
- Project Evaluation - 8

- Road Design - 13
- Road Safety - 9
- Road Transport Planning - 1
- Traffic Management - 13
- Road Tunnels - 3
- Also a Glossary of Terms

Below is a list of the Parts to the "Guide to Asset Management"

Part 1: Introduction to Asset Management
Part 2: Stakeholder/Community Requirements (outcomes)
Part 3: Asset Strategies
Part 4: Program Development and Implementation
Part 5: Pavement Performance
Part 5A – Inventory
Part 5B – Roughness
Part 5C – Rutting
Part 5D – Strength
Part 5E – Cracking
Part 5F – Skid Resistance
Part 5G – Texture
Part 5H – Performance Modelling
Part 6: Bridge Performance
Part 7: Road Related Assets Performance
Part 8: Asset Valuation and Audit

The AUSTROADS Guides also provide the asset management framework and technical basis for the Centre for Pavement Engineering Education (CPEE) higher education material and programs, and are also used to assist research for the pavements industry.

9.3 Challenges for 2012

Although many significant developments and improvements have been achieved over the years, there remains a number of challenging issues that are yet to be resolved, all of which are critical to the implementation of best practice pavement asset management.

Underlying sound asset management, and specifically for this audience, pavement asset management, is sound decision making based on reliable information. One of the critically important elements of this information is performance data. High quality performance data is fundamental to the understanding of how things have performed in the past in order to understand or predict how things will perform in the future. The performance of pavements, including pavement design methodologies, treatment type selections, construction methods, material characteristics, environmental influences etc all have an impact on the decision making framework employed in pavement asset management.

9.4 Laser Profiling

High speed laser profilometry is now commonly utilised throughout Australia with nearly all SRA's collecting laser profile data for most of the main road network annually. The equipment and testing methods have gained widespread acceptance for network performance assessment and the data is routinely used for inputs into the predictive models incorporated in pavement management systems.

The typical data types captured using the multi-laser profiling equipment includes:

- Roughness, (International Roughness Index (IRI)
- Rut Depth,
- Mean Profile Depth (MPD),
- Sensor Measured Texture Depth (SMTD)

Associated with the rapid improvement in data processing and data storage capacity, is the significant development in the capability and functionality of pavement management systems which has occurred during the last decade.

9.5 Pavement Management Systems

A wide range of proprietary software solutions are utilised throughout Australian state and local governments for road management tasks. At the state level, the PIARC HDM 4 and the Canadian dTIMS asset management software packages are predominantly being utilised as network asset management tools, while at local government level, a wider range of packages are being used.

Pavement deterioration is a fundamental input into any pavement performance prediction. Research performed by ARRB over the last decade has been used to calibrate pavement deterioration models for pavements over the wide range of conditions that are encountered in Australia.

Variations in topography, subgrade strength, temperature and rainfall, have been modeled for various conditions and further refinement and calibration of the model assumptions continues.

The use of Geographical Information Systems (GIS) and the rapid sophistication of user interfaces has seen broad based uptake of mapping systems. These tools have assisted pavement asset managers in the presentation of plans and programs which have previously only been readily understood by engineers rather than the asset users.

In Australia, the RTA and CSIRO (Commonwealth Scientific & Industrial Research Organisation) have jointly developed the traffic speed road crack detection device “RoadCrack” , This device is providing valuable data, critical to the understanding of pavement deterioration in both rigid and flexible pavements.

9.6 Data Issues – uniformity and harmonisation

As previously discussed, the formation of the states and territories in Australia has resulted in a diverse range of test methods and specification requirements being developed for essentially the same performance criteria pertinent to the performance of roads. During the last twenty years significant rationalisation of the diversity of differing test methods has been achieved. This has been achieved through broad adoption of the Austroads guidance publications by state road authorities (SRA’s) and supported by the ongoing contributions of the Australian Asphalt Pavement Association (AAPA)12 and other industry representative associations such as the concrete institute (CIA) 13, and a collaborative relationship between Austroads, ARRB and the SRA’s.

Whilst significant progress has been made, there remain gaps in the availability and in the format of data from the various state road authorities (SRA’s) which make the aggregation of data and any subsequent comparisons or analysis difficult and dependent upon numerous qualifications, thus reducing the reliability of any subsequent decisions based on these data sources.

Uniform and consistent performance measures across state and territory jurisdictions are an ongoing challenge and a current area of focus for Austroads and its members. Whilst significant progress in harmonisation of data has been made, reporting of other information, such as historical maintenance treatments and expenditures, are not usually available in a consistent format across jurisdictions.

Similar to many other locations around the world, Australia is facing the challenge of incorporating improvements in heavy vehicle transport capabilities within the current capacity and limitations of existing transport infrastructure. There are significant economic drivers which are influencing policy decisions around land transport efficiencies which depend upon reliable, accurate and informative data. The current status of data, at a national level, is not readily available in a consistent and comparable format and further work in this area is required.

The introduction of Performance Based Standards (PBS) is indicative of the current direction of the Australian government in its attempts to improve efficiencies in the utilisation of existing infrastructure and in the planning and design of future infrastructure requirements in order to deliver expected performance outcomes.

Austroads through its strategic alliance with ARRB Group14 has initiated a number of specific projects aimed at collecting, analysing and interpreting performance data to support future policy initiatives.

One example of a recent initiative is the trialling of the traffic speed deflectometer.15 The summary of the report provides the following:

"The New South Wales (NSW) Roads and Traffic Authority (RTA), engaged the Danish Road Directorate (DRD) to bring its Traffic Speed Deflectometer (TSD) to Australia. Some 18 000 km of the NSW and Queensland (QLD) road networks were surveyed over the 2009/10 Australian summer. While a preliminary assessment of the TSD indicated it could provide reliable and repeatable measurements on the mainly asphalt pavements encountered in Denmark, its performance on granular pavements like those typically encountered in Australia was unknown. This project was established to enable ARRB and Austroads member authorities to work with the RTA to develop an independent national perspective on the applicability of the TSD to Australian conditions and practices."

Another significant challenge facing the country is the increase in traffic volumes, particularly the increase in the size and number of heavy vehicles used for the movement of freight in rural areas, which has placed greater demands on the performance of sprayed seals.

Sprayed seal surfacings are the most common surfacing type in Australia representing about 90% of sealed road length. The technique of sprayed sealing was adopted in Australia because of its relatively low cost and speed of construction compared to other forms of pavement surfacing, and has been the mainstay of road authorities in Australia to provide a safe, all-weather rural road network.16

Where asphalt is the preferred treatment in urban areas, on heavily trafficked urban freeways and arterial roads, and areas of high traffic stresses, sprayed sealing is the surfacing treatment commonly used in rural areas, and is the most economic type of surfacing for the rural road network. Along with the increases in number, size and mass of heavy vehicles, has been an increase in the proportion of sprayed seals that have failed to meet performance expectations.

There is growing concern that some surfacing treatments, such as sprayed seals, which have previously provided good service over many years may be at the limits of their performance in some circumstances, particularly under very heavy loading conditions.

9.7 Heavy duty pavements

The Austroads (2010) Guide to Pavement Technology, Part 2: Pavement Structural Design17, provides the following general statement regarding pavement design:

'The aim of pavement design is to select the most economical pavement thickness and composition which will provide a satisfactory level of service for the anticipated traffic. To achieve this goal, the designer must have sufficient knowledge of the materials, the traffic, the local environment – and their interactions – to be able to predict the performance of any pavement composition. In addition, the designer must have knowledge of what level of performance, and what pavement condition, will be considered satisfactory in the circumstances for which the pavement structure is being designed."

Another factor associated with increasing traffic volumes, is that pavement thicknesses are also increasing and more heavy duty pavements are being constructed to meet the forecast traffic demands. Whilst the number of these heavy duty pavements being constructed is increasing, reliable historical performance data is not widely available and it will be some years before the real in service performance of these pavements under very heavy traffic conditions can be reliably predicted.

Research performed by ARRB using the Accelerated Loading Facility18 is providing valuable information about the performance of a range of pavement types, however the number of test pavements is relatively small and the testing relatively expensive. The Accelerated Loading Facility (ALF) is used to simulate heavy vehicle trafficking on pavement structures under controlled conditions. This allows pavement performance to be evaluated in a very short time compared with test sites under normal traffic.

9.8 Forms of contract

The past twenty years or so, has seen an increase in *outsourcing* of road construction and maintenance works. Where SRA's had historically maintained large workforces of experienced highway construction and maintenance personnel, the current practice in Australia is for the highway agency to manage the highway network and procure by contract all of the construction and maintenance services through open tender bidding. One implication of this move has been the formalisation and documentation, sometimes for the first time, of specific performance measures applicable to the service levels required under the contracts.

Performance criteria are increasingly being incorporated in Design & Construct Contracts which specify pavement characteristics for attributes such as roughness, rutting, cracking, texture and strength which are to be achieved at the end of the defects liability period, which sometimes can be up to ten years after construction. These contractually binding requirements, often with significant payment adjustments applicable for non-compliance, have meant the test methods and measurements used for performance assessment purposes are clearly defined, well understood and highly repeatable.

Where once these measures were used to support decision making for pavement asset management, they are now being used as performance conformance measures and thus their reliability is under increased scrutiny. Non-destructive, highly repeatable and low operational impact testing is increasingly being required for contract performance assessment and devices such as the Traffic Speed Deflectometer are showing promising signs of improved efficiencies for the future.

10.0 THE EDUCATION AND TECHNOLOGY CHALLENGE

Future improved performance is however threatened by the continuing loss of experienced road and pavement engineers, resulting in the evaluation of pavements and the selection of the most appropriate maintenance and rehabilitation being undertaken by less experienced and knowledgeable engineers. Today's roads and pavement engineers however need to be more skilled and knowledgeable, and this is a priority issue in Australia, and becoming more so globally.

How we achieve this is a major task and old paradigms are no longer valid as we continue to become a more global society and technology provides new opportunities.

To enhance the standing of roads and pavements sector for attracting engineers, and to provide improved education and training of our current engineers and technologist, systems and learning materials for personal and career development need to be improved, and readily accessible.

It is a cause for concern that due to the diminishing extent of competency within the industry, much of the expert knowledge and experience doesn't reside, as it once did, within those now required to undertake their specialist roles. Many have not had the appropriate background experience and level of skill development that would have been held by the person who previously undertook the work. This is occurring in roles from design and construction to maintenance and to asset management.

10.1 Engineering skills shortage

In Australia, when considering the issue of the engineering skills shortage we need also to be aware of the bigger picture of the changing demographics and the impact this will have on the supply of labour in the future. It is believed this is mirrored in much of the developed world, however the focus on this aspect of the paper in relative to the Australian environment. In relative terms, there are just not enough young people in our population to be trained. We are an ageing population.

The Australian Government's Intergenerational Report (IGR) projects that over the next 40 years, the proportion of the population aged over 65 years will almost double to around 25 per cent.

- At the same time, growth in the population of traditional workforce age, 15 to 64, is expected to slow to almost zero. This is a permanent change.
- This will have a profound effect on the economy and, potentially, on our living standards.
- In 1970-71, 31 per cent of the population was aged 15 years or younger, while by 2001-02 this proportion had dropped by 30% to 22 per cent.
- The number of Australians aged 65 and over is expected to increase rapidly, from around 2.5 million in 2002 to 6.2 million in 2042. That is, from around 13 per cent of the population to around 25 per cent.
- In 2002 there were more than five people of working age to support every person aged over 65. By 2042, there will only be 2.5 people of working age supporting each person aged over 65.

- There is therefore a major replacement task ahead as, 42% of the present workforce are baby boomers

Much of the focus of recent times has been about training up current and new engineers, but the situation now crystalising is that this is a concurrent battle where we are also competing for a shrinking pool of potential engineers and technologists. The numbers of young coming through in relative terms just aren't sufficient to be educated/trained to feed the demand.

Attracting young people to take up engineering is increasing in difficulty especially as there is a stagnant or declining interest from school leavers in undertaking engineering courses and the number of universities offering traditional graduate civil engineering courses are also diminishing. With the university system more and more about financial viability they are less able to ‘justify’ and conduct the courses that are the very breeding grounds of the roads engineer. The cost of good civil engineering laboratories with the equipment and the space, when low utilisation occurs, is but one of the influencing factors.

Another change to impact on traditional advancement modes, is the lessening of the possibilities to gain further education, targeted to ones chosen profession, by undertaking post graduate courses with subjects directly related to ones career engineering based role. In the past most capital cities and the big rural cities had a tertiary college or university offering such courses, but today these have virtually all but disappeared. The Master of Business Administration (MBA) has become the qualification of advancement, further impacting on the skills shortage as good progressive engineers choose to learn more about being managers.

Attracting “new” people, from the existing workforce, to join the roads and pavements sector faces many challenges, among them being an industry with a poor image, perceived lack of career path, other options providing better remuneration, long hours and concerns over health and safety. In Australia the mining sector remains very strong and growing in activity and is a major challenger for engineers looking at changing jobs. Their ability to pay substantially more than “market” rates has seen many young engineers and technologists take up oportunities providing a further drainand challenge for the roads sector in its recruiting endeavours.

Further to this retaining engineering and technologist specialist staff is challenging as today long term employment of the younger generation often means a 2-3 years stint, thinking nothing of moving from one employer to another. Whilst much of this attitude has resulted from the good economic climate that persisted for decades , employers, as much as employees, had encouraged the turnover mentality. However this does not suit industry sectors such as the roads sector where in reality it can be detrimental overall, for the work is as much an art as it is a science. Being a part of the history of projects and seeing outcomes 10 -15 years later, can be fundamentally important to ongoing decision making.

Much of the above means that retaining older people for longer is needed now as our current stock of engineers are ageing and early retirements are diminishing the adequate passing on of hard earned experience and knowledge. With employment demand exceeding supply, more frequently we are seeing engineers being forced into roles and decision making they are often not ready for, and for which they lack mentors to help them cope adequately. We are therefore inheriting a workforce that is less experience, as each year passes.

10.2 A positive step in improving knowledge, skills and career standing

For many years in Australia there has been a concern about the future availability of technically competent engineers and technicians to meet future demands specifically in the flexible pavements sector.

This concern was identified in the early 90s by AAPA representing industry. AAPA was then joined by the government “Association”, Austroads, (representing Government-State Road Authorities) and the Centre for Pavement Engineering Education (CPEE) was formed in 1964 and became operational in 1996. Into the 1990’s the . Road agencies were largely abandoning their training role and the universities were unable to respond to the highly technical courses sought by young pavement engineers preparing their career paths. Industry was also keen to ensure that their existing (and future) engineers and technicians were well informed and possessed the skills necessary to operate effectively in a competitive and innovative environment.

CPEE developed educational units focussed on the immediate needs of the industry (private and Government sectors) and the pavement engineers and technicians employed by industry. Rapid and effective education/technology transfer has been achieved by carefully designed distance learning programs making on-going education possible in every part of Australia reaching even the remotest locations. The learning has also extended to service many countries through out the world, including many within Europe.

CPEE's unique and targeted Graduate Certificate, Graduate Diploma, Master of Technology and Master of Engineering provide for engineering professionals and technicians to enhance their specialist industry specific knowledge and technical skills, thus effective ly providing a now well established and regarded means of meeting the current employee educational needs. In addition, by creating these specialist courses, recognising a select group of engineering professionals, it elevates the awareness and standing of the roads and pavements engineers and technicians and provides a qualification that enhances the standing of the profession.

A major incentive for "students" and employers alike is that the undertaking of a CPEE course is a guarantee that the "student" will have studied up-to-date industry nominated material (Government and Industry approved) with access to tutors who have significant standing in the industry itself.

CPEE qualifications have raised the bar and provide unique recognition and elevated status to those who successfully complete a qualification.

With the units of study developed by industry experts, mentors who are industry experts and study material revised regularly by industry experts, CPEE has trapped the knowledge and expertise that we face loosing as retirements rob us of the ability to adequately foster and develop those entering the road construction sector.

Industry, and road authorities are all loosing expertise and experience with retirement of acknowledged experts. Are the knowledge enhancement programs of individual organisations for existing personnel delivering desired outcomes? Anecdotal evidence indicates the retention of the "knowledge and wisdom" from these retiring experts is not occurring, or being appropriately passed on, in both the government and private sector. CPEE units are collecting and professionally holding (via units of study) much of the knowledge and hard earned experiences which the new/inexperienced engineers can learn from. Importantly, this knowledge is being updated regularly to ensure its currency.

CPEE also provides the complete "educational package", with students able to apply their newly gained knowledge and skills immediately. In this way, there is little lag between learning and application.

The CPEE and its partner University (University of Tasmania – Utas) qualifications are unique qualifications, not just because they are specialised and largely not on offer anywhere else in the world, either as a disrance learning option or even face to face, but importantly also because they are practical and heavily industry-oriented. The individual subjects, or the complete Course can be studied from any location in the world.

The qualifications are gained via postgraduate distance learning study "units" designed initially to enhance engineering outcomes in pavement design, construction and maintenance. This focus has recently been broadened to include related units in maintenance, rehabilitation, asset management, business administration and environment aspects. Most recent additions to the growing offerings currently at 14 specialised units have been units within "road engineering" such as "Fundamentals of Road Construction" and "Road Drainage".

Working primarily through the University of Tasmania, but also with other selected individual universities and institutions, CPEE has now an enviable track recoer of providing a logistically superior solution to the problems of time and distance facing many students. The unique Graduate Certificate, Graduate Diploma and Masters programs are innovative since they tie the qualifications specifically to an industry as distinct from an open, often unrelated, mix of subjects.

These uniquely specialised, highly relevant technical programs are now producing professional engineers with expertise in pavements well beyond past outcomes.

Enhanced take-up of improved technology and innovations results from this unique and world class learning model.

10.3 Technology- potential for future benefits

Whilst improved education and training will no doubt help with improving the capability of those working within the industry, and will greatly assist in providing a career path - formalised personal development, making the industry more attractive to be part of, it does not in itself provide the full soloution.

Technology and the development in iPads and other mobile phone devices which can rapidly collect and deliver high quality video, data, text and sound, just about anywhere, provides attractive options for improved learning. The capability and adaptability of the electronic medium must be explored further.

In Australia, because of its vast distances and low population density, especially outside its capital cities and its eastern seaboard where over two thirds of its population resides, a significant development in the medical field has occurred by necessity. Similar to the roads sector, the medical profession has faced a critical shortage of skills and experience, Doctors, willing to work in rural regions and as a result many towns have lost or were loosing, through retirements, poor health or relocation, their general practitioners, and in the Rural Cities they were also loosing their medical specialists.

Faced with this, and without significant success in additional recruitment, either through the Univrsity system, or by "importing" Doctors from overseas, the use of technology has been employed to minmise the impact where possible. The Australan Royal Flying Doctor service was created many years ago to enable Doctors to be flown to patients in remote areas in emergencies when crital hours and possibly days would be needed to have the patient reach the nearest hospital or medical centre. This proved an outstanding success, however its future was being threatened by the shortage of Doctors.

A recent trial has resulted in development of medically servicing in homes, by less qualified personell, and often by family members as required, but under instruction of qualified medical practitioners or specialists who are now able to receive instantaneously, vital patient information through electronic means. With computer and internet compatability a patients condition, in respect of both physical appearance and vital signs information can be assessed by qualified persons located hundred or thousands of kilometers away.

If we consider all the technology currently available, and with adaptation to our industry, then it is feasibly that we can follow in the foots steps of the medical fraternity in Australias "outback", and use technology to help overcome the shortage of engineers and technologists. With instantaneous transfer of video material for visual assessment, supported by real time on-site collected data, analysed against known initial design and construction data, and any subsequent updated data, it is quite possible that in the future there will be an outcome where industry specialist in asset management will reside in a "virtual" office making assessments and decisions for "clients" , who may well be the industry at large, thus minimising the number of engineers required and maximising the utilisation of expertise otherwise in short supply.

More specialists may be the answer, but as replacement of the many more "generalists" often viewed as "specialist" by default, in areas such as pavement maintenance , rehabilitation and asset management when technology is creatively used to enable cost effective and resource utilisation to be maximised.

Technology transfer, education and the optimisation of maintenance and rehabilitation are inextricability linked and success in enhancing each will play a big part in the sustainability of the asphalt road in the future.

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REFERENCES

[1] Australian Government Geoscience Australia website
http://www.ga.gov.au/education/geoscience-basics/dimensions/area-of-australia-states-and-territories.html

[2] Australian Bureau of Statistics, Yearbook (various years)
http://www.abs.gov.au/

[3] Commonwealth of Australia Grants Commission
http://www.cgc.gov.au/fiscal_equalisation/the_commissions_methods/road_maintenance2

[4] List of OECD countries by road network size
http://en.wikipedia.org/wiki/List_of_OECD_countries_by_road_network_size

[5] Facing up to the growing freight task (2006), Australian National Transport Commission
http://ntc.gov.au/NewsDetail.aspx?NewsId=172

[6] IIMM (2011), International Infrastructure Management Manual
Version 4.0, 2011 ISBN No: 0-473-10685-X , National Asset Management Support Group (NAMS Limited), PO Box 25315, Panama Street, Wellington 6146, New Zealand
http://www.ipwea.org.au/bookshop/iimm/

[7] Department of Transport and Regional Services Bureau of Transport and Regional Economics, AN OVERVIEW OF THE AUSTRALIAN ROAD FREIGHT TRANSPORT INDUSTRY
Commonwealth of Australia 2003, ISSN 1440-9707, ISBN 1-877081-44-2
http://www.bitre.gov.au/publications/77/Files/wp60.pdf

[8] AUSTROADS
http://www.austroads.com.au/

[9] NTC_Twice_the_Task_Final_Report.doc (2006) , National Transport Commission
http://www.ntc.gov.au/filemedia/Reports/TwiceTheTaskReportFeb2006.pdf

[10] Australian Federation – The Australian Government
http://australia.gov.au/about-australia/our-government/australias-federation

[11] AUSTROADS, NAASRA and COSRA, A history of Austroads and its predecessors
http://www.ozroads.com.au/NationalSystem/naasra.htm

[12] Australian Asphalt Pavement Association (AAPA)
http://www.aapa.asn.au/

[13] The Concrete Institute of Australia
http://www.concreteinstitute.com.au/

[14] ARRB Group
http://www.arrb.com.au/home.aspx

[15] Austroads (2011) Review of the Traffic Speed Deflectometer – Final Project Report Austroads Project No: AT1613, Sydney NSW 2000 Australia

[16] SPRAYED SEALING PRACTICE IN AUSTRALIA, Walter Holtrop, Australian Asphalt Pavement Association, Australia
http://www.arrb.com.au/sealing/PDF/Sealing%20Practice.pdf

[17] Austroads (2010) Guide to Pavement Technology, Part 2: Pavement Structural Design

[18] Accelerated Loading Facility
http://www.arrb.com.au/admin/file/content2/c7/ALF%20broch_Lres.pdf