“A Stitch in Time” Pavement Strategy Over 15 Years

Ian Cossens
Manager, Asset Strategies, VicRoads, Victoria, Australia

ABSTRACT

In 1994 VicRoads adopted its “A Stitch in Time” pavement strategy. The essential elements of the strategy were to carry out:

- Routine maintenance (day-to-day maintenance) where the strategic aim was to minimise the deterioration of the pavement and provide safe and acceptable road conditions at least overall cost to the community.
- Periodic maintenance (cyclically planned maintenance) where the strategic aim was to provide a safe riding surface, and reduce the need for more expensive rehabilitation or excessive routine maintenance by waterproofing the pavement.
- Rehabilitation Maintenance to progressively achieve road conditions that meet the standards in the “A Stitch in Time” strategy, by using the most cost-effective treatments in terms of life-cycle costs.

These components were strongly targeted and helped change the culture of VicRoads by recognising essential works and providing the direction for maintenance works.

VicRoads still uses the “A Stitch in Time” policy for road maintenance however continual review of what was being achieved, and what could be done better; has resulted in the changes and a better understanding of our network.

This paper discusses the:

- Original development of “A Stitch in Time”
- The guidelines for works which stand behind the “A Stitch in Time” policy,
- Some of the investigations that reviewed what “A Stitch in Time” was achieving, its successes and issues still facing the policy.
- Existing and new performance indicators of the condition of the VicRoads network.

VicRoads is the State Road Authority that manages approximately 23,000 carriageway kilometres (14,400 mile) of arterial roads of the 130,000 kilometre (81,000 mile) network in Victoria, Australia. It manages two types of network, an asphalt (bituminous concrete) surfaced network comprising approximately 25% of the network and a sprayed seal (chip seal) network comprising approximately 75% of the network.

DETAILS OF THE VICROADS NETWORK

The VicRoads arterial road network consists of approximately 22,400 carriageway kilometres (14,000 mile) and 51,000 lane kilometres (32,000 mile).
Road pavements are VicRoads’ most significant infrastructure asset, valued in 2008 at approximately $A10.9 billion compared to the total road network asset value of $A21.2 billion.

The State of Victoria is divided into seven regional areas for the management of the major road network. The seven Regions have essentially seven different networks with different climates and geological features, traffic loading and historic treatment regimes. The five rural networks are essentially spray seal surfaced networks, generally over natural gravels, while the two metropolitan networks are 50% to 75% asphalt surfacing.

In the metropolitan areas the pavements are more robust and 50 to 75% have bituminous concrete (asphalt) surfaces. The bituminous concrete (asphalt) surface thicknesses vary from 50mm (2 inch) to around 100mm (4 inch) although there are many deep strength asphalt pavement with generally a cement treated subbase and asphalt thicknesses varying from 175mm to 300mm (9 inch to 12 inch).

THE “A STITCH IN TIME” THEME

The “A Stitch in Time” theme comes from an old English proverb.

The proverb is that “A stitch in time saves nine (stitches at a later date)”. The essence of the proverb is that if you repair something while the problem is small you will prevent or at least substantially delay major works resulting in substantial cost reductions and savings.

STRATEGIC AIMS OF “A STITCH IN TIME” PAVEMENT STRATEGY

Strategic Objectives of “A Stitch in Time”

The strategic objectives of “A Stitch in Time” are to use preventative maintenance and to maintain the network in its current condition or improve the network by:

- Better conditions on higher speed roads than lower speed roads;
- Better conditions on busy roads than lesser trafficked roads;
- Suitable road conditions are maintained at the least cost to the community;
- The right cost-effective maintenance treatment is applied at the right time to ensure that expensive rehabilitation is not required or the need is significantly delayed and that road conditions are maintained at the least cost to the community.
- To minimise long-term maintenance costs, works focus on timely prevention rather than necessarily providing a cure.

These objectives are translated into strategies for the Routine, Periodic and Rehabilitation Maintenance components.

Routine, Periodic and Rehabilitation Maintenance

Pavement maintenance is considered to comprise three different components as follows:

- Routine Maintenance is the day-to-day maintenance of a pavement such as pothole repair, repair of minor depressions and many other day-to-day running repairs,
- Periodic Maintenance is planned maintenance on the pavement which involves resurfacing works which are expected to be undertaken every 10 to 20 years, and
- Rehabilitation Maintenance undertaken when the pavement is not providing an appropriate level of service (measured by roughness and maintenance costs) and major works need to be undertaken.
Figure 1a, 1b and 1c. Details about Australia, Victorian arterial roads and VicRoads Regions
The strategic aims of Routine Pavement Maintenance are to:

- Meet the requirements of the Road Management Plan by achieving the standards given in VicRoads routine maintenance specification;
- Minimise the deterioration of the pavement hence reduce periodic and rehabilitation costs;
- Provide safe and acceptable road conditions; and
- Achieve this at least overall cost to the community.

The strategic aim of Periodic Pavement Maintenance is to:

- Waterproof the pavement and thereby reduce excessive routine maintenance expenditure and the need for more expensive rehabilitation treatments; and
- Provide an appropriate running surface

The strategic aim of the Pavement Rehabilitation Program is to:

- Progressively achieve road conditions that meet the objectives in the VicRoads Pavement Strategy (i.e. A Stitch in Time Strategy).
- Utilise the most cost effective treatments in terms of life-cycle costs and network needs.

**Interaction of the three components**

The “A Stitch in Time” strategy targets:

- Routine Maintenance where it is cost effective to ensure safe travel conditions and minimise pavement deterioration,
- Periodic resurfacing to waterproof pavements, minimise pavement deterioration and defer the need for more expensive pavement rehabilitation where pavement distress is beyond the limits of Routine Maintenance, and
- Rehabilitation maintenance to repair rough roads or those with excessive maintenance which are beyond the capacity of Routine Maintenance or Periodic Maintenance to repair to an economically satisfactory level.

This interrelationship between the three forms of maintenance is shown in Figure 2. The interrelationships are further explained below:

- Unless routine maintenance is adequate the serviceability of the pavement will deteriorate rapidly and we will not get the full potential of the surfacing or pavement resulting in the need for more periodic and rehabilitation repairs to maintain the level of serviceability.
- If periodic maintenance is not carried out at the appropriate time there will be an increased need to carry out extensive routine maintenance leading to the early need for expensive rehabilitation maintenance.
- If rehabilitation maintenance is not carried out at the appropriate time there will be substantial decrease in the level of serviceability and an increase the need for routine maintenance (and probably periodic maintenance).

**ORIGINAL IMPLEMENTATION**

The original implementation involved:

a) Defining what was required in Routine Maintenance and benchmarking costs per lane kilometre across Regions via performance routine maintenance contracts
b) The periodic coverage (treatment) of a fixed percentage of the network using sprayed seals (chip seals) and a maximum of 40mm of asphalt (bituminous concrete)
c) The rehabilitation coverage of areas selected so that 20% or more of the treatment length had roughness greater than 4.2 IRI (i.e. it was moderately or very rough). The candidate projects were prioritised based on a simple, pseudo-economic formula.
The periodic coverage requirement was approximately 9% of the network (which brought total coverage to approximately 10% when rehabilitation was included). This coverage was intended to ensure that the network remained waterproof hence would ensure that deterioration was minimal.

The original rehabilitation coverage rate was 1% of the network. Rehabilitation projects were ranked (valued) using the following formula:

\[
\text{Ranking value} = (\% > 4.2) \times D \times T \times L / C
\]

Where:
- \(\% > 4.2\) = The percentage of the treated segment that was greater than 4.2 IRI (with a minimum percentage of 20%)
- \(D\) (Rate of change of roughness, derived from three successive roughness surveys/year) =
- \(T\) (Traffic Volume) = Traffic volume (up to a maximum of 2000 vpd rural and 4500 vpd urban)
- \(C\) = Unit cost of treatment ($ per m²)
- \(L\) = Expected treatment life (years) (Maximum 20 years)

Projects were strictly targeted on roughness, if the proposed project did not meet the minimum \(\% > 4.2\) IRI or it did not rank well it was rejected.
RESULTS OF THE ORIGINAL STRATEGIC APPLICATION

Routine Maintenance

Benchmarking of routine maintenance costs had the effect of driving down routine maintenance costs and the concentration of staff and contractors on safety related matters.

It is unclear whether benchmarking achieved improvements in routine maintenance or minimised preservation works in preference to safety related works.

Periodic Maintenance Coverage

In both the rural and metropolitan regions the periodic coverage requirements were generally accepted although there appeared to be concern that the concentration on coverage was excessive. Some Regions felt the coverage rates were marginally too high.

Rehabilitation Maintenance

The ranking formula generally determined which rehabilitation projects were selected for funding. This concentration on the ranking formula resulted in:

- Encouraging projects which were relatively inexpensive. Cost was on the numerator (bottom line) and increased the score, hence the chance of funds being made available. This was considered good.
- Encouraging projects with high deterioration rates and high traffic volumes. These factors were both on the denominator (top line) hence increased the chances of funds being made available.
- Encouraging projects with high percentages of the treated length greater than >4.2 IRI. This was generally considered good however in the metropolitan regions the treatment of 500m lengths where there were short, unusual roughness spikes generally over about 100m was of concern.

The ranking formula in the rehabilitation program encouraged innovative treatments and forced proposers of projects away from “rebuilds” and substantial resheets\(^1\). Innovative treatments to improve (reduce) roughness included regulation with slurry seals or thin asphalt followed by resealing. If the pavement was badly cracked often these innovative treatments included geotextiles which reinforced the surface and minimised the return of cracking.

The concentration on roughness also resulted in the transferral of traditional periodic maintenance projects to the rehabilitation program to increase the area of the particular region’s network being treated.

Influence of Key Performance Indicators

The key performance indicators for “A Stitch in Time” are:

- The percentage of the network greater than 4.2 IRI (>%4.2 IRI)
- Smooth travel exposure (STE\(_{4.2}\)) which is a measure of the proportion of travel undertaken on smooth roads and is calculated based on the proportion of the network below 4.2 IRI
- The percentage of the network cracked (treated or untreated)
- The length of distressed pavement.

The results of the first five years of the strategy showed significant reductions in the %>4.2 IRI and significant improvements in the STE\(_{4.2}\), refer to *Stitch In Time - Five Years of Successful Road Maintenance in Victoria*.

---

\(^1\) A resheet in the sprayed seal network consists of ripping the existing surface and adding one, two or three 100mm layers of crushed rock or natural gravels and resealing the surface. This treatment is expensive but it adds strength to the pavement.
General

Over time questions were asked about how to do things better. This led to many changes in an attempt to improve performance.

Routine Maintenance

Attempts to improve the performance of Routine Maintenance have been made through amendments to the routine maintenance specification. These changes include:

- Increasing the term of the Contract so that the contractor had more ownership
- Increasing the area of major patches from 5m² to 30m² where the responsibility transferred from the contractor to VicRoads to pay for the repair. The aim of this change was to encourage the contractor to repair the patch early rather than have it grow to the point it became VicRoads’ responsibility
- Reducing the risk in routine maintenance from almost totally the contractors to a more equitable risk sharing
- Changing contractual relationships from traditional to a more partnering model.

Periodic Maintenance

Resealing Component: In the periodic resealing program we asked “Why are we resealing these roads?”

A contractor was given the research so it was independent of VicRoads. The answer came back that we were resealing because in about 60 to 85% of the cases the inspectors felt the bitumen binder (asphalt in USA terminology) was old and oxidized and soon would allow rapid deterioration of the pavement. See Figure 3.

VicRoads provides guidance on prioritising pavements to be resealed using the SIRP score (Surface Inspection Rating Procedure). This procedure ranks or scores seven surface condition parameters using scores of 0, 1, 3 and 5 and totalling the scores to provide an indication of the likely needy projects.

Figure 3. Average SIRP ratings for different elements in different Regions
The assessment of the binder (asphalt) condition parameter, intended to indicate the degree of oxidation hardening of a seal binder, is done by visually ascertaining the viscosity (consistency) after rolling the aggregate pieces in the hands and the adhesion properties of the binder sticking to the aggregate particles as they are removed from the seal at 20°C Celsius.

The laboratory evaluation of the binder (asphalt) was also considered as part of the research. This research indicated that the “cracking” life of the binder was significantly higher than the SIRP visual assessment indicated.

As a result of this research VicRoads decided to decrease its coverage rate in the sprayed seal network from 10% (including rehabilitation) to 7% (including rehabilitation). This reduction in coverage rate allowed the reinvestment of approximately $A30m/year on other parts of VicRoads Assets.

Asphalting (Bituminous Concrete) Component: In the periodic asphalt (bituminous concrete) resurfacing program we asked “Why are we resurfacing these roads?”. VicRoads undertook an audit of random projects to subjectively assess value on the projects selected. The audit suggested that there was significant value to be obtained by further training staff to recognise the real needs to treat asphalt (bituminous concrete) pavements.

Rehabilitation Maintenance

General: There have been many reviews of the rehabilitation program resulting in changes and amendments to the guidelines which help Regions target appropriate projects for repairs.

Understanding Roughness (IRI): Investigations showed many unexpected results caused by the concentration on roughness. Some of these unexpected results were:

• Treatment of reasonably acceptable pavements in the metropolitan area because the roughness information suggested the pavement was excessively rough
• Treatment of very rough areas, often concentrated over 100m (330 ft) or 200m (660 ft) and the works not producing any noticeable improvement.

Investigation of the methodology for using laser measurement of road profile and how the IRI is calculated helped explain many of the results mentioned above.

Laser profilers effectively measure the longitudinal shape of the pavement the profiler traverses and the “Roadruf” computer program calculates the theoretical “bounce” between the rear axle and the body of the vehicle for the vehicle travelling at 80 kph.

As a result of these investigations it was realised that in many locations we build real but inconsequential roughness into many locations in the metropolitan network. We were happy with the ride of these features because traffic uses them at low speed and therefore there was no need to repair these areas. In the Victorian network these features include roundabouts, tram and train crossings and cross roads. It was estimated that this type of roughness represented 50% to 70% of the roughness above the >4.2 IRI performance indicator in the metropolitan area. It also has an influence on the STE4.2 performance indicator.

The investigations also resulted in the:

• Increase in the “hurdle” roughness at which a project could enter the rehabilitation program, from 4.2 IRI to 4.6 IRI for projects in low speed metropolitan locations.
• Decrease in the “hurdle” roughness, from 4.2 IRI to 3.5 IRI for freeways.

Getting What We Paid For: The investigations also showed that:

• The ranking formula resulted in pavements carrying high traffic volumes being treated while very low
traffic volume roads, which were very rough, were not being considered.

- The ranking formula did not allow for differential roughness between wheel paths. For some pavement sections one wheelpath can be extremely rough but quite smooth in the other resulting in only moderate lane roughness which would not be funded for repair. This defect also induced a “roll” that was of particular concern to drivers of freight vehicles.
- Some inexpensive projects producing marginal improvements in roughness when slightly more expensive treatments would have produced better network value.
- Some projects that were not excessively rough but were providing poor service because they were potholing excessively and requiring major expenditure of maintenance funds and were not being funded.

As a result of these learnings the following additional sub programs were introduced:

- Rehabilitation for the Freight Industry where the target was to remove the differential roughness between the wheel paths, which was a problem for the freight industry, on apparently moderately rough roads.
- Rehabilitation for Social Equity so that some excessively rough pavements on very low traffic volume roads can be improved.
- Rehabilitation of Distressed and High Maintenance Pavements for pavements where there was excessive maintenance costs being expended on moderately rough pavements which would otherwise not be funded.

Additionally the formula for ranking the “value” of projects was amended to include expected improvement in the formula rather than “%>4.2 IRI”. This amendment has attempted to place more emphasis on getting the best improvement in roughness for each dollar invested rather than treating the biggest area that is rough.

Parts of the proposed amended guidelines for rehabilitation projects are attached as Appendix A.

Histogram Considerations: The concentration on roughness in the “A Stitch in Time” strategy has resulted in detailed investigation of the roughness, rutting and cracking histograms of the whole network and individual Regions. These investigations have resulted in better understanding of what is happening on the network and what may be able to be done to improve the way we manage the network.

Details of the histograms are contained in Appendix B.

A major learning from the investigations was the changing in the shape of the rural Region’s histogram compared with the metropolitan regions. This has lead to the development of the:

- New program element “regulation at 3.5 IRI” to minimise the build up between 3.5IRI and 4.2 IRI, and
- Zone 2 Index which measures the build up between 3.5 IRI and 4.2 IRI.

THE “A STITCH IN TIME” PAVEMENT STRATEGY OVER 15 YEARS

General

The current “A Stitch in Time” has evolved over many years of review and the performance indicators of its success have also changed with time.

Major Performance Indicators

The major performance indicators for “A Stitch in Time” are:

- % roughness >4.2 IRI
- Smooth Travel Exposure (<4.2 IRI)
- % length of cracking (treated or untreated)
• Length of Distressed Pavement

As can be seen by Table 1:

• The % roughness >4.2 IRI for the overall network and for the metropolitan regions has improved
• The smooth travel exposure (<4.2 IRI) has improved for all Regions
• The length of cracking (treated and untreated) has increased
• The length of distressed pavement has increased.

Discussion of Major Performance Indicators: From a community perspective there have been substantial reductions in the % roughness improvements in the % roughness => 4.2 IRI and substantial improvements in the amount of travel on smooth (<4.2 IRI) roads therefore “A Stitch in Time” should be considered successful.

Considering the increase in the length of cracked (treated and untreated) pavement and the amount of distressed pavement there must be questions about the success of “A Stitch in Time” in adequately waterproofing the network to minimise deterioration.

Other Indicators: Table 1 also shows a number of other indicators as follows:

• % of the network with rutting >10mm,
• The Zone 2 Index, and
• HATI.

% of the network with rutting > 10mm: The % rutting > 10mm is simply the percentage of the network where rutting is greater than 10mm using a 1.2m straight edge. This indicator shows a marginal increase for the whole network however the story is very different when the rural and metropolitan regions are compared.

The metropolitan regions show a marked improvement, or decrease, in the proportion of their networks which have rutting >10mm. The reason for this is that these networks have 50 to 75% asphalt (bituminous concrete) surfaces and every time a periodic maintenance overlay or a rehabilitation treatment is undertaken the rutting is substantially reduced.

Zone 2 Index: The purpose of this recently introduced statistic is to give an indication of the:

• Build up of roughness between 3.5 IRI and the 4.2 IRI statistic, and
• Potential substantial increases in the proportion of the network available for rehabilitation in the future and possible future funding problems.

This statistic is graphically illustrated in Figure 4.

If the Zone 2 Index is:

• Greater than 1.0 the proportion of the network in the range 3.5 to less than 4.2 IRI has increased and this is likely to create a problem in the future sustaining the condition of the network.
• Less than 1.0 the proportion of the network in the range 3.5 to less than 4.2 IRI has decreased and there is likely to be less pressure sustaining the condition of the network in the future.

As can be seen in Table 1 the rural regions all have a build up behind the key performance indicator “%>4.2 IRI”. This is simply because there has been insufficient shape correction within the rural regions because the main periodic maintenance retreatment method is a sprayed seal (chip seal) which does not rectify shape.

---

2 For the purposes of a network assessment, a distressed segment of pavement has been defined as having at least 30% of a pavement segment with more than 10mm lane rutting together with at least 10% cracking.
<table>
<thead>
<tr>
<th>Region</th>
<th>% Network &gt;= 4.2 IRI</th>
<th>Distressed Length (km)</th>
<th>Smooth Travel Exposure (STE 4.2)</th>
<th>Rutting (%&gt;10mm) (km)</th>
<th>Cracking (% Length)</th>
<th>Sustainability Statistic (Change in roughness ≥ 3.5 but &lt; 4.2 IRI) (network now) (network in 1994)</th>
<th>HATI&gt;2.2 (Length Km)</th>
</tr>
</thead>
</table>

Notes:
1. Distress length for Metropolitan North West comes from 1996 data (1994 data was incomplete).
2. Cracking data is for 1996 (Previous data was incomplete).
3. The HATI truck ride indicator has only existed since 2004.
4. 10mm is approximately 3/8 inch.

Table 1. Key Performance Indicators
Table 1 also shows that both the metropolitan regions have a reduction in the build-up behind the key performance indicator “%>4.2 IRI”. The reason for this is that these networks have 50 to 75% asphalt (bituminous concrete) surfaces and every time a periodic maintenance overlay or a rehabilitation treatment is undertaken there is an improvement in roughness.

**HATI:** The Heavy Articulated Truck Index (HATI) is an index that has been introduced to help target those parts of the network where differential roughness between the wheel paths creates a problem for the freight industry.

The figures are particularly interesting as they suggest there may be an issue with truck ride on about 10% of the rural network.

**Discussion of Other Indicators and “A Stitch in Time”:** The Zone 2 Index and % rutting > 10mm are generally not indicators that the community appears to feel strongly about. These indicators are really related to an asset manager’s perception of the condition of the network, particularly the rural sprayed seal network.

Both of these parameters are considered important for the long-term sustainability of the rural networks so we have introduced a new program element to attempt to reduce the build up behind 4.2 IRI and reduce the rutting. The program element involves investing in regulating the shape of pavements that are generally in the roughness range 3.5 IRI to 4.2 IRI. The aim of the program is to reduce the roughness of these projects by about 30% and hence further delay the need for rehabilitation works, consistent with the “A Stitch in Time” preventative maintenance strategy.

The HATI, and the treatment program associated with it, has been developed to minimise the differential roughness problem on our network. It is too early to determine whether it is going to improve the condition of our network relative to its cost.
CONCLUSION

“A Stitch in Time” has provided substantial benefits when considering the key performance indicators that matter to the community and consequently it would appear the “A Stitch in Time” program has been very successful.

There are a number of areas where the original “A Stitch in Time” performance indicators, i.e. cracking and distressed pavement, where there has been deterioration of the network. It is anticipated that with amendments to the original “A Stitch in Time” guidelines and adequate funding we will be able to improve the conditions in the rural regions.

There are a number of new performance indicators which are helping us better understand what is happening on the network and how better to target maintenance activities. With appropriate funding these issues will be addressed.

Funding for maintenance works has and will remain under pressure. Tight funding has had its benefits; it has driven us into areas other than traditional solutions where the community has gained. Notwithstanding this, adequate funding is essential to maintain a safe and acceptable road network. “A Stitch in Time” has served Victoria very well for 15 years. With appropriate funding the strategy is expected to continue to deliver cost-effective maintenance outcomes into the future.

ACKNOWLEDGMENTS

I would like to thank Ken Russell, Director Asset Management for the encouragement to document the “A Stitch in Time” experience and Amutha Thananjeyan, formerly the Pavement Assets Engineer, for her investigations and detailed help over many years.

The opinions expressed in the paper are mine alone.

REFERENCES


APPENDIX A

Parts of the proposed 2010/11 “A Stitch in Time” Pavement bidding Guidelines

Ranking of Conventional and Freight Industry Rehabilitation Projects

The ranking formula will be used to determine priority using the funding available for rehabilitation. The ranking will be applied to projects across the State within the Urban and Rural networks separately. Projects that meet the criteria above will be ranked on economic evaluation using the following formula:

\[ \text{Ranking value} = R_{\text{improvement}} \times D \times T \times L / Cm \]

Where:
- \( R_{\text{improvement}} \) = Estimated improvement in roughness from the current to the final value in NRM. The estimated final roughness shall be calculated by recognised methods considering the proposed treatment procedure (see Table No: 1 below for the estimated value).
  
  NOTE: Where the Region believes RAS roughness data has under estimated the existing conditions the RAS data should still be used unless it has been remeasured. The estimated roughness should be highlighted in the comments section of the bid.

- \( D \) (Rate of change of Roughness) = Rate of change of roughness, derived from three successive roughness surveys which have been aligned, but limited to between one and five. In addition, \( D \) shall be calculated using data from the proposed project PLUS 200m on each side of the proposed job. Also refer to N&AP Work Instruction under 2.03 Pavement Rehabilitation for the mechanics of calculation \( D \).

- \( T \) (Traffic Volume) = Traffic volume (up to a maximum of 2000 vpd rural and 4500 vpd urban).
  
  NOTE:
  a) The traffic volume on a two way carriageway is the two way volume while it is the one way volume on a divided carriageway.
  b) RAS traffic volumes are one way volumes.

- \( Cm \) = Unit cost of treatment considering maintenance = \( C \times (1 - (2m) / C) \).

- \( C \) = Unit cost of treatment ($ per m2) excluding urban drainage costs as indicated below.

- \( M \) = Expected maintenance costs per square metre per year currently being incurred (justified by maintenance expenditure records) and a belief that similar costs are likely to continue to occur (\( m \) is limited to 5% of \( C \)).
  
  (Note: Regions are to input total maintenance cost in the field ‘Maintenance Cost M’ in the bid database. Bid database will then calculate the unit cost (\( m \)) using the ‘Treated Area’.)

- \( L \) = Expected treatment life (years) (Max 20 years).

The estimated final roughness shall be calculated by considering the proposed treatment procedure and \( R_{\text{improvement}} \) shall be as given in Table No: 1.
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Asphalt Overlay</th>
<th>Slurry Treatment</th>
<th>Reconstruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Applications:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Layer</td>
<td>70% of average roughness (i.e. improvement 30% of average roughness)</td>
<td>85% of average roughness (i.e. improvement 15% of average roughness)</td>
<td></td>
</tr>
<tr>
<td>Double Layer</td>
<td>49% of average roughness or a maximum of 60 NRM (i.e. a maximum improvement 51% of average roughness)</td>
<td>72% of average roughness (i.e. improvement 28% of average roughness)</td>
<td>70 NRM – (stabilisation projects)</td>
</tr>
<tr>
<td>More Layers</td>
<td>Maximum of 60 NRM or 35% of average roughness (i.e. a maximum improvement of 65% of average roughness)</td>
<td>Max 70 NRM or 61% of average roughness (i.e. a maximum improvement of 39% of average roughness)</td>
<td>50 NRM – (resheet projects)</td>
</tr>
</tbody>
</table>

*Research has shown that where parts of a project have roughness above about 130NRM a single layer of asphalt regulation does not produce good roughness reductions. All parts (locations) within a project where the roughness exceeds 130NRM should be treated using two or more layers.*
APPENDIX B

Histogram Data for the Network

Figure B1. Pavement Conditions for the Whole Arterial Network
Figures B2A to B2G: Roughness, Rutting, and Cracking Histograms for Each Region

### Eastern Region

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
<th>Reason for Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roughness &gt; 4.2 IRI (% of network)</td>
<td>10.3</td>
<td>Community Satisfaction</td>
</tr>
<tr>
<td>Zone 2 Index (Change in roughness between 3.5IRI and 4.2IRI since 1994 (%)) (network now) (network in 1994)</td>
<td>1.19</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>Percentage of network with rutting &gt; 10mm (% of network)</td>
<td>16.3</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>Percentage of network with cracking &gt; 5%</td>
<td>16.7</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>Distressed length (km)</td>
<td>127.6/80</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>HATI &gt; 2.2 (Poor and very poor) (km)</td>
<td>363/227</td>
<td>Freight Industry Satisfaction</td>
</tr>
</tbody>
</table>

Figure B2A. Eastern Region
Figures B2A to B2G: Roughness, Rutting, and Cracking Histograms for Each Region

Northern Region

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
<th>Reason for Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Roughness &gt; 4.2 IRI</strong></td>
<td>8.0</td>
<td>Community Satisfaction</td>
</tr>
<tr>
<td>(% of network)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Zone 2 Index</strong></td>
<td>1.09</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>(Change in roughness between 3.5IRI and 4.2IRI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>since 1994 (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(network now)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(network in 1994)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Percentage of network with rutting &gt; 10mm</strong></td>
<td>13.6</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>(% of network)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Percentage of network with cracking &gt; 5%</strong></td>
<td>28.3</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td><strong>Distressed length (km/mile)</strong></td>
<td>247.2/154.5</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td><strong>HATI &gt; 2.2 (Poor and very poor) (km/mile)</strong></td>
<td>330/206.3</td>
<td>Freight Industry Satisfaction</td>
</tr>
</tbody>
</table>
Figures B2A to B2G: Roughness, Rutting, and Cracking Histograms for Each Region

**Northern Eastern Region**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
<th>Reason for Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roughness &gt; 4.2 IRI (% of network)</td>
<td>6.4</td>
<td>Community Satisfaction</td>
</tr>
<tr>
<td>Change in roughness &gt; 3.5 but &lt; 4.2 IRI since 1994 (% network now)</td>
<td>103</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>Percentage of network with rutting &gt; 10mm (% of network)</td>
<td>11.6</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>Percentage of network with cracking &gt; 5%</td>
<td>19.9</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>Distressed length (km/mile)</td>
<td>112.7/70</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>HATI &gt; 2.2 (Poor and very poor) (km/mile)</td>
<td>204/128</td>
<td>Freight Industry Satisfaction</td>
</tr>
</tbody>
</table>

Figure B2C. Northern Eastern Region
Figures B2A to B2G: Roughness, Rutting, and Cracking Histograms for Each Region

**South Western Region**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
<th>Reason for Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roughness &gt; 4.2 IRI (% of network)</td>
<td>6.4</td>
<td>Community Satisfaction</td>
</tr>
<tr>
<td>Zone 2 Index</td>
<td>1.05</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>(Change in roughness between 3.5IRI and 4.2IRI since 1994 (%))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(network now)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(network in 1994)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of network with rutting &gt; 10mm (% of network)</td>
<td>20.8</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>Percentage of network with cracking &gt; 5%</td>
<td>23.9</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>Distressed length (km/mile)</td>
<td>364.8/228</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>HATI &gt; 2.2 (Poor and very poor) (km/mile)</td>
<td>326/204</td>
<td>Freight Industry Satisfaction</td>
</tr>
</tbody>
</table>

Figure B2D. South Western Region
Figures B2A to B2G: Roughness, Rutting, and Cracking Histograms for Each Region

![Western Region Declared Road Network](image)

<table>
<thead>
<tr>
<th>Western Region</th>
<th>Indicator</th>
<th>Value</th>
<th>Reason for Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Roughness &gt; 4.2 IRI (%) of network</td>
<td>11.0</td>
<td>Community Satisfaction</td>
</tr>
<tr>
<td></td>
<td>Zone 2 Index</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Change in roughness between 3.5IRI and 4.2IRI since 1994 (%) (network now) (network in 1994))</td>
<td>1.11</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td></td>
<td>Percentage of network with rutting &gt; 10mm (%) of network</td>
<td>15.2</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td></td>
<td>Percentage of network with cracking &gt; 5%</td>
<td>8.6</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td></td>
<td>Distressed length (km/mile)</td>
<td>245.6/154</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td></td>
<td>HATI &gt; 2.2 (Poor and very poor) (km/mile)</td>
<td>469/293</td>
<td>Freight Industry Satisfaction</td>
</tr>
</tbody>
</table>

Figure B2E. Western Region
Figures B2A to B2G: Roughness, Rutting, and Cracking Histograms for Each Region

**Figure B2F. Metro North Western Region**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
<th>Reason for Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roughness &gt; 4.2 IRI (% of network, 2006)</td>
<td>12.0</td>
<td>Community Satisfaction</td>
</tr>
<tr>
<td>Zone 2 Index (Change in roughness between 3.5 IRI and 4.2 IRI since 1994 (% network now) (network in 1994)</td>
<td>0.89</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>Percentage of network with rutting &gt; 10 mm (% of network)</td>
<td>11.3</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>Percentage of network with cracking &gt; 5% Distressed length (km/mile)</td>
<td>32.8</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>HATI &gt; 2.2 (Poor and very poor) (km/mile)</td>
<td>NA</td>
<td>Not used in the “asphalt/BC” networks</td>
</tr>
</tbody>
</table>
Figures B2A to B2G: Roughness, Rutting, and Cracking Histograms for Each Region

![Histograms for the Metro South Eastern Region](image)

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
<th>Reason for Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roughness &gt; 4.2 IRI (% of network)</td>
<td>10.2</td>
<td>Community Satisfaction</td>
</tr>
<tr>
<td>Zone 2 Index</td>
<td>0.85</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>(Change in roughness between 3.5IRI and 4.2IRI since 1994 (%))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(network now)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(network in 1994)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of network with rutting &gt; 10 mm (% of network)</td>
<td>12.9</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>Percentage of network with cracking &gt; 5%</td>
<td>28.5</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>Distressed length (km/mile)</td>
<td>163/102</td>
<td>Future Sustainability</td>
</tr>
<tr>
<td>HATI &gt; 2.2 (Poor and very poor) (km/mile)</td>
<td>NA</td>
<td>Not used in the “asphalt/BC” networks</td>
</tr>
</tbody>
</table>

Figure B2G. Metro South Western Region