WHAT "TAILS" TELL A HIGHWAY MANAGER

Sean Miller
EnterpriseMouchel
Rosalind House, Jays Close, Basingstoke. RG22 4BS.England
E-mail: sean.miller@enterprisemouchel.com

Peter. Scott
Highways Agency, England, UK
Federated House, London Road, Dorking, Surrey. RH4 1SZ. England
E-mail: peter.scott@highways.gsi.gov.uk

Scott Cooper
EnterpriseMouchel
Rosalind House, Jays Close, Basingstoke. RG22 4BS.England
E-mail: scott.cooper@enterprisemouchel.com

ABSTRACT

Highway managers hold many years of useful network data on their PMS. Maintenance programmes are initially identified from partial information, (together with knowledge of construction and maintenance histories, and remaining service lives.) This information is contained in the many 'Tails' of the measured condition parameters. But there may be valuable information contained in the condition tails which is often overlooked or not utilised. This paper explores how all this valuable data is mined and harvested. The paper also looks back at historic 'Tails' and how they have been realized in renewal schemes, as well as being used as a reliable predictor.

Condition projections of the current 'Tails' use data that includes: Rutting, SCRIM, CVI (coarse visual inspections), Cat 1's & 2's defects (safety and serviceability defects), linked with other network survey data such as LPV's, (longitudinal profile variances over 3m, 10m, and 30m), Texture, Fretting (Ravelling), and Cracking. It means that candidate schemes may be more reliably generated. To help determine rehabilitation schemes, other data is utilized in the scheme identification cycle such as Traffic Speed Deflectometer (TSD). As scheme specific data becomes available, it can be then fed back into the PMS and Decision Support Tools (DST) to validate or redefine the originally generated schemes.

By sifting and justifying collected data and presenting the data in a reverse "S" curve or more simply "Z" curve, potential candidate schemes can be accurately identified some five or six years ahead of their full renewal. Decision Support Tools therefore indicate where and when Highway Engineers needs to investigate, to ensure that the intervention occurs at the optimum time. The "Z" curves have the added value of comparing network Areas against whole Networks and determining whether pavement assets are remaining at a steady state, or deteriorating or improving, based on funding allocations.

1 CUMULATIVE DATA DISTRIBUTION CURVES,‘Z’ CURVES, ‘S’ CURVES, AND ‘TAILS’

1.1 Z and S Curves

The Z curve, or a reverse S cumulative distribution curve, is a simple yet powerful device which is used to transform normal distribution curves for measured defects. Cumulative distribution curves show the 0% to 100% range on the ‘y’ axis, either to the left or the right hand side. This then presents the data as a notional “S” curve with the long tail to zero on the left or more preferably, in the authors’ view, as a reverse-“S" curve, more simply described as a notional “Z” curve with the long tail to zero on the right, (which may be then curtailed in presentations without the loss of visual impact.)

Z and S curves are of value when comparing data from a single section of road say, with a Route or an Area network. They are also used for comparing individual network Areas against national networks. In this way, any failing Areas, Routes and sections may be identified and targeted for investigation and treatment where they are significantly below the average.

They are also used for determining whether pavement assets are remaining at a steady state, deteriorating or improving over several years depending on the changing budgets and targeted maintenance: showing the overall improvement or deterioration, year by year. So they are a powerful tool for communicating complex facts in a simple way.

1.2 Z Curves and Condition Indicators

Z curves have been used provide condition indices for different condition parameters. They are calculated by integrating the annual curves and making the base year equal to 100, say. In this way, for different condition parameters, Areas may be simply compared with each other across several years, and against the whole network. This is not discussed further in this paper.

1.3 Tails

‘Tails’ are simply the representation of data at the extremes or ends, ‘tailing’ down to zero or up from zero. Tails are easily visible and the ranges varied on GIS mapping layers to show sections of the network which have defined values. In this paper they are used with Z curves as visible presentations of change via GIS across varying values. They are also used when projecting condition in future years.

Condition data ‘Tails’ together with information such as pavement surface type and age, are used by PMS in assessing potential maintenance interventions and treatments across future years using their decision support tools (DST).

2 DECISION SUPPORT TOOLS (DST)

Decision Support Tools (DST) includes:

1. Z curves,
2. Tails
3. Analysis of construction histories, condition projection to develop suggested treatments for future years assuming no maintenance by the use of algorithms
4. The use of GIS for visual presentations of condition parameters, treatments and future programmes.

They are used by highway maintenance managers in monitoring the road network and identifying candidate maintenance schemes.

Potential maintenance schemes are the identified by analysing the data and information held. The data is analysed by a DST using algorithms which considers all the condition data held, lane by lane, projecting this data for future years. The DST also uses the knowledge from the PMS (pavement management system) of surface material type and age, whether it is a long-life pavement, deflections, visual surveys, patching history. From this information, a range of treatments are suggested for each 100m length, lane by lane, and for any number of years ahead.

2.1 The use and application of DSTs

The use and applications of DSTs are demonstrated in this paper, by including examples of the use of:

1. Z curves, showing network and scheme level deterioration, or improvements
2. GIS screenshots showing visually, the use of tails in highlighting the sections where the defects are within a range of different sensitivity levels
3. Screen shots of funded maintenance renewal programmes developed and justified through this process and the use of the DST algorithm process, with projected suggested treatments.

3 IDENTIFYING PAVEMENT MAINTENANCE SCHEMES

Highway managers hold many years of useful network data on their PMS' (pavement management systems.) Rolling maintenance programmes are identified from a range of technical information, both limited and detailed, together with knowledge from the construction and maintenance histories.

The Highways Agency in England is responsible for the motorways and trunk roads, carrying traffic in excess of 150,000 vehicles per day. Network surface condition surveys are carried out annually, using various versions of the TRACS - RST (TRAffic-speed Condition Surveys - Roads Surface Tester). These measures are:

- Rutting
- texture
- cracking
- fretting
- longitudinal profile variances (LPV) over 3m, 10m & 30m (LPV's instead of IRI (international roughness indicator)

Skid resistance is also routinely measured at network level using SCRIM (Sideways force Coefficient Routine Investigation Machine.

Deflections are measured across the network by the TSD (Traffic Speed Deflectometer) and at proposed schemes using Deflectograph and FWD surveys.

This technical information is usually reported on at 10m and 100m lengths, with average and maximum values. This data can be graphically shown as normal distribution curves, cumulative distribution curves, or simply through the 'tails' of the curves, and this can then be shown as data, or visually, through simple GIS. It can show a range of information, from network-wide data to 'scheme' data.

Category 1's & 2's defects (Cat. 1 & 2) (safety and serviceability defects) are reported where there have been local defects were repaired.

3.1 Deterioration of a pavement surface showing the deterioration of serviceability and safety over time

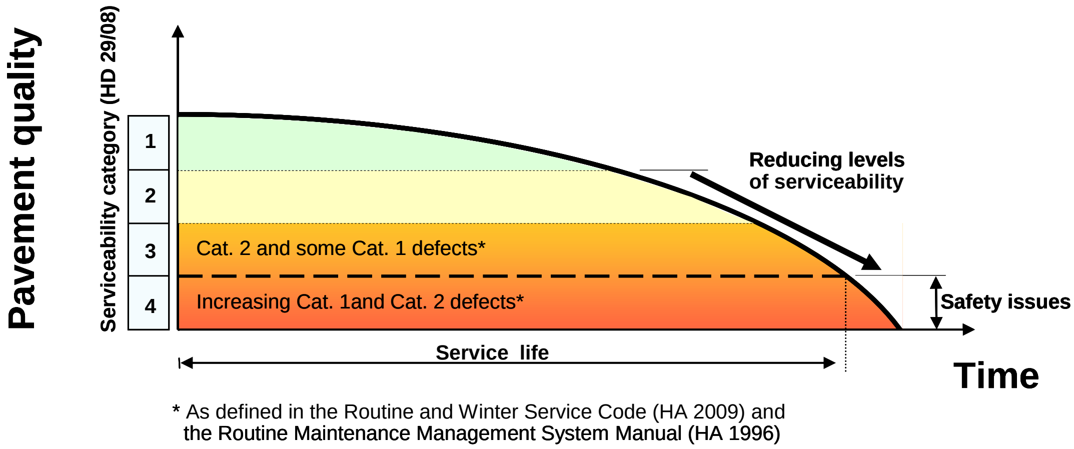


Figure 1: A conceptual diagram demonstrating how levels of safety and serviceability deteriorate over the service life of a pavement

3.2 Pavement Condition Data

However data is shown and used, highway asset managers and pavement engineers can now simply view this data on their computers. Snapshots of all the latest defect parameters can be compared on their PMS. But they can also compare the data from many years, to track the development of defects, and also project when the length of road should be renewed at the optimum time to ensure minimum whole life costs.

All the measured defect parameters are banded from very good to very poor, and these may be identified on a simple scale of 1 to 4 with different thresholds. Alternatively, they can be separated at different sensitivity thresholds, where the defects are showing something of interest, as potential predictors of future failure. These are referred to as the defect tails when the early signs of future failure are shown or when certain threshold levels are passed. The incidences of lengths falling into the tails can be tracked over several years and this gives time for the best year of treatment to be assessed.

The extents and treatments may be assessed through the scheme specific investigations and additional surveys such as the TSD (traffic speed Deflectometer), Deflectograph and FWD and this ensures that suitable candidate schemes are identified, confirmed and programmed.

Modern PMS use algorithms which project conditions and propose treatments, as decision support tools (DST), over several years generating perhaps a five to ten year rolling programme. These use all the available information across all lanes, whether detailed or skimpy. The actual treatments and timing of schemes can be related back to the previous signs that were available to provide invaluable feedback for improving the algorithms. These have been used now for four years in the Highways Agency’s Area 3.

A cautionary note however needs to be born in mind with the use of some historic condition data:

- The Highways Agency has used three different TRACS vehicles over twelve years which may lead to some variability in the data across years, unrelated to the condition.
- The calculation for LPV’s which producing different results in the later ELPV (enhanced LPV’s).
- SCRIM surveys have changed, from a third of the network surveyed three times a year, to the whole network being surveyed once each year. The speed of the survey vehicle has been changed and the seasonal correction calculations, has been revised. So different sub standard sections need to be viewed with caution.
- CVI surveys may vary between operator, weather and light conditions.
- Whole carriageway disintegration may be estimated or measured, depending on the machine technology and algorithms used.
- Crack detection is frequently non repeatable.
- The network is a live network which will have treatments and repairs carried out which may give changed or false readings. A history of defects and repairs is invaluable information to be used.
- The extreme local level defects, measured in one year, may well have been removed in subsequent years through temporary or permanent intervention.

However, with this knowledge and understanding, many of the variations and changes may be used to explain away many of the otherwise random variations, leaving the ongoing deterioration to be sifted and recognized by the experienced eye.

4 THE HIGHWAYS AGENCY NETWORK IN ENGLND

The Highways Agency Area 3 Network

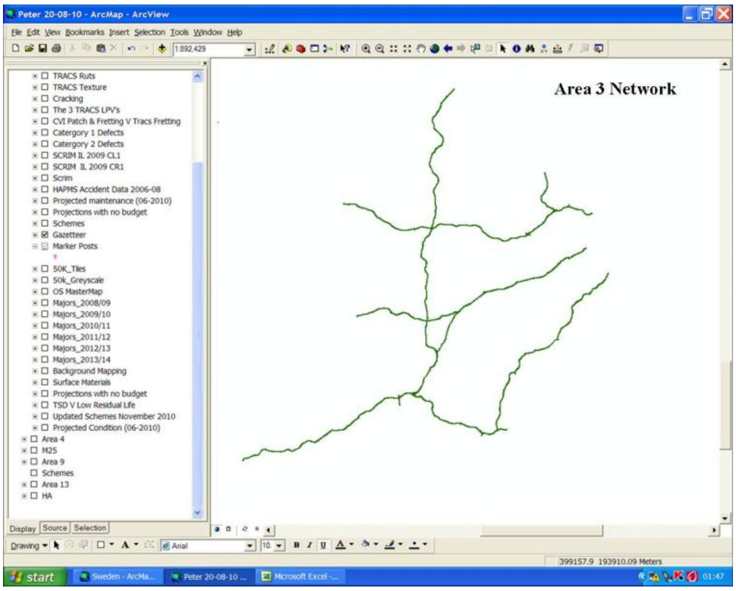


Figure 2: Area 3 Network, with 510 route km, 1,250 carriageway km & 3,175 lane km

The Highways Agency’s Area 3 network has been used to demonstrate the use of these techniques in this paper, which have been successfully used for several years.

5 THE USE OF Z Curves - CUMULATIVE DISTRIBUTION CURVES, AND NORMAL DISTRIBUTION CURVES

5.1 Z – Curves of Ruts in Area 3

An example of the use of Z curves is shown below for rutting in lane 1 on the HA's Area 3 network, covering Surrey, Hampshire, Oxfordshire and Dorset. The Area 3 network is 1,250km long. The Y-axis shows the %, and the X-axis the degree of rutting from 0mm to >25mm. The graphs show at any point, the percentage quantity of the network exceeding the defect on the X-axis.

The curves show the variation of rutting on the network between 2002 and 2011, with the normal distribution curves and cumulative distribution curves.

The network, historically, was the worst HA Area for rutting and there was a targeted programme to deal with excessive ruts over four years. Since the, there has been a further maintenance programme of work which have tackled service-life expired roads. This has had a side benefit of further reducing the lower ruts on network.

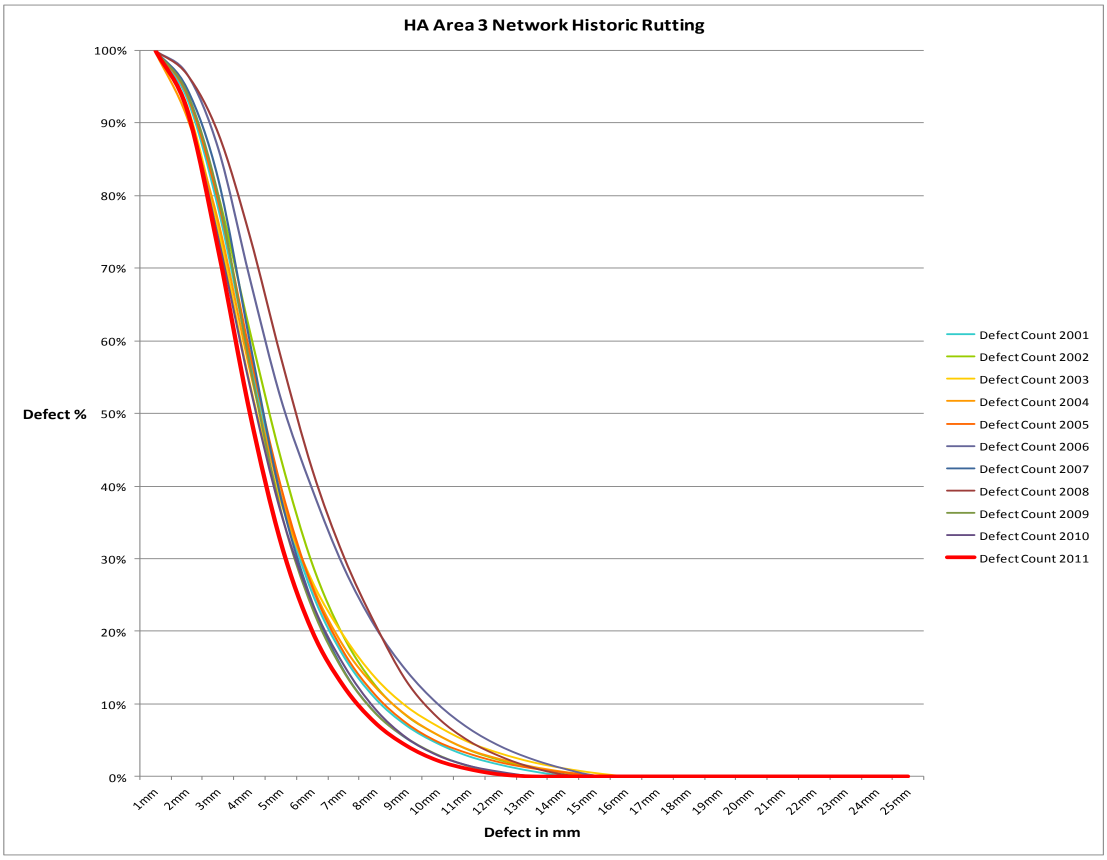


Figure 3: Ruts - Cumulative and Normal distribution curves (2006-2011); showing the results and benefits from targeted maintenance at the <u>network</u> level

The graphs in figure 4 below show, in the same way, the distribution curves on what was one of the most rutted routes in Area 3. The road, the A34, is a dual two-lane trunk road carrying a high degree of HGVs (heavy goods vehicles or trucks). The route has a variable construction along its length which has needed major maintenance over the last ten years. The Z curves demonstrate the improvements made over a number of years as a result of a targeted maintenance programme

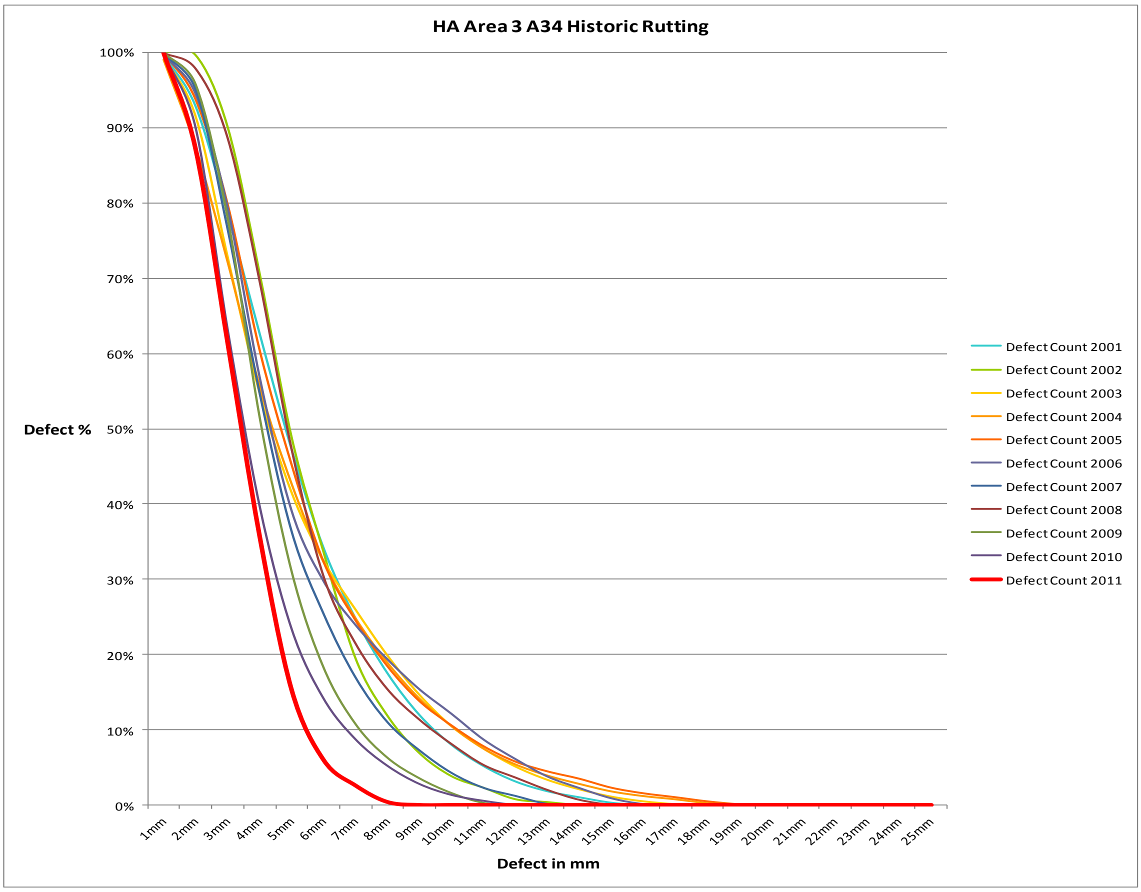


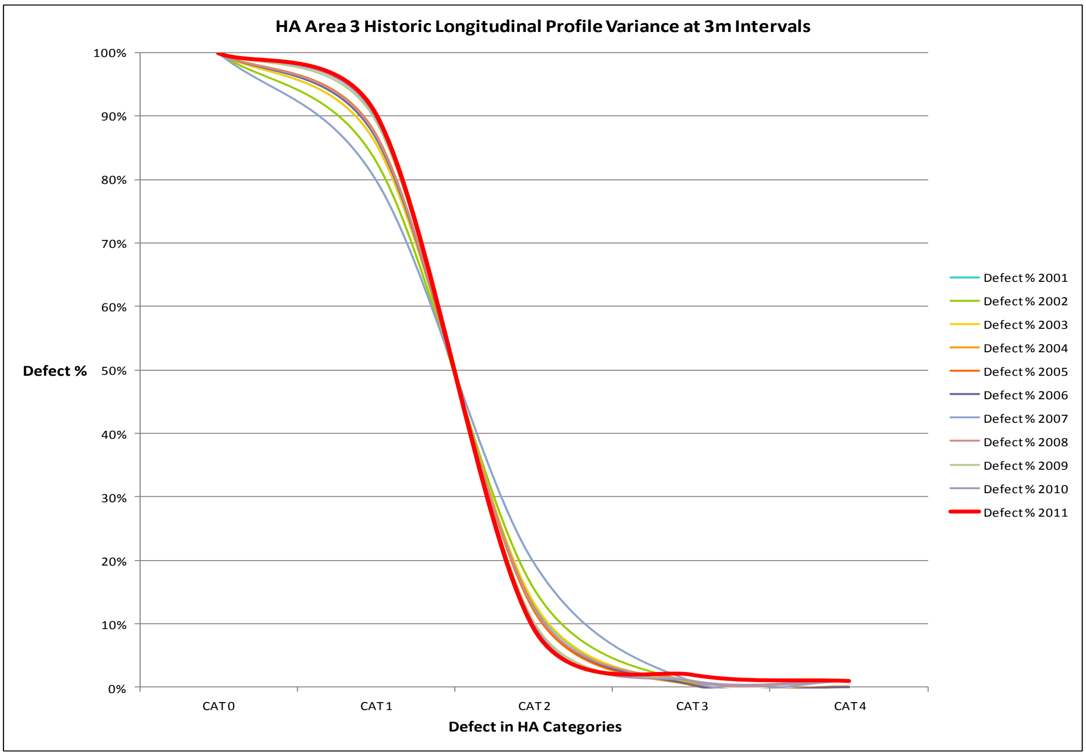
Figure 4: Ruts: Cumulative distribution Z curves for A34, between 2001 - 2011. The curves show the significant improvement in ruts on this route over time, as a result of the targeted maintenance programme at the route level

5.2 Z Curves – LPV3m (Longitudinal profile variance 3m)

Other measured surface condition parameters may have a narrower band of sensitivity for demonstrating trends in defects. LPV3m is a ‘manufactured’ surface condition parameter which has been found to be a good indicator of surface disintegration, and this is shown for a number years below. The section of road has been demonstrably deteriorating.

At the scheme level, LPV 3m has been found to be an extremely could predictor of surface disintegration as demonstrated in the graphs below. It can be used to show the deterioration taking place over a number of years, prior to maintenance being carried out.

Figure 5: Z curves using LPV 3m for Area 3: between 2001 -2011.



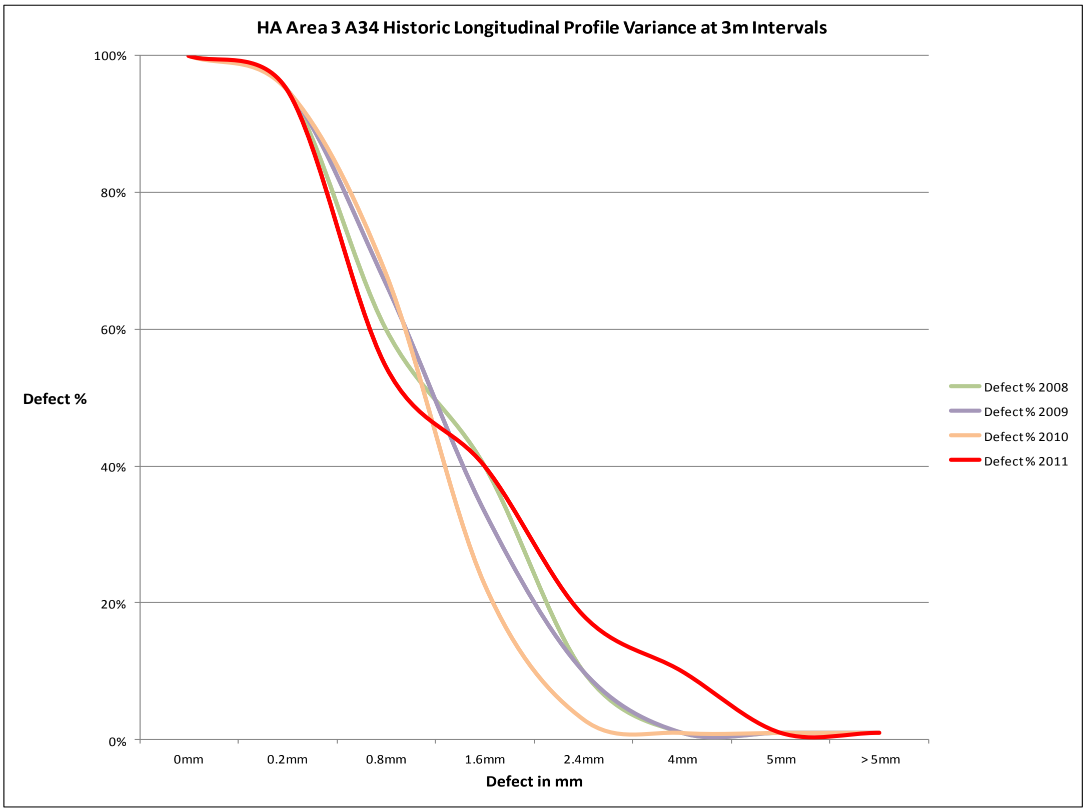


Figure 6: This Z curve for the A34 is showing that from 2008 to 2010, target treatments reduced the defect values for LPV 3, with a move down and to the left, however 2011 data is showing a marked increase in defects with a move to the right and up justifying further treatments.

By identifying potential schemes from the Tails and PMS DST, and presenting data in “Z” curves, the candidate schemes can be not only accurately identified some five or six years ahead of their full renewal, but their changing condition can be visibly tracked.

6 THE USE OF GIS USING ‘TAILS’

GIS is an invaluable and indeed essential tool for identifying the candidate maintenance schemes, some years ahead. Screenshots are included below of the Area 3 network with examples of schemes identified or confirmed in this way.

The starting premise for pavement engineers is to use all the available information. This includes the construction and maintenance histories, expected remaining service life of sections, as well as historic and current condition surveys. So the ‘tails’ are just one of the tools in the engineers armoury, but powerful ones nonetheless.

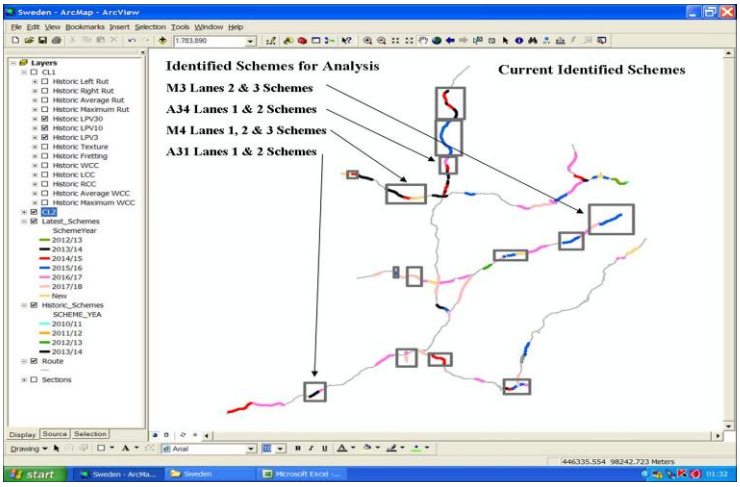
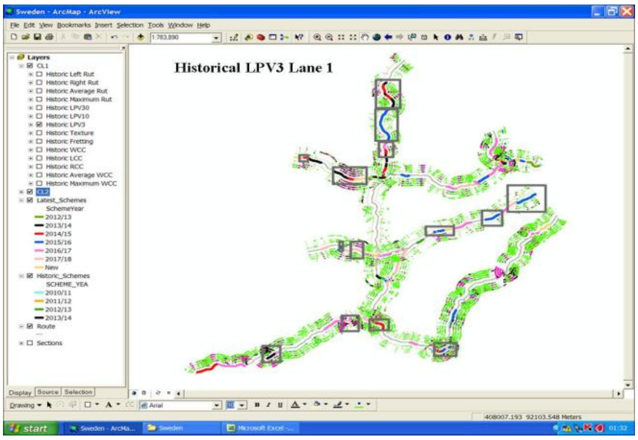


Figure 7: Show’s examples of identified schemes derived from the PMS DST on the Area 3 network, with some completed and others still in the rolling programme.

The screenshots included below, demonstrate the use of GIS in viewing all the available condition data of one of the condition parameters. The latest data is normally shown closest to the centre-line, and the oldest on the outside.



Figures 8: Four years of LPV3m data, the most recent next to the centre line, and the oldest on the outside, show the concentration of defects and the development of defects over five years.

6.1 The Use of GIS at the Scheme Level

The following screenshots show TRACS defects, zoomed in on the GIS, to show how the defects and 'Tails' developed over the years, with the latest surveys closest to the centre line, and the oldest on the outside.

These were used with other data to identify and confirm maintenance schemes, for their extents and the timing of the works.

7 Identified Scheme on M4 west of A34

The next screenshot (figure 9) shows a section of the M4, with the GIS having been zoomed in to show more detail

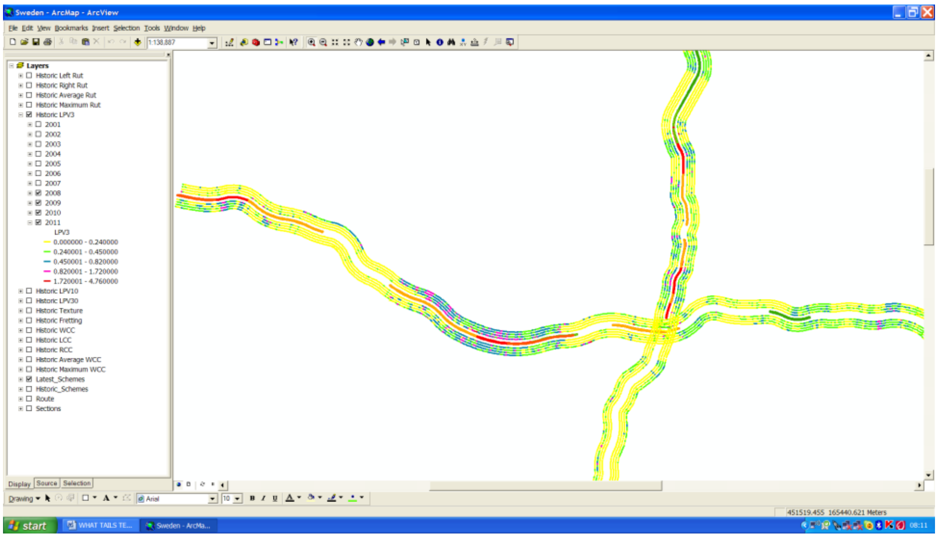


Figure 8: Historic LPV3 showing clearly the development over four years and extents of deterioration in the pavement surface through the use of LPV 3m 'Tails'

Schemes on the M3 showing below the history of ruts development and treatment
The zoomed in screenshot below in figure 10 shows the data held over 11 years on the rutting parameter.

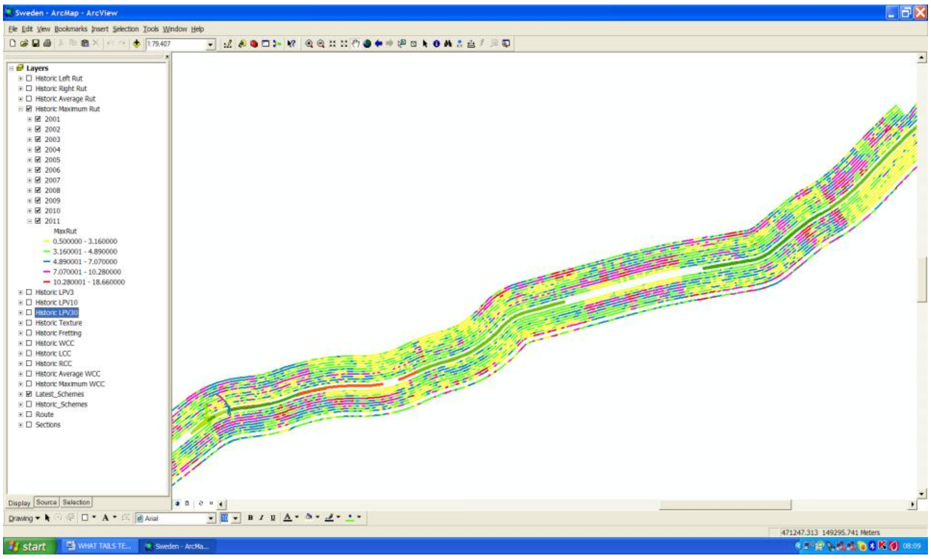


Figure 9: Eleven years of Maximum Rut data over 100m, showing the development of ruts on some sections, as well as the intervention and treatment of other sections.

The whole past maintenance history is visible. Future schemes which are being monitored are indicated coloured along the centre-line.

8 THE USE OF PMS, DST, TAILS, GIS AND MAINTENANCE ALGORITHMS TO GENERATE MAINTENANCE PROGRAMMES

Maintenance planning is an iterative process which involves using as much information as possible, with the best tools to identify and monitor highway networks. The tools we have are: knowledge of materials, understanding of their expected service life, data obtained from the various regular surveys, monitoring the network, and scheme specific surveys. This data is analysed using a predictive DST, and the results reality tested against the machine data and field data and inspections.

This may be summarised as:

(Knowledge + Condition (shown in the Tails))* Algorithm = Proposed treatments (confirmed)

Identified schemes can then be tracked using Z curves and all this is visible on the pavement manager’s computer using GIS and the Tails, so that schemes can be confidently and productively bid for, funded and included in the rolling maintenance programme.

The screenshot below (figure 11) demonstrates three schemes identified using a PMS DST algorithm.

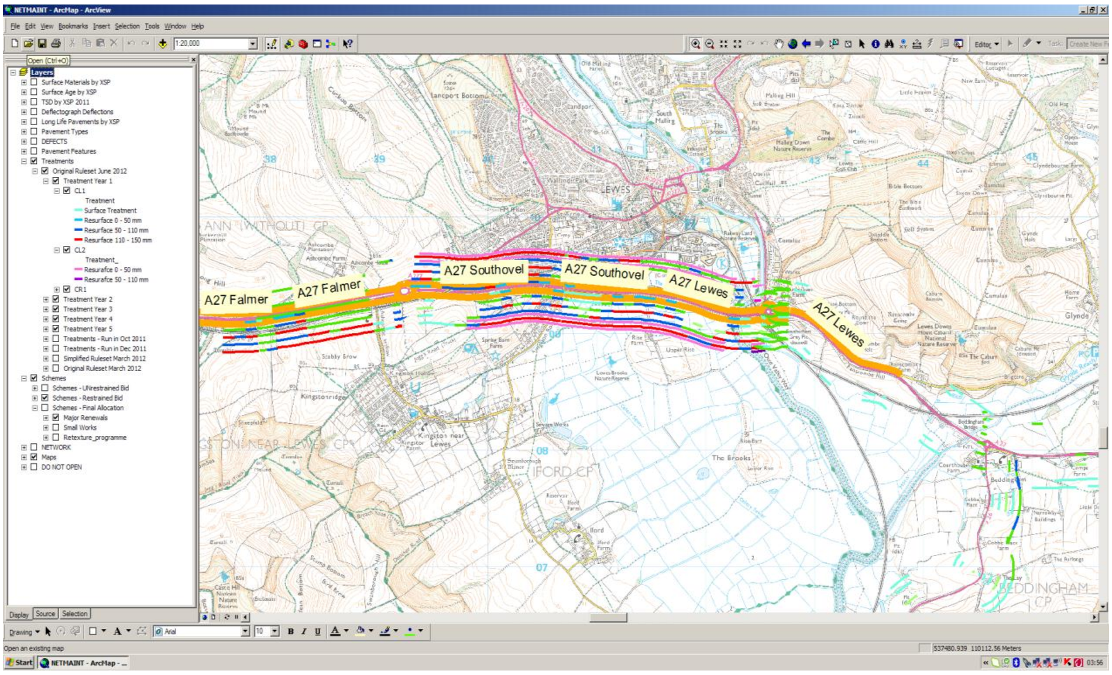


Figure 10: Showing the part of the Highways Agency’s network with three identified schemes which were identified and confirmed with the support of a PMS with a DST

9 SUMMARY AND CONCLUSION

The Highways Agency and Area 3 has been using and developing PMS's and GIS for many years, using of-the-shelf PMS. There has been commitment to refine the treatment algorithms to more accurately correlate the knowledge contained in the PMS with the maintenance treatments, extends and timing. Consideration is given to constrained budgets as well as informing the bidding and scheme justification process.

Due to the complexity of data produced, PMS with GIS has proved to be a good platform to display this information to a wide audience. It can be either drilled into by an engineer or presented at high level asset manager reviews.

GIS helps to intuitively inform pavement engineers. It is used to identify and confirm when and where, it is best to intervene on the network, based on safety and serviceability threshold levels. This ensures that defects are treated at the correct time.

The principle of "Z" curves has been used to represent how 'samples' of defects may be compared equally, at the network, route and scheme level. And they clearly show changes over time which can be measured and monitored.

The use of PMS with GIS has been invaluable in establishing a robust rolling programme of maintenance works. And this has been successfully employed at the network level as well as the scheme and route level.