A SYSTEMS APPROACH TO THE MANAGEMENT OF SKID RESISTANCE DEFICIENCIES ON A ROAD NETWORK

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ABSTRACT

This paper describes a systematic approach to the assessment and treatment of sites with insufficient skid resistance as part of a Performance Specified Maintenance Contract (PSMC). Typically, the inspection of skid deficient sites is undertaken by experienced road engineers, who decide what type of action is needed to address skid resistance deficiencies on the network. However, this approach, based on site inspections alone, can lead to significant oversights and errors in the assignment of treatments to skid deficient sites.

To address this problem, Transfield Services NZ Ltd developed a systematic approach which synthesizes historic skid resistance trends, accident data and pre-scheduled works. Using this integrated approach in conjunction with site inspections, the road inspector can make a more informed and holistic assessment of the site deterioration trends, likelihood of accidents and cost of intervention.

The approach outlined in this paper has been implemented on several road networks with significant gains in inspection process efficiency and consistency of assigned interventions.

The paper outlines the background to the methodology, putting specific emphasis on the PSMC context and the need for innovation. The key motivators behind the system are described and a detailed description of the methodology, with example outputs, is presented.

INTRODUCTION

This paper describes the development of a software-based system within a Performance Specified Maintenance Contract (PSMC) environment to optimise the pavement skid resistance on predominantly rural roads while reducing unnecessary pavement treatments. The system has been implanted on several road networks and across a range of contract delivery models in New Zealand, and was found to add significantly more rationale and consistency to decision making related to the treatment of areas of road networks with deficient skid resistance.

Network managers involved in the implementation of the system have found it to be intuitive and easy-to-use both in a desk-study and field inspection context. The success of the solution has been in its simplicity and focus, which aids decision making without becoming a “black box”. Specifically, the system outlined in this paper does not replace the human intelligence required for good decision making but rather provides the asset manager all the information required to make good decisions in a consistent and transparent manner.

BACKGROUND

The development of the system presented in this paper was initiated in a Performance Specified Maintenance Contract (PSMC) in rural New Zealand. The contract covered a network of 450 centreline kilometres of rural highway and it included the requirements to maintain the pavement to a list of performance standards including skid resistance.

The PSMC is one of four procurement models used by NZTA to manage and maintain its highway network. All maintenance is outsourced through either all-encompassing contracts of the PSMC or Maintenance Alliance, or with a consultant Network Manager and one contractor in the lump–sum hybrid model or several contractors in the traditional measure and value model.

With this degree of outsourcing NZTA has elected to collect pavement data on a national basis and thus maintaining control and consistency in the data collection process. NZTA engages WDM Ltd of the United Kingdom to undertake an annual survey of the surface characteristics of the entire state highway network.

The result of the annual skid resistance survey is published in two rounds. The first, at the completion of the pavement survey, provides an exception report which summarizes the seasonally unadjusted results for sections of pavement where the observed skid resistance is below the Investigation Level (I.L.). The exception report is released before the application of adjustment factors based on benchmarking and calibration in order to give maintenance teams across the country the opportunity in more favourable weather to correct deficiencies that could cause a safety problem during the wetter winter months.

Following the completion of the final calibration and seasonal adjustments the final results are published, where a further analysis is undertaken to ensure adjustment factors have not produced further sites requiring remedial intervention.

From a PSMC contractor's perspective, it is the analysis of the initial exception report results that creates the greatest and most urgent work load and cost to the network management teams and physical works providers. Client expectations are justified in the requirement to address all skid challenged road surfaces within the summer construction season, before the unfavourable winter months. For Transfield Services, on the PSMC001 contract, the SCRIM® exception report was received each year in the month of January or February, leaving the February and March summer months to inspect, option analyse, programme and physically intervene.

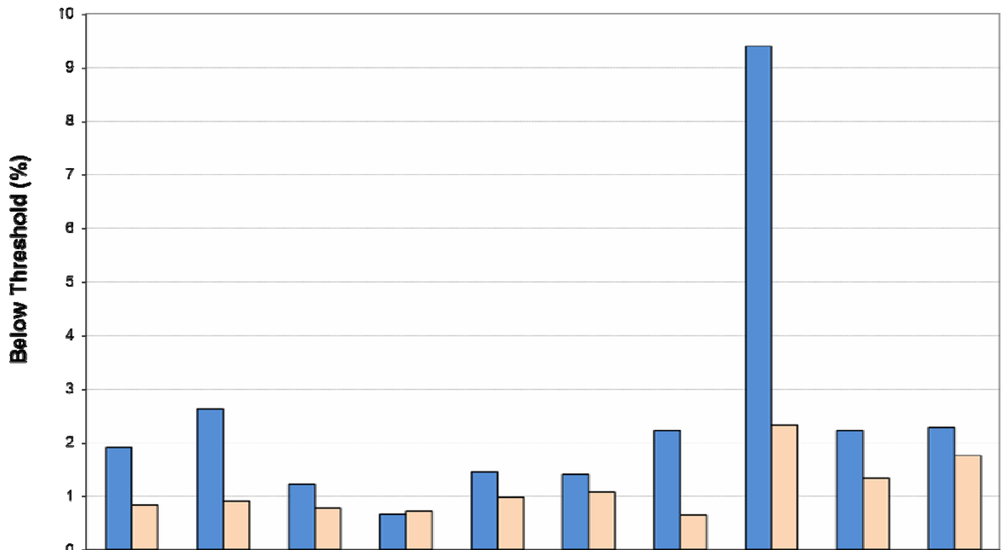
The NZTA has established simplified guidelines for the investigation and treatment of these results, but within a PSMC lump sum environment, where all risk lies with the Contractor, more efficient systems are always targeted, and with respect to skid resistance, Transfield Services identified the need for process and procedure improvements in the areas of:

- Improve good skid exposure to road users
- Reduce the contractor and Client risk against legal liability actions
- Making informed, evidence based decisions, in the field
- Reduce administration costs with processing data
- Speed up the decision making process and get to the physical intervention as quickly as possible
- Deal with fluctuating data as a result of equipment tolerances and extreme seasonal weather effects (a PSMC Contractors risk).

In PSMC001, the network maintenance contractor is required to mitigate all segments of the network with skid resistance values below the threshold limits within two months. It is a further requirement of the PSMC contract model to display demonstrable compliance of risk mitigation, through robust reporting of site observations and actions undertaken to ensure road user safety

The contract model generates tension between the economics of mitigating skid deficient sites and safety due to the lump sum environment. Where low cost option such as water cutting is quick and has an immediate effect, re-treatment is required after 1-3 years, and can create other maintenance issues. Conversely a full rehabilitation of the site will be a long lasting solution, but is time consuming and expensive, and a balance must be sought. With a contract term of 10 years the downstream effects from poor decision making can expose the contractor to significant financial risk, and the road user to a significant safety risk.

In the summer of 2008 the Waikato region was declared a drought disaster zone, the first in recorded history. As a result of minimal rainfall and sustained heat build-up in pavements the accumulation of contaminates and bitumen migration was unprecedented. The SCRIM® Exception Report returned over four times the average number of skid deficient sites and provided a driver for a step change (see Figure 1). This situation was the catalyst for the need to a more systematic and streamlined approach to the analysis and mitigation of mass amounts of skid deficient site information within a PSMC context.



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
PSMC 006	1.92	2.63	1.22	0.67	1.45	1.41	2.22	9.40	2.22	2.29
National	0.85	0.91	0.78	0.72	0.98	1.08	0.66	2.32	1.34	1.76

Figure 1: PSMC001/6 Skid Resistance versus National Average

THE NEED FOR A SYSTEMS APPROACH TO MANAGING SKID RESISTANCE DEFICIENCIES

It should be clear from the preceding discussion that – within the context of a PSMC – the requirements with respect to managing skid resistance creates a high priority task that needs to be handled with urgency, but at the same time a systematic and consistent manner.

To address this need Transfield Services NZ developed, in conjunction with Juno Services Ltd, the T-SKAN system (acronym for Transfield SKid ANalyser). This system has now been made freely available to roads authorities operating in New Zealand.

Prior to the development of the T-SKAN System, the network manager would typically send staff to the field to identify the skid deficient sites. While inspecting sites they would only have the latest exception report data (in paper or spread sheet format) at their disposal. Essentially, this means that decision making was driven by the current year's SCRIM® data, supplemented by the site observations.

As such, site observations would rely only on the top surface condition without consideration or knowledge of the history and type of underlying layers. The process was time consuming and cumbersome, and involved an initial desk top assessment interrogating separate data sets via isolated systems and included crash and curve data, maintenance costs, forward works programmes and historic skid survey results., a site assessment and then another final desk top analysis and report. This was often carried out under time constraints so as to catch the last of the favourable weather before the wet winter season started.

As such, the process was somewhat disjointed and inefficient, leading to an inconsistent and un-informed selection of treatments. Specifically, the process failed to implement a repeatable approach to the management of skid resistance, from site to site and year to year.

The T-SKAN system was devised to provide a total yet effective solution to the management of skid resistance deficiencies on a road network. In developing this system, a careful assessment of past experiences was made, and this was used to develop a more systematic approach that optimally incorporates available technology and experience. Figure 2 shows the key elements of the T-SKAN system, which include the following aspects:

- Proper training of network managers and site inspectors in the fundamental aspects of skid resistance behaviour and available remedial measures for skid deficient areas.
- A structured site inspection process, characterized by a template inspection form to guide the observation process and electronically capture observations
- Incorporation and synthesis of all relevant data in the decision making process (including historical skid resistance trends, Forward Works Programme considerations, pavement and surfacing history, accident data and curve radius data).
- Automated post-processing of captured data resulting in a consistent electronic report summarizing statistics and key trends of the overall action plan.
- Visual presentation of mass data.
- Traceable decision trail

Each of the above factors will be discussed in more detail in the following sections.

TRAINING AND UNDERLYING KNOWLEDGE

As shown in Figure 2, the starting point for the T-SKAN system is ensuring that asset managers and/or site inspectors have sound understanding of the factors that influence skid resistance, and remedial measures for skid deficient sites. In this respect, asset managers and site inspectors are required to be thoroughly familiar with the factors listed in Tables 1 and with the remedial measures listed in Tables 1 and 2.

Table 1: Factors influencing skid resistance

Factor	Description
Polishing of the aggregates	Over time the aggregate faces that are contacted by vehicle tyres are worn smooth by the abrading action of water and fine material. The rate of polishing is predominantly determined by the type of aggregate, traffic volume and camber. On the PSMC001 network the predominant seal aggregate was a crushed greywacke. This was regularly tested for its polished stone value which was typically in the range of 52-57.
Flushing	Flushing is the condition where the binder is near or above the uppermost surface of aggregate particles, reducing tyre contact with the seal chip.
Tracking of Bitumen	This defect originates when bitumen is carried by vehicle tyres from another site onto the subject seal, with the aggregate micro texture being contaminated with bitumen, producing similar temporary poor skid characteristics as flushed pavements.
Wheel Skipping	Surface irregularities can cause the test wheel to skip, thus reducing the resistance force applied by the pavement and giving results indicating low skid resistance.
General Build-up of Grime	Skid resistance of a section of pavement can reduce when there is a build-up of dust, rubber particles and oil drippings. This leads to a very low skid resistance during the initial wetting of the pavement when it rains. However the residual skid resistance is restored as more rain washes these contaminants off the road. However, during the skid testing, sufficient water is applied to wet the surface, thus leading to low results if there has been no rain in the area for some time.
Localized Contaminants	Localized contamination can also lead to the recording of low values for skid resistance. The road surface can be contaminated by spills

Factor	Description
	and leakages from vehicles, such as stock effluent, or by tracking material from off the highway (unsealed driveways). This may lead to localized areas of low skid resistance results

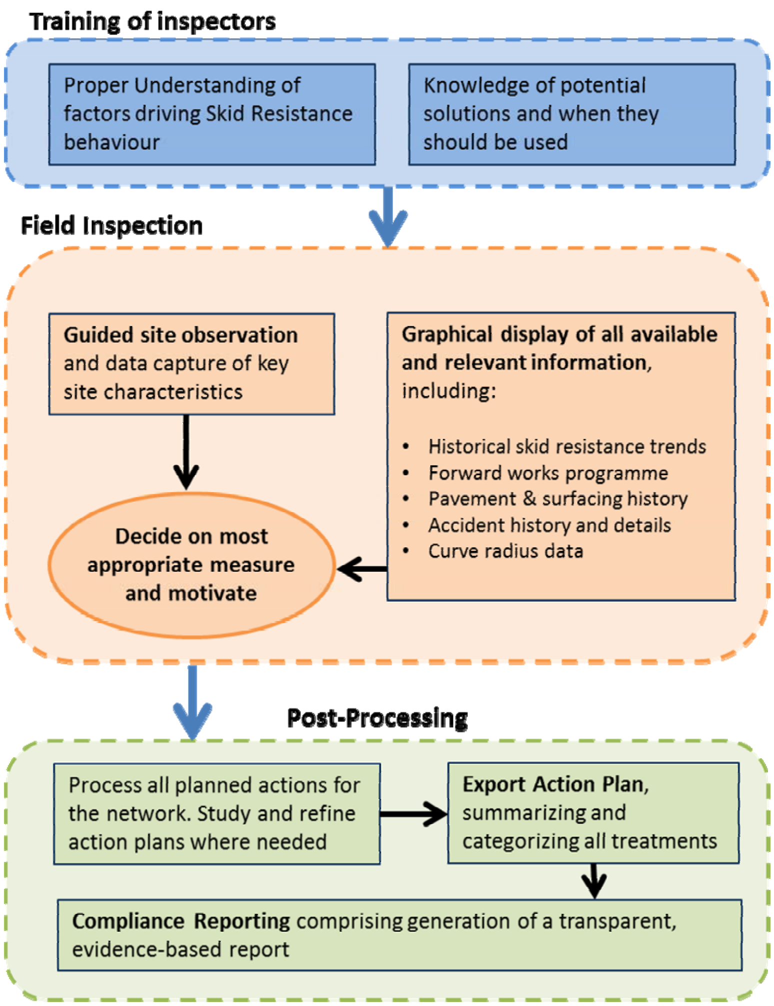


Figure 2: Overview of the T-SKAN system approach

Table 2: Short-Term remedial measures for skid deficient sites

Remedial Measure	Description
Localised reseal of the skid deficient area.	The area of skid deficiency is resealed. If done late in the sealing season, often a softer binder is used in conjunction with a diluent to assist in retaining the sealing aggregate over the winter months, but these treatments often flush the following summer.
Water cutting (also referred to as water-blasting)	In this process, water is sprayed in small quantities and under high pressure onto the road surface to remove bitumen from on and between the surfacing aggregate. However if the site has multiple unstable seal layers, or flushing depth is extensive, the bitumen may rise again, or the exposed chips may be punched further into the seal layer, and the problem may return within a couple of months (especially during hot weather). Alternatively, there is the risk in thin seals of removing too much bitumen so that the surface is no longer water proof, leading to pavement failures.

Remedial Measure	Description
	Essentially skid resistance rejuvenation through water cutting only lasts for one winter, but is a good temporary treatment that can be done in the cold seasons, when other treatments are out of season.
Hot chipping	This treatment can be used on heavily flushed sections. Small grade sealing chip is heated in an asphalt plant and spread on the flushed areas and rolled in. Specialist crews and supervision is required, along with peak summer hot conditions.
Install warning signs	When re-surfacing or other measures in the near future is imminent, warning signs can be employed to warn road users of a high skid risk requiring speed reduction. NZTA permits the use of these signs as a temporary measure but also requires that the sites are treated as soon as feasible and that the signs then be removed.

Table 3: Long-Term remedial measures for skid deficient sites

Remedial Measure	Description
Reseal	This treatment is effective when a suitable seal design can be employed, with a least whole of life success. On more difficult sites showing flushing, resealing can still be an option using specialist techniques such as sandwich seals or using a polymer modified binder. However care needs to be taken to prevent the new reseal from destabilizing the existing layers.
Asphalt Friction Course	Some sites may not be suitable for sealing due to issues such as high tyre stresses. If seals continue to fail in such locations, the least whole of life solution maybe to place asphalt instead. This is particularly effective in low radius curves and intersections.
Recycle pavement surface	This treatment is used when the combined surfacing layer has become unstable and/or skid issues combined with pavement structural issues, the best whole of life solution includes pavement rejuvenation. On the network, sites were found with seal depths up to 100mm and where water cutting or the installation of another seal layer would only be a short term solution. In these locations the best solution is to recycle the pavement thus mixing the surfacing layers with the underlying base course and re-trimming and compacting. This enables the seal cycle to be reset.
Asphalt Surface Milling (Scabbling)	Poor texture on asphalt can be rejuvenated through light surface milling or grooving, exposing new surface texture and aggregate.

SITE INVESTIGATION

Site inspection lies at the heart of the T-SKAN system, and, as indicated in Figure 2, proper execution of this task relies on two factors: (a) an informed and guided site inspection; and (b) incorporation and synthesis of all relevant information that can lead to a more informed treatment selection. These two aspects will be discussed in more detail in the following paragraphs.

Guided Site Inspection

Since the system is implemented using a lightweight computer programme (programme size is 1.1 GB including 58MB of photos) installed on a laptop, site inspectors can capture observations electronically while they are on site. In addition, the use of a template input form guides inspectors to perform a thorough assessment of all the likely factors which may explain why the site is skid deficient.

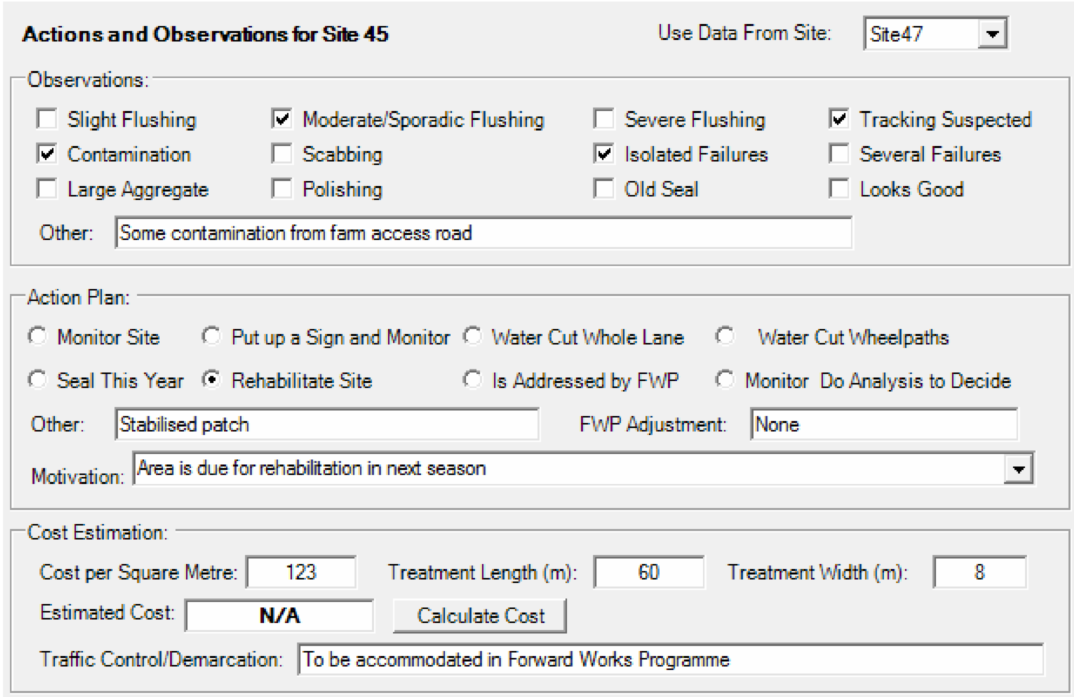


Figure 3: Input form for electronic capture of site observations

By explicitly noting observed conditions, the inspector is guided towards considering all relevant observations. Figure 3 shows a screen-shot of the input form used to capture site observations in the system. As can be seen from this figure, this input form also allows the inspector to select a treatment and motivate the selected treatment. An optional cost estimate can also be made.

Incorporating Other Sources of Information

The interpretation of the survey outputs and the decisions made during the process are of great importance to the success of the overall pavement strategy. As can be seen from the available treatment options, the success of each treatment is dependent on having a good understanding of the site condition, correct assessment of failure mode and the previous surfacing history. Furthermore, any treatment to improve the skid resistance at a site should fit in to the overall pavement lifecycle and network maintenance strategy. A final but critical consideration to bring into the decision making process is the pattern of accident occurrence, clear zone areas curve risk and rating in the area of the skid resistant site.

Figure 4 shows the layout of the T-SKAN system's programme main window. As can be seen from this figure, the system allows all of the above information to be integrated and displayed in an intuitive graphical format. Table 4 shows an example pf the types of information that is accessible through the screen panels, and can be used to allow a holistic approach in the selection of a most appropriate treatment type.

Table 4: Information types used when allocating treatments

Information Type	Why and How is it Used?
Forward Works Programme (FWP)	The FWP information shows the planned future treatments for the area in which the skid deficiency site is located. This allows the inspector to optimally integrate the selected remedial measure with the long term strategic maintenance plan. Specifically the FWP information is used to ensure that the selected measure is congruent with, and minimizes disruption to, the current FWP
Accident Data	Accident records over the past five years are obtained from the NZTA accident database (CAS) and graphically displayed for the skid deficient area (see Figure 4 for details on how this is achieved). Site inspectors

Information Type	Why and How is it Used?
	consider the accident history at the site and specifically note if there is a prevalence of recent wet-weather accidents, in which case a more expensive and urgent measure is likely to be adopted
Historical SCRIM® Data Trends	When a skid deficiency site is selected on the computer screen, a graph shows the historical trend in skid resistance data. This trend graph allows the inspector to assess whether the site recently became skid deficient or not. Also, the trend graph can be used to identify anomalies in the skid resistance data, which typically prompt further desktop analysis.
Pavement Surfacing History	The existing surfacing type, surfacing age and pavement age is displayed for the area in question. This allows the inspector to determine if the site has rapidly deteriorated or if the skid deficiency is due to long term deterioration.
Curve Radius Data	The curve data is obtained from the NZTA Out Of Context Curve table and displayed adjacent to the relevant highway section. Details on curve risk are binned depending on the risk. The inspector is able to assess the impact the change in geometry has at the site will note if there is a case where a specialist treatment (such as a higher PSV seal) is required

New Zealand highway networks are typically managed using a Forward Works Programme (FWP) covering a ten year horizon. In the FWP, each network is subdivided into discrete treatment lengths with each length being defined as a section of pavement that is reasonably homogenous within itself, but different to the adjacent sections of pavement. The FWP indicates the type of treatment that is planned for each treatment length and its projected timing. This allows for the establishment of credible budgets that become the basis for funding. The plans are reviewed and updated regularly, but continue to reflect the asset managers' strategic direction for the network.

One of the challenges to the asset manager is to undertake the reactive work required to correct areas of low skid resistance identified by the skid survey while at the same time maintaining congruency with the long term pavement strategy implanted in the Forward Works Programme. As shown in Figure 4, the T-SKAN system allows site inspectors to integrate FWP information with skid deficiency measures.

Consideration of accident history is an important aspect of managing pavement skid resistance. New Zealand operates a world class national database of road crashes which is of great assistance to this process. The source information is based on reports prepared by police who have standardised fields and location data. This location data enables the records to be related to the highway linear referencing system and the standardised fields enable sorting by particular details. The reports may also contain other information in either diagram or long text specific to the crash and therefore the report must be available through the system.

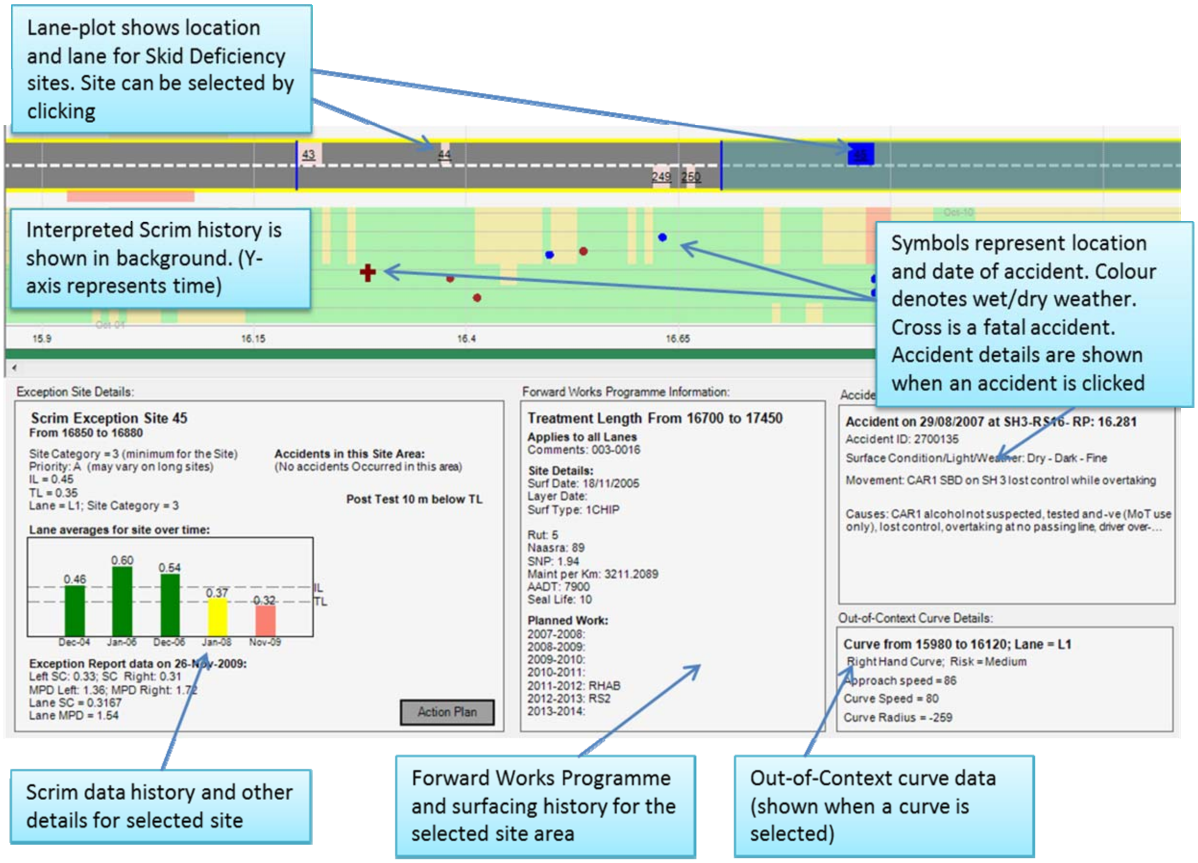


Figure 4: Main Window of the System's Computer Interface

OPERATION

In the interest of national road safety in New Zealand, Transfield has made the T-SKAN system available to roads-agencies operating in New Zealand. The standardized format of NZ FWP's and accident data greatly simplifies the process of implementing the system on other networks. To date, the T-SKAN system has been successfully implemented on four road networks.

The T-SKAN system was programmed in Microsoft .NET and is fairly simple to deploy on Windows operating systems. Operation of the system generally proceeds in three short phases: (a) data retrieval; (b) data processing and implementation, and (c) field operation. Key features of these processes include:

Data Retrieval and Initial Preparation

In this step, data such as historical SCRIM® data, FWP and accident data are obtained from the relevant databases and authorities. The skid resistance data is typically obtained in a delimited text file format, while the accident data and FWP is in spread sheet format. This data is then formatted so that it can be readily imported into the processing database.

Data Processing:

In this step, the imported data is processed using an algorithm that groups accidents into road lengths, extracts and groups historical skid resistance data, and calculates averages over skid deficient sites. The algorithm also scans the FWP and obtains the planned treatments and surfacing information for each skid deficient site.

Data Exporting and installation:

The processed and grouped data are exported in XML text file format. These files are transparent, lightweight and pose no security risk. As such the data processing can be done at a centralized location and the processed XML files can be sent to an asset manager via email, or via a web server.

Once the asset manager or site inspector has received and installed the processed XML files, the software can be installed on a laptop and taken to site, (the programme is small – 4.5MB). As shown in Figure 4, the layout of the system allows the inspector to view the road in a lane plot format, and also shows historical data and accidents in a date-linear format.

Skid deficient sites are displayed in the lane plot, and sites can be selected by clicking on them with the mouse. The historical data trend for the selected site is automatically displayed when a site is selected, together with the FWP data in that area. Similarly, accidents and out-of-context curves can be selected by clicking with the mouse. Details of accidents and curves are then displayed in separate boxes, as shown in Figure 4.

An action plan can then automatically be assigned to the selected site using the form shown in Figure 3. Once all skid deficient sites have been inspected, a summary of all allocated treatments, together with relevant statistics, can be exported to a spread sheet. This spread sheet is used in number of ways, firstly as a work programme, and secondly, as the basis of the annual report.

The annual report contains all the skid deficient sites, site observations, treatments and a decision trail, enabling a high degree of transparency to be demonstrated. Furthermore the report fulfils one to the fundamental values of the PSMC contract model, which is demonstrable compliance of risk mitigation for both the Client and road user.

SUMMARY

The greatest benefit that T-SKAN offers is that it allows the inspector to visualise all the data in a single application, and enables them to be able to make holistic and sound engineering judgement decisions to minimise the risk to NZTA. Being fully portable and developed for use in the field allows actual site conditions to be compared with the survey results, and these historic observations are recorded and reported as part of the annual report to NZTA

The framework outlined in T-SKAN provides for a consistent and repeatable approach to dealing with the SCRIM® Exception Report and as such improves the speed with which the field inspections are undertaken. Furthermore this allows any remedial works to be programmed early and undertaken in suitable weather conditions to improve risk mitigation success.

The introduction of the new T/10 Specification in October 2010 can be accommodated within T-SKAN with minimal upgrade. As it essentially ring fences the SCRIM® Exception Report, it can be utilised by uploading the new Curve Context tables, adding further field observations, and refining the tracking of the decision process in relation to the risk adjustments applied at site level.

As T-SKAN provides a consolidated view of a significant amount of network data, it can be used as a tool to help confirm and hardwire the I.Ls throughout the network, based evidence.

The reporting requirements in the new specification require traceability of the decision making process. T-SKAN is currently able to provide this degree of transparency and display demonstrable compliance of risk mitigation.

It must be noted this tool is not a substitute for the experienced engineer making sound engineering judgement decisions in a consistent and transparent manner

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AUTHOR BIOGRAPHIES

Glenn Foster has been involved in the maintenance and management of roading assets for the past 25 years. He holds an NZCE (Civil) from the Waikato Institute of Technology, and has worked in a variety of strategic roles both in the Contracting and Local Government Sectors. For the past 3 years he has been involved in the delivery of the PSMC001/006 network.

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Fritz Jooste received his Ph.D. in Civil Engineering from Texas A&M University in 1996. After this time, he worked as a senior researcher at the CSIR in South Africa until 2000. Since 2001, Fritz has worked in several countries including South Africa, Malaysia and New Zealand. Fritz is currently a director of Juno Services Ltd, New Zealand, where his focus is on model and software development related to pavement management systems.