

Recent Developments in Pavement Management on Irish National Roads

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ABSTRACT

The Irish National pavement network is Ireland's strategic road network consisting of over 5,300 centreline kilometres of road and is managed by the National Roads Authority (NRA). There is a very significant variation across the network under a variety of headings, including pavement construction, pavement age, carriageway width, lane width, geometric design and traffic volumes carried. A large proportion of the network consists of "legacy" roads that have evolved from historic routes that are often constrained by physical or environmental conditions. This diversity in road construction as well as varied traffic volumes, leads to significantly different deterioration and failure modes across the network. Constraints in the geometrical alignment also tend to alter how the route is driven. eg. the average inter-urban speed is lower for routes with tight radius bends. Accordingly, a range of innovative measures have been adopted to customise and adapt the Authority's Pavement Management System for the Irish National road system. The objective of this paper is to describe these innovative measures to an international audience.

Pavement Condition data collection using high speed machine survey vehicles has been carried out annually on the National road network. Most of the road condition data is collected using the Road Surface Profiler (RSP) machine. The skidding resistance data is collected using the Sideways-force Routine Investigation Machine (SCRIM). In 2013, LCMS has been used to collect cracking and ravelling data on the entire network. In addition, in 2013, a Ground Penetrating Radar (GPR) survey has been carried out on the entire network to improve the pavement construction and layer thickness data.

To manage this diverse network effectively, it was decided to define a series of five subnetworks by grouping similar sections such that there is considerably less variation in pavement condition, traffic and construction type. This approach enabled the service levels set for the different subnetworks to take account of the differences in traffic levels, pavement type and foundation characteristics of each subnetwork. The approach recognises the necessity to adopt progressively lower performance levels on Subnetworks 1 to 4, as compared to Subnetwork 0 (the motorway / dual carriageway network). In effect it recognises the constraints and adopts a "fit for purpose" approach. The performance levels are also used at tactical and strategic level for management of the network.

There is a comprehensive managed skid resistance programme based on 100% measurement of the skid resistance of the network on an annual basis. Principles of risk equalisation have been developed with a range of skid resistance investigatory values used on the network, dependent on the road section characteristics – approaches to roundabouts and traffic lights having significantly higher skid resistance requirements than straight line non-event sections, for example. This skid resistance policy is applied consistently across all subnetworks.

The NRA corporate GIS, ArcGIS, is used to co-ordinate and cross-reference the data from a range of management systems including the PMS, Bridge Management System, Accident Database, Traffic modelling database, Routine Maintenance Management Systems among others. A new ArcGIS add-in has been developed for the NRA to allow display and querying of the imagery collected on the annual surveys. The processed video is also available to the NRA and its clients through a web browser system.

INTRODUCTION

In the absence of a widespread rail or water transport network, Ireland's road network plays a vital role in the country's economy and wellbeing of its people, providing an essential route for freight and communities and enabling people to get to and from work or other

activities. The road network serves major population centres, ports, airports, public transport facilities and meets local civic requirements.

The National Roads Authority (NRA) undertakes a programme of annual pavement condition surveys (skid resistance, longitudinal and transverse road profile, texture depth and other parameters) in order to identify asset need and prioritise renewal activities. In 2011 the NRA procured a new Pavement Management System in order to provide a more comprehensive database of current and historical network annual surveys and network inventory. The PMS also allows the Authority to predict future condition, supporting better decision making to achieve better annual programming and prioritisation of pavement improvement and renewal works.

The National pavement network consists of over 5,300 centreline kilometres of road (1). There are 33 National Primary routes and 32 National Secondary routes. Road pavements in Ireland are predominantly made of layers of flexible materials that are designed to be strong enough to support the loads over their lifespan (c. 20-40 years). In addition the surface course must also provide adequate wet skidding resistance, acceptable ride quality, contribute to the generation of acceptable noise levels and resist deterioration induced by environmental conditions. There is a very significant variation across the network under a variety of headings, including surface type, pavement construction, pavement age, carriageway width, lane width, geometric design and traffic volumes carried.

The Motorway and Dual Carriageway roads are typically of recent construction and have been designed structurally and geometrically to carry the high traffic volumes using this portion of the network. There is a further substantial portion of the network where the pavements have been designed structurally and geometrically to carry the vehicle traffic. These are termed "Engineered Pavement".

A large proportion of the network consists of "legacy" roads that do not meet the above criteria and may have evolved from historic routes that are often constrained by physical or environmental conditions. An example would be our bog rampart roads that are built on very weak foundations and often originated from access tracks for horse drawn vehicles. This diversity in road construction, as well as varied traffic volumes, leads to significantly different deterioration and failure modes across the network. The principal cause of deterioration is usually from repeated traffic loading and in particular heavy commercial vehicles. In some cases, roads with lower construction quality but also with lower traffic volumes may remain in their current state for much longer. Often these can be allowed to operate to a reasonably satisfactory level for an extended duration. In contrast, heavily trafficked roads will normally deteriorate more quickly and may benefit from earlier intervention to prevent rapid deterioration leading to more significant intervention and ultimately to failure of the asset. Exceptional events such as significant changes in established traffic patterns, weather events such as persistent heavy rainfall with associated flooding, and the sustained heavy frosts of 2010 & 2011 can cause unexpected acceleration in the deterioration of weaker roads, especially those with weaker / water susceptible foundations.

AVAILABLE DATA FOR REPORTING

Road Surface Profiler (RSP)

The RSP is a multi-purpose data collection system equipped with computers, high frequency lasers, accelerometers and inertial motion sensors for recording pavement performance data using a number of on-board sub-systems (2).

The RSP is capable of real-time continuous high-speed measurements of:

- Longitudinal Profile (including International Roughness Index (IRI))
- Transverse Profile (Rut Depth)
- Macrotexture (Mean Profile Depth)
- Geometrics (Crossfall, Gradient and Radius of Curvature)
- Forward View/Pavement Oriented Digital Video
- DMI linear chainage coordinate system
- GPS geo-referencing coordinate system



FIGURE 1 The RSP Multi-function Survey Vehicle

The Laser Crack Measurement System (LCMS)

The Laser Crack Measurement System (LCMS) is a high-speed and high-resolution transverse profiling and imaging system (3). The LCMS uses laser line projectors, high speed cameras and advanced optics to capture high resolution 3D profiles of the road. The LCMS Survey Vehicle is shown on Figure 2. Typically, the LCMS system can capture one road profile every few millimetres (5 mm at 100km/h) by using two laser profilers that acquire the shape of the pavement. Each profile consists of up to 4160 data points giving full 4-metre width 3D profiles of the road. The LCMS acquires both range (height) and intensity (image) data of the road surface with 1 millimetre resolution allowing for the characterisation and the visualisation of high quality images, cross-sectional shape and macrotexture of the road surface. Both the resolution and acquisition rate of the LCMS are high enough to enable the detection of cracks at high speeds of up to 100km/h but is typically operated at a speed of c.80km/h.

The LCMS measurement covers a width of up to 4 metres allowing the whole carriageway width to be examined during the day or at night. Night-time data acquisition has

been carried out in areas with very high daytime traffic congestion. The use of the LCMS is weather dependent and the survey cannot be carried out in wet conditions. Custom optics and high power pulsed laser line projectors allow the system to operate in full daylight or in night time conditions..

The LCMS data is analysed using specialised software to detect and analysis cracks, lane markings, ruts, potholes and macro-texture (MPD). Patches, ravelling (fretting), sealed cracks and joints in concrete surfaces are also identifiable and quantified using the LCMS data.



FIGURE 2 The LCMS Survey Vehicle

In the absence of high speed structural assessment at network level, the data collected can be used as index referencing for more detailed structural analysis at project level.

Digital Video

A high-resolution digital video (DV) camera system is used to record a forward view surface-orientated video of the road pavement. The digital video is recorded in with frames captured every 5 metres. The header of each video frame is stamped with survey date, route id, direction, time, speed, chainage and ITM co-ordinates, and the frames are compressed using state-of-the-art compression algorithms to retain maximum definition at minimum storage space. In addition, left and right-oriented digital video cameras are used to record right-of-way imagery at 5 metre intervals.

The digital video can be subsequently post-processed in the office to carry out a visual condition survey of the road pavement. The video provides a permanent record of the road surface at the time of testing, and can also be used for other pavement management purposes such as identification and visual assessment of pavement defects, signage, line markings etc.

SCRIM

The equipment used to generate frictional resistance measurement on 100% of the pavement network annually is the SCRIM (Sideway force Coefficient Routine Investigation Machine). The SCRIM is pictured in Figure 3.



FIGURE 3 The SCRIM Survey Vehicle

The equipment is mounted on a truck chassis, with a large capacity water tank (c. 4000 litres). It is specifically designed to allow large lengths of road network to be continuously tested. Daily outputs of c. 200 kilometres can be expected using the SCRIM. The test wheel is contained within a loading frame that is mounted mid-machine, between the front and rear axles of the truck.

When the test vehicle moves forward along the road section, the test wheel is rotating, but slides in the forward direction due to the angular difference. The standard test speed for SCRIM is 50 km/h in Ireland, with a permitted range of operation of 25 to 85 km/h. Readings are speed-corrected back to the standard test speed. Based on research carried out in 2011 and 2012, testing at 80 km/h on high speed sections, primarily motorways, is permitted for safety reasons. On bends with low radii of curvature (less than 100 metres) and on roundabouts, testing is carried out at 20 km/h.

GPS Referencing Equipment

The survey vehicles are equipped with GPS technology so that all recorded data is referenced to 3-dimensional spatial co-ordinates. The GPS data must be differentially corrected in order to improve accuracy. The GPS equipment is fully integrated with an inertial measurement system (INS) in order that the Irish Transverse Mercator (ITM) grid co-ordinates can be derived from the GPS data irrespective of the quality of the satellite coverage.

ROAD CONDITION PARAMETERS USED ON NRA NETWORK

International Roughness Index (IRI)

The International Roughness Index (IRI) is a scale for roughness based on the response of a standardised motor vehicle to the road surface. The IRI simulates response to the surface profile, and also considers the effect of vehicle suspension. Roughness or ride

quality is important as numerous studies have shown that there are strong correlations between motorists' subjective ratings of ride quality and the ratings derived from measurement of IRI. The road user's view of satisfactory or unsatisfactory road condition is primarily influenced by roughness or ride quality. There is also significant correlation between IRI and the maximum speed at which a road user is comfortable while driving on the road in question.

Longitudinal Profile Variance (LPV-3)

In addition to IRI, the profile output is used to calculate a 3 metre variance parameter (4). Essentially, this parameter is used to identify locations with distress that causes short wavelength ride problems for the driver. Examples would be bumps and sags, potholes, and poor utility trench reinstatements. This parameter, in conjunction with the IRI parameter which examines vehicle response over a wide range of wavelengths, is used to measure the ride quality of the pavement from the user's perspective.

Rut Depth

Rutting in the wheelpath is a structural distress induced by heavy vehicle traffic. Rutting is identified as a permanent deformation of the pavement, creating channels in the wheelpaths. It can be caused by the consolidation of material under repeated traffic loading, inadequate compaction of the pavement layers during construction or inadequate thickness of pavement layers. Rutting in the left wheelpath is generally more severe than in the right wheelpath (in Ireland, vehicles drive on the left).

Surface Texture

The macrotexture or surface texture of the pavement surface refers to the coarser texture defined by the shape of the individual coarse aggregate particles used in a surface course mix, and by the spaces between the individual aggregate chips. Macrotexture is a major influencing factor on frictional resistance at higher speeds (>50km/hr) and is particularly important in relation to wet conditions. This is particularly relevant in Ireland, where there is a predominant mild and damp climate, with significant rainfall throughout the year. The macrotexture is continuously measured using the RSP laser is expressed as Mean Profile Depth (MPD) in millimetres at 1 metre intervals.

Cracking

Cracking at the road surface may indicate a deterioration of the surface course and may also represent defects deeper in the pavement structure. The cracks may allow water to penetrate the pavement layers and weaken the foundation. The LCMS data identifies the locations, quantities and widths of cracking in the pavement surface. The types of cracking that can be identified include longitudinal cracking, transverse cracking, edge cracking and alligator cracking. Both longitudinal and transverse cracking are linear features and are measured in linear metres, whereas edge and alligator cracking are an area of cracking and are measured in square metres.

LCMS measures cracking at the surface of the road pavement, which is reported as the location of each crack in the form of a crack image. The crack images are analysed using proprietary software to produce the images and XML's on the quantity and details of the defects of the road which are reported at 10 metre intervals. When the data is collected all distresses detected are reported in 10m distress images both with and without distress overlays. These values are subsequently quantified into each of their individual crack categories.

SCRIM Coefficient (SC)

The horizontal and vertical forces are measured continuously when the SCRIM test wheel is in contact with the ground. The ratio of sideways force to vertical force is used to calculate an average SCRIM reading (SR) value at 10 metre intervals for the NRA network. The SR values coming directly from the machine are raw values, uncorrected for speed, seasonal adjustment factors etc. After correction for speed, temperature and machine variability, the SCRIM coefficient (SC) is derived, and forms the basis for network skid resistance management.

SUBNETWORK DEFINITION AND USE

Sub Network 0 comprises the high speed, high volume pavement network, made up of the Motorway and Dual Carriageway sections of the network. This sub network typically has fully designed geometric cross-sections and pavement structure, and much of this sub network is relatively new (10 years or less). This subnetwork is predominantly the major interurban routes and is concentrated on radial routes from the capital city, Dublin.

Sub Network 1 comprises the remainder of the pavement network where significant geometric and pavement design has taken place in the construction and/or rehabilitation of the pavement sections. Typically these sections are carrying reasonably large volumes of traffic, and can be identified by the presence of hard shoulders adjacent to the carriageway. The network sections are distributed countrywide, and are found most frequently on extensions of subnetwork 0, and on relatively high traffic intercity routes.

Sub Networks 2, 3 and 4 are the legacy sub networks, typically constructed without formal geometric or pavement design over many years. The sub networks are distinguished from one another by traffic volume, with sub network 4 carrying very low volumes of traffic of less than 2000 AADT. Subnetwork 4 is predominantly situated on the Western seaboard or west of the Shannon River. Subnetwork 2 and 3 sections are geographically distributed across the entire country.

The distribution of centreline length across the 5 subnetworks is shown in Table 1:

TABLE 1 Subnetwork Classification and Length

Subnetwork	Classification	Length (km)
0	Motorway/Dual Cway	1147
1	Engineered Pavements	990
2	Legacy Pavements > 3500 AADT	1129
3	Legacy Pavement, 2000 to 3500 AADT	884
4	Legacy Pavement, < 2000 AADT	1170

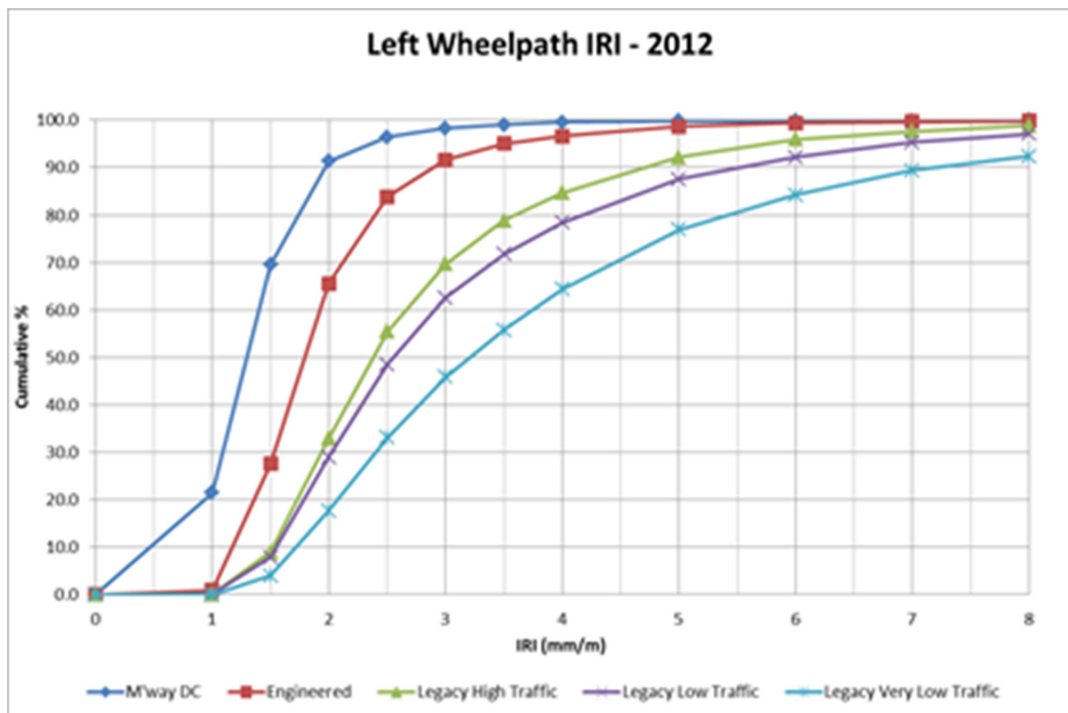


FIGURE 4 Cumulative Frequency Distribution of IRI across Subnetworks

Differences in Condition across Subnetworks

Figure 4 shows the cumulative distribution frequency curves for the International Road Index (IRI), a measure of the ride quality of the road which can be a useful index test for the functional performance of the road. Lower values of IRI indicate better ride quality on the pavement section— the lower the number the better the functional performance, particularly from a road user standpoint. It can be seen that the 5 sub networks are clearly distinguishable from one another, with sub network 0 having clearly the best performance (e.g. 70% of the sections on sub network 0 have an IRI of 1.5 or less) and sub network 4 having clearly the poorest performance (e.g. 70% of the sections on sub network 4 have an IRI of 4.5 or less).

Similar trends can be seen in relation to the other performance parameters, confirming the approach taken by the Authority in defining separate performance standards for each of the subnetworks.

SUBNETWORK APPLICATION IN NRA NETWORK MANAGEMENT

Key Performance Indicators (KPI) are reported at strategic level and tactical level. Strategic level reporting is intended for managers and decision makers at an executive level. Typically KPIs at this level are qualitative rather than quantitative in nature. These KPIs are designed to answers some pertinent questions such as: are the road authority's investments targeting and obtaining the right/best outcomes? The KPIs reported at this level are derived from quantitative measurements.

At tactical level, the KPIs and other parameters are more detailed, yielding information on what impact the investment is achieving in various areas of the road management operation. Close monitoring of trends over time, rates of change in technical and economic parameters, and monitoring of regional (sub network) differences are included .In

keeping with best practices in other jurisdictions (5), there are four areas used to monitor pavement performance. These are:

- **Pavement Structural Health**
- **Pavement Surface Health**
- **Skid Safety**
- **Economic Efficiency**

At tactical level, the parameters currently measured group under the four performance areas as follows:

- **Pavement Structural Health** – Rutting, Structural Cracking, 3m Variance, IRI
- **Pavement Surface Health** – Other Cracking, Ravelling, Roughness, Macrotexture
- **Skid Safety** – SCRIM Coefficient (SC) compared with site-specific Investigatory Level
- **Economic Efficiency** – Unit costs per treatment, Kilometres treated

It should be noted that 2013 is the first year that cracking and ravelling data has been collected on a full network basis and this information has not yet been fully incorporated into KPI values.

At strategic level, qualitative indicators are used for the three technical performance areas. This is achieved through the use of 5 levels of service brackets, namely Very Good, Good, Fair, Poor and Very Poor, that have been defined for many of the technical parameters. Trend analysis showing percentages in each category, and changes in distribution over time, are used to monitor overall network health, and impact of maintenance budgets on pavement condition. Tables 2 to 4 below show the current NRA service bracket definitions.

TABLE 2: IRI Descriptive Categories (mm/m)

Category	Subnet 0	Subnet 1	Subnet 2	Subnet 3	Subnet 4
V Poor	> 3	> 3.5	> 5	> 5	> 7
Poor	2.5 to 3	3 to 3.5	4 to 5	4 to 5	5 to 7
Fair	2 to 2.5	2.5 to 3	3.2 to 4	3.2 to 4	4 to 5
Good	1.5 to 2	2 to 2.5	2.7 to 3.2	2.7 to 3.2	3 to 4
V. Good	< 1.5	< 2	< 2.7	< 2.7	< 3

TABLE 3: Rut Depth Descriptive Categories (mm)

Category	Subnet 0	Subnet 1	Subnet 2	Subnet 3	Subnet 4
V Poor	>9	>9	> 15	> 15	> 20
Poor	6 to 9	6 to 9	9 to 15	9 to 15	15 to 20
Fair	5 to 6	5 to 6	6 to 9	6 to 9	9 to 15
Good	3 to 5	3 to 5	4 to 6	4 to 6	6 to 9
V. Good	< 3	< 3	< 4	< 4	< 6

TABLE 4: LPV Descriptive Categories

Category	Subnet 0	Subnet 1	Subnet 2	Subnet 3	Subnet 4
V Poor	> 4	> 4	> 6	> 7	> 10
Poor	3 to 4	3 to 4	4 to 6	5 to 7	7 to 10
Fair	2 to 3	2 to 3	3 to 4	3.5 to 5	4 to 7
Good	1 to 2	1 to 2	2 to 3	2 to 3.5	2 to 4
V. Good	< 1	< 1	< 2	< 2	< 2

PAVEMENT REHABILITATION SCHEME CREATION

Tables 2 to 4 are also used to identify and prioritise pavement maintenance and rehabilitation (M&R) schemes for the current year, and under a 3 year rolling programme. The categories are based on the Left Wheelpath IRI, Left Wheelpath Rut and Average of Left and Right Wheelpath 3 metre longitudinal profile variance. Sections in Poor and Very Poor categories are candidates for inclusion in the Pavement Maintenance and Improvement (PMI) schemes. The creation of PMI schemes is carried out as follows.

Threshold values are assigned to each Sample Unit parameter for each subnetwork. In this instance the threshold values were selected to be the lower limit of the “Poor” category e.g. IRI of 2.5 mm/m for Subnet 0, 3.0 mm/m for Subnet 1 etc. Each sample unit (100m in length) parameter value is compared to its appropriate subnetwork threshold value for each parameter. Sample units were checked for values **at or above** the threshold level. Sample Units with **two or more** parameters at or above the threshold level are designated as candidate sample units for inclusion in M&R schemes. The use of two or more parameters at or above threshold level was found to align much more closely with the selection of sections based on expert engineering judgement at local level when compared with a single parameter approach. This in turn has raised confidence levels in the output from the PMI scheme process across the organisation from upper management to project level engineers.

In addition, recognising the importance of rut depth as a single parameter reflecting structural condition, any sample unit with a rut depth ≥ 25 mm, is selected as a candidate sample unit. The candidate sample units selected using the criteria outlined above are merged into candidate sites based on contiguity criteria. We use a maximum gap of 300 metres between sample units when merging sites i.e. sample units within 300 metres of each other are merged into a single site, sample units greater than 300 metres apart are left as separate sites.

A list of sites greater than or equal to 400 metres in length is created. Each of these sites will have at least 2 sample units that meet either of the selection criteria outlined above. A second list of sites not included in the 400 metres or greater list above is also created to identify patch/repair sections. This list largely consists of individual sample unit locations but patch/repair sites of up to 300 metres in length are possible

Pavement M&R Scheme Ranking

Utilising condition prediction modelling in the PMS, the ranking of M&R schemes is carried out using a “most in danger first” approach. Schemes are ranked based on the percentage by which each of the 3 selection parameters (IRI, Rut, LPV3) in the section exceeds the relevant threshold values for the section and is further refined by reference to

predicted deterioration rates. Using percentage values normalises the value for each parameter and allows direct comparison and ranking across the subnetworks.

For each of the candidate sample units in the scheme the PAT (percentage above threshold) for each parameter was calculated. PAT was capped at 150% for all parameters. The Sample Unit characteristic PAT was the sum of the worst two parameter PATs. The PMI Scheme PAT was the average PAT of the Sample Units. N.B. the Scheme PAT is calculated based on the “failed” sample units only (i.e. sample units with values above the threshold values), not on all of the sample units in a scheme. This ranking scheme has been developed through a process of multiple refinements, with direct comparison of the ranking to rankings produced by experienced pavement engineers working within the NRA. There is now a high confidence level that the ranking scheme based on the PAT approach does identify and accurately rank maintenance schemes on the NRA network.

SKID RESISTANCE PRIORITISATION

Skidding resistance is managed on the network in accordance with NRA Maintenance Standard HD28/11 (6). The skidding resistance of the entire national road network is measured annually in the left hand wheel path using SCRIM. The output is a measure of the microtexture and low speed frictional resistance available on the pavement surface. The SC value is the relevant parameter used in HD28/11.

Data on the skid resistance offered by the pavement surface is collected over the entire network annually. The objective of the Standard is to manage the risk of skidding collisions in wet conditions so that this risk is broadly equalised across the National Road Network (7). Event locations with greater potential for vehicle/vehicle or vehicle/pedestrian interactions (e.g. roundabouts, approaches to traffic lights) are assigned more onerous levels of required skid resistance to reflect the higher risk of collisions. HD28/11 contains the details of the relevant investigatory levels. The network has been divided up into over 16,000 separate event locations, with an appropriate investigatory level of skid resistance assigned to each event location.

Site category and definition		Investigatory Level at 50km/h							
		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65
A	Motorway								
B	Dual carriageway non-event								
C	Single carriageway non-event								
G1	Gradient 5-10% longer than 50m								
G2	Gradient >10% longer than 50m								
K	Approaches to traffic signals. pedestrian crossings								
Q	Approaches to and across major and minor junctions,								
R	Roundabout								
S1	Bend radius <250m – dual carriageway								
S2	Bend radius <250m – single carriageway								

FIGURE 5 Skid Site Category and associated Investigatory Levels

The darker box indicates Investigatory levels for road sections with traffic levels of greater than 250 commercial vehicles / lane/ per day, the lighter box indicating IL levels for sections with traffic levels of less than 250 commercial vehicles/lane/ per day. Investigatory Levels represent a limit above which the skid resistance is assumed to be satisfactory. Any event locations with measured skid resistance above the assigned investigatory level are therefore not considered further. Event locations with measured skid resistance at or below the assigned investigatory level are candidates for a detailed visual site investigation to consider whether treatment to improve the skid resistance is required or whether some other action is required. This investigation includes observations of site geometrics and traffic; current and historic skid resistance measured values; collision history on the site, age and type of the pavement surface and many other factors.

A prioritised approach to site investigations is followed and investigations are currently prioritised based on the amount by which the measured skid resistance is below the Investigatory Level at each event location. This order may be refined to take into account other information gathered during the early part of the investigation, such as the recent collision history.

The process of site investigation results in a number of locations being recommended as benefiting from treatment to improve the skid resistance. The priority for treatment is established taking into account the observed collision history, the need for other maintenance works in the vicinity, the cost and the budget available for the works.

INNOVATIONS IN IMAGERY STORAGE AND USAGE

The National Roads Authority (NRA) collects a number of video data-streams as part of the annual network pavement condition survey contract. The video data is used for a number of functions within the pavement management section, including support to the HD 28 skid resistance management programme and the Pavement and Minor Improvements site assessment and selection process. The video data has also been extensively used by the Safety section and the Routine Maintenance section within the NRA.

The video data was integrated with pavement condition data through ArcGIS, the NRA corporate GIS. ArcGIS does not have the capability to display video using its inbuilt tool set. Accordingly, there is currently an inability to view the video gathered and integrate the video with condition data through the NRA corporate GIS. The video collected can still be viewed through standard video and image viewers such as Windows Media Player.

Under the latest NRA network data collection contract, four separate video datastreams are collected. These are

Forward-view: SCRIM survey

Forward/Downward view: Road Surface Profiler (RSP) survey

Left Oriented Side view: RSP Survey

Right Oriented Side View: RSP Survey

Imagery is collected at c. 5 metre intervals over the c. 5300 kilometres of the annual network survey. The total storage requirements are between 600 and 800 GB annually. It is desirable to make the video collected available widely across the NRA organisation. It is also a requirement of the pavement management section that the video is available for viewing and display through the ArcGIS software for ease in interpretation of the pavement condition parameters collected. It became clear that there were three different requirements desirable:

- A software add- to function with the existing ArcGIS version 10 NRA installation. Video would be stored and accessed on the NRA in-house servers.
- A cloud-based storage solution whereby the video would be stored external to the NRA on secure servers, and the video software add-in would access the video from these external servers.
- A web browser solution whereby the video would be stored externally on secure servers and access to the video would be available over the web, rather than the current situation where it is accessed through the NRA computer infrastructure. The web browser solution would also allow access to additional video collected by the NRA.
- An Irish technology company, iGeotec, was able to provide a solution using an adaptation of their Ubipix software. There are two components to the Ubipix system; the Smartphone/Camera App that enables user capture, tag and upload multimedia datastreams and a Client-Server architecture that supports publishing, discovery and sharing of users' spatial multimedia content. The second component, the Client-Server architecture, was adapted and leveraged to provide access to the NRA georeferenced video data.

A number of meetings were held with iGeotec personnel to explore the potential to leverage the Client-Server architecture developed, and the ability of the architecture to handle the volume of video generated by the NRA surveys on an annual basis. Separate discussions and assessments were also carried out on a prototype ArcGIS extension software module under development at iGeotec to allow geo-referenced imagery (video and still images) to be accessed and manipulated within the ArcGIS 10 environment. Development work progressed satisfactorily, and the NRA now has the ability to view and manipulate multi-camera imagery within the ArcGIS desktop environment. In addition, the video is uploaded to cloud-based storage, and is available through a web-based browser solution, allowing many more users access to the annual network imagery collected.

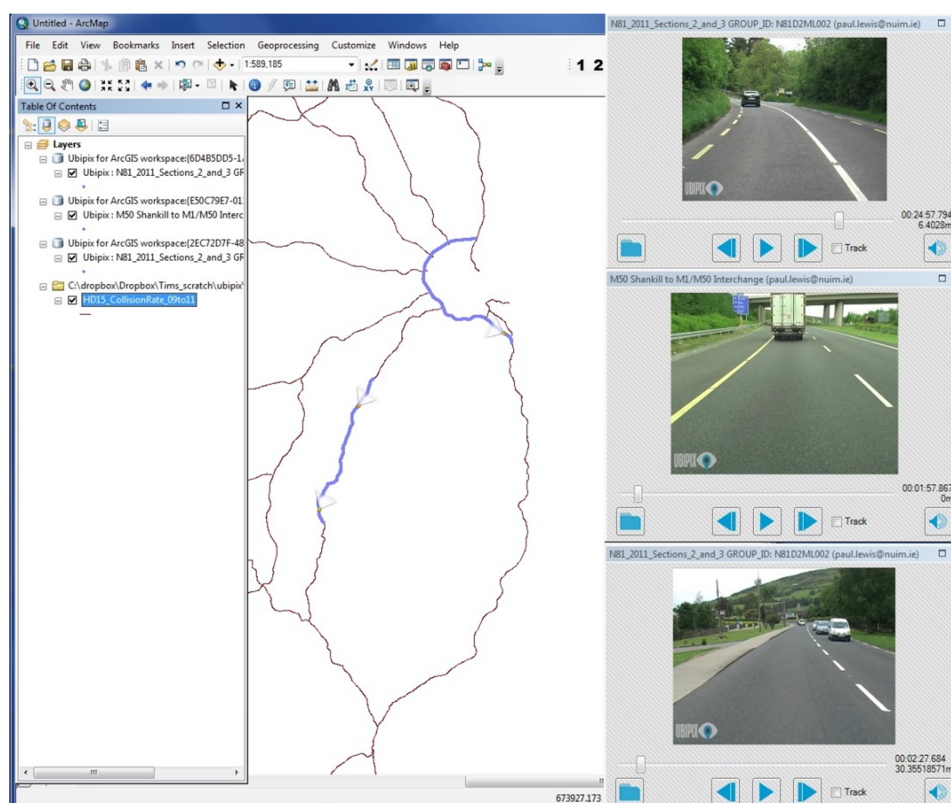


Figure 6: Multiple Video Displays within ArcGIS environment

Conclusions

There have been a number of innovative developments in the NRA's management of the national network of pavements since the implementation of a new PMS in 2011/12. A number of subnetworks have been defined, with significantly different characteristics, and different levels of service brackets and intervention levels. In turn, this has led to the development of a new system of M&R scheme selection, based on a combined Percentage Above Threshold approach for two or more performance parameters that accords very well with scheme selection based on expert engineering judgement at local level. A comprehensive approach to managing skid resistance, introduced in 2011, is discussed. Recent developments in the integration of video imagery with ArcGIS using both local server and external cloud-based storage and web browsers are outlined. The objective of this paper is to describe these innovative developments to an international audience.

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