AN ROINN COMHSHAOIL, OIDHREACHTA AGUS RIALTAS ÁITIÚIL

The Department of the Environment, Heritage and Local Government.




Pavement Condition Study Report

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SECTION 0: EXECUTIVE SUMMARY

The Department of the Environment, Heritage and Local Government (DEHLG) commissioned RPS – MCOS Ltd. and PMS Pavement Management Services Ltd to carry out a pavement condition study on the Non-National roads. The main objectives of the 2004 Pavement Condition Study, as set out in Schedule 4 of the Request for Proposals document are:

- To establish, by county and nationally, the lengths and areas of various categories of non-national roads requiring remedial works, and
- To review existing pavement management systems and recommend a system suitable for use on the non-national road network.

A 2001 National Roads Authority study on vehicle-kilometres of travel in Ireland indicated that the Non-National road network carries 59% of all car travel, 56% of all LGV travel, and 43% of all HGV travel, clearly showing the importance of the Non-National road network in the Irish context.

There has been a very large growth in Heavy Goods Vehicles (HGV) numbers since 1995. The HGV numbers have grown by 6% per annum over this period. Taking Light Goods Vehicles (LGV) and HGV together, there was an annual growth of 7.6% over this period, exactly the same as the average GDP growth rate of 7.6% per annum from 1996 to 2003.

The increase in HGV numbers has been predominantly in the provision of much larger and more damaging HGV. The combination of growth in numbers and damaging power has dramatically increased the structural loading on the network since 1996.

Overall, it can be concluded that the economic boom in Ireland since the last condition survey in 1996 has fundamentally changed the loading regime on the Non-National road network, with much higher and more frequent loadings by heavier vehicles being the norm in 2004.

A total of over 8,000 kilometres of Non-National roads were surveyed in 2004. The Engineering Area was chosen as the base unit for sampling, with roads in all 4 road classes (Regional, Local Primary, Local Secondary, Local Tertiary) selected for survey in every Engineering Area in the country.

A data collection methodology to maximise the speed of data collection in the field was developed. The entire data collection effort was completed using 4 video vans over a 15 week period in early 2004.

The methodology relies on high-definition digital video to capture the road surface condition. The video is subsequently post-processed in the office to produce condition information on each 100 metre sample unit.

The condition measurement produces a Pavement Condition Index (PCI). A new pavement (theoretically distress-free) has a PCI of 100. For each distress measured, there are deduct values depending upon the nature of the distress, its severity and quantity. The deduct values are summed, adjusted to take into account the total number of distresses identified, and then subtracted from 100 to give the PCI index for the pavement.

In addition, a further condition parameter, the ride quality of each pavement section, was recorded in the 2004 survey. This parameter is measured in International Roughness Index (IRI) units. The IRI is important as the road user's view of satisfactory or unsatisfactory road condition is primarily influenced by roughness or ride quality.

The remedial works categories are Surface Restoration, Road Reconstruction and Restoration of Skid Resistance. Surface Restoration was defined to include improvement of drainage, pothole patching, restoration of road width and strengthening of road edges as well as localised surface dressing of the repaired areas. Road Reconstruction was defined to include reconstruction of existing road pavements, overlaying of existing road pavements with bound or unbound materials surface dressed, and raising of road levels to prevent flooding with provision of drainage. Restoration of Skid Resistance covers the application of a surface treatment to restore adequated skid resistance. A fourth category, Routine Maintenance, was defined by the consultants to include road section lengths not requiring any of the three remedial work types defined above. Road sections in this category would be in very good existing condition.

The initial assignment of each surveyed sample unit to one of the remedial works categories is primarily based on the PCI value. This is consistent with the approach taken in the last major national study of Non-National road conditions in 1996.

In the 2004 study, the ride quality data is also used to modify the results derived from the visual survey. In particular, road segments with poor or very poor ride quality characteristics are moved into the Road Reconstruction category. Only the Road Reconstruction activities can restore the ride quality of the pavement section to an acceptable level.

There is a clear downward progression by road class in average PCI, from 68 on Regional (R) roads down to 50 on Local Tertiary (LT) roads. The IRI ride quality average values show a similar trend. The smoothest roads (lowest IRI) are on the R roads with an average value of 5.3 m/km, while the LT roads show the highest average value at 11.8 m/km, more than double the value for the Regional roads. The differences in PCI and IRI by road class are large, and reflect clearly different conditions nationally by road class.

When individual distress patterns are examined, it is clear that Ravelling occurs much more frequently than other distresses. Rutting is the second most frequently occurring distress. This is significant as Rutting is a structural distress, carrying a relatively high deduct value, and having implications for the maintenance requirements of the section. Patching and Bleeding have a similar rate of occurrence, significantly higher than Edge Breakup. Potholes, Alligator Cracking and Depressions have a relatively low rate of occurrence, with Road Disintegration and Other Cracking having a very low rate of occurrence.

When the 1996 and 2004 surveys are compared, the main trends are:

There has been a substantial increase in the occurrence of Ravelling in 2004 compared to 1996. The percentage occurrence of Bleeding is lower in 2004. These differences may reflect the difference in the time of year when the survey was carried out.

There has also been a substantial increase in the occurrence of Rutting between 1996 and 2004. This reflects the much larger traffic volumes, and in particular the much heavier and wider commercial vehicles using the road network over the past 8 years. There has been a very significant increase overall in commercial traffic volumes in line with economic growth.

Without the strengthening programme that was put in place since the mid 1990's, the rate of occurrence of all structural distresses in 2004 would have been much higher than in 1996. In fact, the rate of occurrence of Potholes and Road Disintegration has effectively halved over the period from 1996 to 2004, while the rate of occurrence of Patching is also substantially reduced. This reflects the significant investment in the road network with priority obviously being applied to road sections with surface breaks.

Overall, the distress comparisons show that the Non-National network is very significantly better in 2004 in reducing the incidences of surface breaks (Potholes and Road Disintegration) that produce high levels of road user dissatisfaction. This reduction has occurred in the context of much heavier and more frequent loadings on all road classes of the Non-National network. However, this greater loading has increased the amount of rutting on the network substantially, and this has significant implications for the structural maintenance budgets required going forward.

SECTION 1: INTRODUCTION AND BACKGROUND

1.1 DEHLG REQUIREMENTS

The Department of the Environment, Heritage and Local Government (DEHLG) commissioned RPS Group and PMS Pavement Management Services Ltd to carry out a pavement condition study on the Non-National roads. The main objectives of the 2004 Pavement Condition Study, as set out in Schedule 4 of the Request for Proposals document are:

- To establish, by county and nationally, the lengths and areas of various categories of non-national roads requiring remedial works, and

- To review existing pavement management systems and recommend a system suitable for use on the non-national road network.

A primary requirement was to establish the lengths and areas of various categories of non-national roads that require various types of remedial works. The lengths and areas were to be established nationally, and on a county-by-county basis. It was not required that all roads be inspected to determine the lengths and areas. A statistical sample of the roads in each county was selected to represent all such roads. It is necessary that there should be a very high degree of confidence that the sample size chosen is large enough to accurately represent the true total lengths and areas requiring the various types of remedial works for each county.

Another stated requirement was that comprehensive information on the current status of regional and local roads should be obtained from the 2004 Pavement Condition Study. This information is required both to quantify the current status of road conditions within counties and nationally, and to provide a benchmark measurement against which the future actual road conditions can be compared, both within counties and at a national level. In particular, a previous pavement condition study was carried out in 1996, and a further study may be undertaken in 2007.

The DEHLG further stated that the results of the study "will form an important part in the ongoing process of securing and allocating resources to the non-national road network and in the implementation of the multi-annual restoration programmes". To this end, information on actual road conditions, as well as on lengths and areas of various types of remedial works, needs to be gathered to facilitate comparisons over time, and to allow for the development of additional or modified criteria that may differ from the criteria applied in this study.

Finally, it was a requirement that all survey data collected should be available in electronic format, and further that, where appropriate, maximum use was to be made of the Local Government Computer Services Board (LGCSB) MapRoad package as this is already installed in all local authorities and provides the most appropriate and most efficient means of distribution of the collected data at local authority level.

1.2 SUMMARY OF CONSULTANT'S RESPONSE

In response to the DEHLG requirements, the consultancy team carried out the following steps:

1. Develop a statistical sampling approach based on the survey methodology proposed to ensure that the estimates of lengths of road requiring various types of remedial works can be identified at the confidence levels, and to the accuracy required by the Department of the Environment, Heritage and Local Government within each county, and nationally.

2. Identify a survey methodology

- that is consistent, repeatable and accurate
- that is implementable within the timeframe specified
- that can deliver the expected outturn (quantification of remedial works types), determine actual road conditions and provide a basis for comparison with 1996 and 2007 surveys if required.
- that relies on proven technology to produce the required outputs
- that provides a permanent record of the road condition at the time of survey in a suitable format and file size compatible with MapRoad

3. Put in place a system of data collection and data processing to

- ensure that the survey is being carried out correctly
- allow auditing of the survey results at a reasonable cost and in a short time period
- allow simultaneous data collection at many locations throughout the country
- allow easy, low-cost independent inspection by DEHLG if required
- maximise subsequent utility of data collected to DEHLG and local authorities

4. Develop survey tools**,** manuals, forms, equipment to maximise the uniformity and consistency of approach, while retaining the survey procedures and recording of results at the simplest and quickest possible level. Put in place training courses, follow-up site visits and ongoing auditing of data collection and data processing to ensure maximum consistency and accuracy of data.

5. Make maximum use of computer hardware and software at all stages of the project to minimise repetitive tasks, and maximise ease of data entry, data processing and data manipulation.

6. Put in place quality assurance and quality checks at all phases in the project to ensure that the project is being carried out to the highest quality levels.

SECTION 2: DEVELOPMENT OF SAMPLING METHODOLOGY

2.1 SAMPLING METHODOLOGY

An essential requirement of the brief is that the sampling method and size shall be sufficient to achieve an outturn accuracy in the lengths of road requiring remedial works of at least +/- 10% at the 95% confidence level for each county. In order to achieve these confidence levels, the following approach was adopted.

The Engineering Area was chosen as the base unit for sampling, with roads in all 4 road classes selected in every Engineering Area in the country. Road segments as defined in each local authority road schedule were selected randomly, and each 100 metre length within a road segment was treated as a separate sample unit. All sample units in a road segment were surveyed. Stratified random sampling methodology was used to determine required sampling sizes. The target sampling rates and lengths are shown in Table 2.1 below. Full details of the sampling methodology are included in Appendix A of this document.

Road Class	Kilometres	Recomm. %	Survey Km
Regional (R)	11349	15	1702
LP (Local Primary)	23611	9	2125
LS (Local Secondary)	32021	6.25	2001
LT (Local Tertiary)	20169	9.75	1966
Total	**87150**		**7795**

Table 2.1 – Lengths to be surveyed

SECTION 3: SURVEY EQUIPMENT

3.1 ROAD CONDITION DATA COLLECTION EQUIPMENT

The survey methodology proposed is a modified version of the PCI windshield survey method used in the 1996 DOE Pavement Condition survey. The 1996 methodology provided an accurate and repeatable measure of visual distresses on each surveyed road section.

Over 70 teams of local authority personnel, surveying roads simultaneously in each local authority, carried out the 1996 survey. Surveying and data entry typically took 4 to 6 weeks in each local authority and was carried out in July, August and September 1996. The consultants in 1996 audited c. 10% of the surveyed roads to ensure consistency across the many teams of surveyors.

In the 2004 survey, the consultants are the primary data collectors. Notwithstanding the difference in manpower resources available, it is desirable to measure the road condition parameters in all counties within a relatively short time period to give an accurate countrywide snapshot of road condition. Accordingly, a data collection methodology to maximise the speed of data collection in the field was developed.

The methodology relies on high-definition digital video to capture the road surface condition. The video is both chainage-referenced and geo-referenced for ease of post-processing. This ensures maximum compatibility with the LGCSB MapRoad package (where the underlying data storage is chainage-based) as well as full compatibility with any GIS including MapInfo as the data is also geo-referenced using GPS technology.

A very accurate DMI (Distance Measuring Instrument) is attached to the vehicle and connected to the hardware interface. A high-specification GPS device (Trimble Ag132 with real-time differential correction allowing sub-metre accuracy) is also attached to the vehicle and connected to the hardware interface. The video camera outputs a high-resolution digital video (DV) stream to the hardware interface. Each video frame is stamped with road segment id, date, time, chainage and GPS co-ordinates, and the frames are compressed using state-of-the-art compression algorithms to retain maximum definition at minimum storage space. The video frames and associated information are then written to a high-speed hard disk. All of the data capture is in real time. The video is subsequently post-processed in the office to produce Video PCI (VPCI) data on each 100 metre sample unit as described in section 4 below.

In addition, a further condition parameter, the ride quality of each pavement section, was recorded in the 2004 survey. Two bump integrators are attached to the vehicle, one in each wheelpath. The output from the bump integrators is calibrated to produce International Roughness Index (IRI) values for each 100 metre sample unit. The bump integrator outputs are also processed through the hardware interface in real time, and the IRI values can also be stamped on the video if required.

A total of almost 8000 kilometres of roadway was surveyed in the 2004 Pavement Condition Survey. The video/ride quality data collection can be carried out at normal driving speed, and is typically carried out at 10-50 km/h depending on road condition and road geometrics. Each video van is operated by a single operator, reducing the costs of field data collection significantly.

Copies of MapInfo with underlying base maps and a layer showing the road segments to be surveyed for the 2004 survey was loaded onto the data storage computer in each van, and a feed from the GPS device was also connected to the data storage computer. A flat screen monitor was connected to the computer so that the driver could check on his position in real-time. This real-time navigation speeds up the location of the start and end of the road segments significantly, and also ensures that the correct road segments are being surveyed.

3.2 FIELD DATA COLLECTION

On arriving at the start of a selected road segment, the operator chooses the road segment id from a drop-down list. He/she then activates the data collection system and drives the road segment at an appropriate speed. The flat screen monitor displays the video footage and ride quality data that is being saved to the hard disk for ease of checking. When the end of the road segment is reached, the data capture is terminated, all files are closed, and the operator can drive to the next road segment. The video data is stored in compressed .AVI files using an MJPEG format to maximise the quality of each video still and to allow subsequent playback of the video in a chainage-based (eg. MapRoad) or georeference-based (eg. within a GIS such as MapInfo) system. Using this setup, c. 8000 kilometres of video can be stored in just over 100 gigabytes, making it entirely feasible to load all of the video into a server for display purposes. All of the video data can be handed over on a single external data drive.

The entire data collection effort was completed using 4 video vans over a 15 week period in early 2004. A typical 2-kilometre section takes c. 4 minutes to collect all the relevant data. Given the dispersed nature of the road segments, typically 4 to 5 road segments per hour, or c. 8 to 10 kilometres per hour, were surveyed. Average daily data collection rates of 50 to 60 kilometres were achieved, in spite of the survey being carried out from late January to early May when weather conditions were poorer and daily hours of light were significantly shorter than the summer months when the 1996 survey was carried out.

3.3 PAVEMENT CONDITION EVALUATION FROM VIDEO

Once the data is collected in the field, all of the remaining post-processing can be carried out indoors, and is completely independent of weather conditions. Very considerable research, field trials and completed projects have been undertaken into the use of the video PCI (VPCI) as a suitable replacement for the windshield PCI used in 1996. Use of video for condition evaluation has some clear advantages over a manual windshield inspection:

- The video can be played at different speeds, paused, reversed etc. when the inspector wants to be sure that the distress identification is correct
- The inspector can concentrate completely on distress identification – in the manual survey, the distress identifier is usually the driver as well
- Multiple inspectors can be used in the post-processing phase to expedite the duration of processing

- Inspection and identification is carried out in safe and comfortable surroundings
- Auditing of the distress identification process is very straightforward and much less costly than field auditing
- A permanent record of the road condition is saved and can be subsequently re-processed if required for other uses, eg. Presence/absence of road markings, road signs, number of junctions, edge drainage etc.
- DEHLG or local authority personnel can view the video at any subsequent time for any required purpose
- The video files can be subsequently attached to the road segments in MapRoad and can be viewed from within MapRoad in conjunction with the road condition data derived from the video and ride quality measurement devices.

SECTION 4: CONDITION PARAMETERS

4.1 PAVEMENT CONDITION INDEX (PCI)

A visual inspection of the pavement condition, identifying pavement distress types, quantities and severities is an invaluable aid in the evaluation of a pavement's performance, and the causes of poor performance in either structural or functional modes. One of the most comprehensive visual inspection systems developed is the Pavement Condition Index (PCI) procedure, developed by the U.S. Army Corps of Engineers in the early 1970's and extensively refined and improved over the past 20 years. The system is built around the concept of the PAVEMENT CONDITION INDEX or PCI. A new pavement (theoretically distress-free) has a PCI of 100. For each distress measured, there are deduct values depending upon the nature of the distress, its severity and quantity. The deduct values are summed, adjusted to take into account the total number of distresses identified, and then subtracted from 100 to give the PCI index for the pavement.

The power of the PCI inspection system revolves around the provision of a defined index between 0 and 100 that all pavements must lie between. In addition, all of the detailed distress data is available on a section and sample unit basis so that the engineering manager is not reliant upon the PCI alone when deciding what maintenance action to pursue for a specific section. This combination of disaggregate data (the individual distress types) and an aggregated close-ended index for comparison purposes (the PCI) is what makes the PCI inspection methodology particularly appropriate for the current project. A rough breakdown of pavement classification by PCI is

PCI Range	Pavement Condition
85 to 100	Very Good
65 to 85	Good
50 to 65	Fair
40 to 50	Poor
20 to 40	Very Poor
< 20	Failed

This section PCI can then be used to compare sections with one another, to monitor pavement performance over time for that section, and to show a picture of the entire network condition by examining the number of sections in each PCI range. In addition, relationships between PCI and cost can be established, making budget estimation and prediction more accurate and easier to perform.

4.2 PCI WINDSHIELD SURVEY FOR IRISH NON-NATIONAL ROADS - 1996

Manual condition inspection, where the pavement is examined by eye, and the distress quantities measured by hand is the most accurate and complete form of visual inspection. It also requires the least amount of additional equipment. However, there are situations where it is uneconomical to perform a detailed manual distress survey on pavement sections. This is particularly the case on lower class roads, where the available budget per kilometre is at a low level, and the costs of data collection per kilometre become excessively high as a percentage of the available budget. A system whereby greater lengths of road can be surveyed in a given time period is obviously attractive for these road classes. Additionally, there is a safety aspect involved in the manual survey procedure, with personnel being physically located on the carriageway and shoulder surface.

A windshield survey, where the pavement condition is identified from a slowly moving vehicle, provides the ability to cover much larger distances. The inevitable tradeoff is in the quality and detail of the distress data gathered. As the speed of the vehicle increases, the types of distress, and the minimum severity of distress, that can be identified decreases. In addition, there is no physical measurement of the extent of the distress, with "ballpark" estimates being required. Given these problems, the identification of an acceptable speed/accuracy trade-off is essential.

A windshield survey methodology for use on local and regional roads was developed in Ireland through research carried out at University College Galway. The system was designed to complement the manual survey carried out under the PCI inspection system, and correlations were developed between the PCI obtained from the windshield survey, and the PCI obtained from a detailed manual survey over the same road sections. This system was successfully used in 1996.

4.3 VIDEO PCI (VPCI) FOR 2004 SURVEY

Further modifications to the windshield methodology were developed since 2001 to allow estimation of distress types and quantities from high definition video. Based on the results of the 1996 survey, the number of distresses to be identified was reduced. Of the original 19 distresses specified under the manual PCI methodology, 10 distresses have been retained, as they are by far the most common distresses encountered on Irish non-national roads. The distresses can be grouped into four categories as follows:

Surface Defects:

Bleeding

Ravelling

Patching

Openings in Surface

Potholes

Road Disintegration

Cracking:

Alligator Cracking

Edge Breakup

Cracking - Other

Pavement Deformation:

Rutting

Depressions

For each distress type as shown above, there are one, two or three severity levels defined, depending upon the particular distress type. Bleeding, for example, has only one severity level defined, while Potholes and Patching have three severity levels. A detailed pavement inspection manual has been produced specifically for Irish road conditions, with descriptions of each distress type, how to distinguish between severity levels, and full colour photographs for every distress type/severity combination.

A significant advantage of the video PCI (VPCI) survey that results from the detailed definitions of distress type and severity level is that a wide range of personnel can be trained rapidly in carrying out the survey accurately. No previous experience of road conditions is necessary. To date, PMS Pavement Management Services Ltd. personnel have trained engineers, technicians, overseers, and engineering students in carrying out the surveys. In addition, numerous auditing exercises have been carried out to ensure the consistency and repeatability of surveys. The pavement distress definitions have been improved and modified to ensure maximum consistency across teams, and a number of pavement distresses that occur infrequently in Irish conditions have been discarded from the survey to simplify the survey process. In particular, pavement distresses and severities that had few occurrences and/or that had very small areas as identified in the 1996 survey have been modified or combined to streamline the processing of the data for the VPCI.

4.4 CALCULATION OF PAVEMENT CONDITION INDEX (PCI)

Deduct curves from the Corps of Engineer manual PCI system have been adopted, with some minor changes based on Irish conditions, as these curves have been developed, refined and validated based on engineering experiences worldwide over the last 20 years. In particular, there has been a high level of satisfaction in the Irish local authorities that have implemented the PCI system with the relative rankings of roads based on the PCI deduct curves. For each pavement distress type/severity combination identified by the pavement inspectors in a sample unit, a deduct value is calculated from the appropriate deduct curve, based on the quantity of distress present. The deduct curves are significantly different from distress to distress, reflecting the implications for present and future road conditions of the particular distress type. Load-related distresses, such as alligator cracking and rutting, have much steeper deduct curves (i.e. a given quantity of a load-related distress will result in a higher deduct value than the same quantity of a non-load related distress such as bleeding).

The individual deduct values are totalled, adjusted to account for the interaction of multiple distresses, and subtracted from the "perfect" PCI of 100 to give the actual PCI of the sample unit inspected. The deduct value computation and correction is performed by computer software; the pavement distress data are entered (distress type, severity and quantity for each distress type/severity combination) and the software performs all of the remaining calculations. As the estimation of quantity of the distress defects is based totally on visual assessment from the video, it was found that it was most consistent and reproducible to give the pavement inspector ranges of magnitude (<1, 1-5, 5-10 etc), of the estimated percent area of the distress to choose from. The value of the ranges vary by distress. Use of the ranges has worked out well in practice, with good levels of repeatability in surveying sections with different teams of inspectors.

4.5 INTERNATIONAL ROUGHNESS INDEX (IRI)

Road roughness has been defined as the variation in surface elevation that induces vibration in moving vehicles. In particular, 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's subjective ratings of ride quality and the ratings derived from measurement of IRI. In fact, the road user's view of satisfactory or unsatisfactory road condition is primarily influenced by roughness or ride quality.

There are a number of different ways to measure ride quality, but the IRI has become the standard international scale. The IRI was developed in the late 1970's and early 1980's based on initial research in the United States and subsequent research sponsored by the World Bank. The IRI can be measured by an extensive range of equipment from rod and level through response-type meters to very accurate laser-based profilometers.

The IRI is expressed in units of metres per kilometre, with low values indicating smooth roads, and high values indicating rough roads with poor ride quality. There is also significant correlation between IRI and the maximum speed at which a road user is comfortable. Table 4.1 shows a rough description of IRI scale translated into likely road defects and maximum speed with comfortable ride. The table is based on ASTM standard E1926-98, Standard Practice for Computing International Roughness Index of Roads from Longitudinal Profile Measurements.

IRI Value	Comfortable Ride Speed	Description
2	over 120 km/h	Very Smooth
4	100 to 120 km/h	Smooth
6	70 to 90 km/h	Perceptible movement
8	50 to 60 km/h	Some Swaying and Wheel Bounce
10	40 to 50 km/h	Significant Swaying
12	30 to 40 km/h	Consistently Rough
14	< 30 km/h	Very Rough

Table 4.1 IRI Scale

In the 2004 Pavement Condition Survey, each video van was fitted with 2 roughness response meters to measure the ride quality in the left and right wheelpaths. The meters are connected to the rear axle of the vehicles, and independently measure the vertical movement of the left and right rear wheels as they traverse the road. The results are stored for each wheelpath, and post-processed using specialised software to determine the average IRI value for each wheelpath over every 100 metres travelled. The average value of IRI from both wheel tracks is reported, as this is considered a better measure of road surface roughness than the IRI for either individual wheel track.

Response meters are significantly less expensive than laser profilometers in measuring IRI, and are also substantially more robust on rougher roads which was a key factor in their choice for the 2004 survey. However, it is possible for the response meters to go out of calibration over time if there are changes to the vehicle suspension, tyre pressures etc. Frequent calibration and checking is required when response meters are used for IRI measurement.

Calibration sites were established in Galway and Cork using very accurate laser profilometer measurements, and the IRI values for the calibration sites were established from the profilometer measurements. The roughness meters in each van were then calibrated so that the IRI outputs from the roughness meters matched the IRI values determined from the profilometer measurements. IRI measurements were carried out on the calibration sites whenever a test van left to do data collection or returned from data collection. In this way, consistency in IRI measurement was controlled across all of the county road samples. Initially, there were some problems with shearing of connecting pins in the roughness meters. This was addressed prior to the main data collection phase, and the response meters proved to be very robust and repeatable over the course of the data collection phase.

SECTION 5: SURVEY OF NON-NATIONAL ROADS

5.1 PROJECT MANAGEMENT/REGIONAL OFFICES

A system of regional offices was set up by the consultants to co-ordinate the data collection and data processing phases. A project engineer was nominated in each office to co-ordinate all activities relating to the training and data collection phases of the project. The data collection was effectively split into a Border-Midlands-West (BMW) region and a South-East region, with PMS taking responsibility for the BMW region and RPS Group having responsibility for the South-East region.

5.2 TRAINING OF THE CONSULTANTS SURVEY TEAMS

The consultant's engineers and survey personnel were provided with copies of the survey manual and data entry software to allow time for familiarisation. On-site training was then carried out on 3 days over a two-week period, with detailed analysis of the survey results. Clarification of the details of distress identification and quantification, followed by further survey inspections, was performed until all survey teams were producing consistent and repeatable survey results. A series of video clips of standardised road sections was developed, and all survey personnel rated the clips independently. Training and feedback continued until all personnel were rating the road conditions consistently.

5.3 ROAD SCHEDULE SAMPLING

A full road schedule, listing all of the road sections in each local authority using a standardised road numbering system, was supplied by each local authority. Table 5.1 shows the total lengths of road, in kilometres, in each local authority. The lengths are shown by road classification. For each road section, information was typically provided on the road number, road name, engineering area, descriptions of the start and end of the section, and the length and average width of the road. The road classification is included in the road number, allowing retrieval of related road sections.

County	R	LP	LS	LT	Total
Carlow	158	328	337	284	1107
Cavan	399	710	1352	396	2857
Clare	598	1094	1407	807	3906
Cork-North	374	913	1390	707	3384
Cork-South	531	1354	1979	735	4599
Cork-West	401	900	1490	799	3590
Donegal	688	1978	2071	1259	5996
Dun L/Rathdown	103	96	87	310	596
Fingal	197	273	211	273	954
Galway	762	1390	2474	1429	6055
Kerry	449	1183	1035	1554	4221
Kildare	388	332	1043	324	2087
Kilkenny	313	790	1350	397	2850
Laois	281	620	600	445	1946
Leitrim	334	680	579	515	2108
Limerick	463	1005	1413	512	3393
Longford	151	416	508	347	1422
Louth	196	293	468	190	1147
Mayo	579	1220	1673	2295	5767
Meath	476	549	765	1115	2905
Monaghan	290	526	575	975	2366
North Tipp	338	906	750	460	2454
Offaly	339	493	556	450	1838
Roscommon	343	1106	1570	982	4001
Sligo	214	601	963	771	2549
South Dublin	99	106	456	46	707
South Tipp	426	921	891	462	2700
Waterford	353	889	1012	228	2482
Westmeath	229	509	893	366	1997
Wexford	439	968	1218	572	3197
Wicklow	424	466	904	170	1964
Total	**11335**	**23615**	**32020**	**20175**	**87145**

Table 5.1 Total Length (kilometres) by Road Class and Local Authority

5.3.1 Selection of Sample Road Sections

A random sample of road sections was selected from each road schedule, using the Engineering Area as the base unit, and sampling rates as outlined in Section 2 and Appendix A of this report. Road sections were chosen randomly from the road schedule for each engineering area. The sampling rate was chosen to give the desired confidence level of 95 percent in the out-turn lengths, as specified in the consultancy brief.

The list of selected road sections in each engineering area of the local authority was sent to the local authority. The local authority then produced maps showing the locations of all chosen road sections, with copies being provided to the consultants. Generally, the local authorities were able to provide electronic maps linked to the LGCSB MapRoad package. Local Government Computer Services Board developed software and provided training to the consultant's staff to enable the selected sample of road sections to be displayed through MapRoad/MapInfo, and this was extremely helpful and useful in the subsequent data collection in the field described in section 3.2 of this report.

5.4 DATA ENTRY AND POST-PROCESSING

5.4.1 Video PCI Software

Computer software was developed to allow rapid distress type/severity/quantity estimation and storage from video, to carry out the PCI calculations for each sample unit based on the distress data recorded, to provisionally allocate sample units to the appropriate remedial works category, to allow use of ride quality data in modifying the remedial work allocation, and finally to allocate stretches of roadway to appropriate remedial works categories based on agreed criteria.

The VPCI software shows a split screen with the video on the left and a sample unit distress form on the right. The software automatically plays the video for each 100-metre sample unit, and the inspector completes the distress form using tick boxes and pulldown menus for that sample unit. The video can be paused, reversed, played multiple times etc. as necessary. When the inspector is satisfied, the sample unit data is stored to an Access database, the distress form is blanked for the next sample unit and the video plays on the next 100 metres. The software speeds up the data processing element considerably, and reduces fatigue of the inspector very considerably. Typically c. 50 kilometres of road per day could be rated and recorded using the software.

When the distress data files were validated, the Pavement Condition Index (PCI) calculations were carried out using software prepared by the consultants. The PCI, Structural PCI and Surface PCI are calculated using deduct curves and adjustments outlined in section 4.4 of this report.

5.4.2 IRI Post-Processing

When the data is being collected in the field, vertical deviations are integrated by the response meters over each 10-metre length. In the post-processing software, the vertical deviations over each 100 metres are used to calculate the average IRI for the left and right wheelpaths, and the results are stored in an Access database for each road segment. The Local Government Computer Services Board developed some software to integrate the entire road segment IRI data for each county into a single database for each county, compatible with the latest version of MapRoad.

5.5 LOADING OF DATABASE

When all of the files for each local authority were ready, they were loaded into a Microsoft Access database. Effectively, there are three key tables. The first table contains the distress data for every sample unit derived from the video condition survey. The second table contains the processed PCI results for each sample unit. The third table contains the IRI results for every sample unit. There are a total of 76,538 sample units with PCI, IRI and distress data in the final database. The process of uploading the data was extremely straightforward, and customised queries of the data tables were then defined within Microsoft Access to form the basis for the analysis, tables and figures set out in the remainder of this report.

5.6 AUDIT CHECK OF RESULTS FOR REPEATABILITY

It was decided to carry out a second fully independent survey in one local authority to determine the repeatability of the survey results. Longford was chosen, and the second survey was carried out towards the end of the project in October 2004. A second set of road sections in every engineering area for all four road classes was randomly selected and surveyed. The detailed results are included in Appendix C of this report. In summary, there was very good repeatability and comparability between the first and second surveys on the Local Primary, Local Secondary and Local Tertiary roads where relatively large number of road segments were surveyed in both surveys.

On the Regional roads, there was a significant difference in average conditions between the first and second surveys. This difference can be attributed to the much longer average section lengths on Regional roads in the Longford road schedule (3127 metres in Longford compared with an average of 1840 metres for Regional roads nationally). As a consequence, far fewer Regional road sections were required to be surveyed to meet the 15% target length. Accordingly, the random selection of a small number of road sections in very good condition in the second survey had a very large influence on average road conditions measured. The survey results illustrate the desirability of adopting a maximum section length of approximately 3 kilometres in cases where road schedules are to be used subsequently for surveys that involve sampling. Overall, the exercise confirmed the repeatability of the approach taken to sampling and data collection in the project.

SECTION 6: REMEDIAL WORKS CATEGORIES

The primary outturn of the 2004 Pavement Condition Study is the length and average width of the various categories of road in each county requiring remedial works as defined in the consultancy brief. The VPCI of each sample unit (100 metres in length) is used to define appropriate remedial works, based on the absolute value of the VPCI, and the contribution of individual distresses. This approach was used in the 1996 survey and the 2004 results are consistent with this approach. The IRI values are used to supplement the VPCI in allocating additional road segments to the road reconstruction category based on minimum acceptable levels of roughness by road class.

6.1 DESCRIPTION OF REMEDIAL WORKS CATEGORIES

The remedial works categories specified in the consultancy brief were Surface Restoration, Road Reconstruction and Restoration of Skid Resistance. Surface Restoration was defined to include improvement of drainage, pothole patching, restoration of road width and strengthening of road edges as well as localised surface dressing of the repaired areas. Road Reconstruction was defined to include reconstruction of existing road pavements, overlaying of existing road pavements with bound or unbound materials surface dressed, and raising of road levels to prevent flooding with provision of drainage. Restoration of Skid Resistance covers the application of a surface treatment to restore adequated skid resistance. A fourth category, Routine Maintenance, was defined by the consultants to include road section lengths not requiring any of the three remedial work types defined above. Road sections in this category would be in very good existing condition.

6.2 ALLOCATION OF SAMPLE UNITS INTO MAINTENANCE CATEGORIES

As previously described, the PCI rating, a structural index and a surface index were computed and stored in the database for every sample unit (100 metre stretch) surveyed. The PCI has already been described and documented in some detail, and provides an overall measure of pavement condition running from 100 (perfect) to 0 (completely failed). The Structural Index reflects the percentage contribution of structural distresses (potholes, rutting, alligator cracking, edge cracking, road disintegration) to the overall PCI deduct value calculated in each sample unit. The Surface Index reflects the percentage contribution of surface-related distresses (bleeding, ravelling) to the overall PCI deduct value of each sample unit.

The initial assignment of each surveyed sample unit to one of the remedial work types, or to the routine maintenance category, is based on a combination of Video Pavement Condition Index (VPCI) brackets, and particular values of Structural Index and Surface Index as outlined below.

If the VPCI value of the sample unit is greater than 85, the sample unit is deemed to be in very good condition, and is assigned to the Routine Maintenance category.

If the VPCI value of the sample unit ranges from 51 to 85, there are two brackets into which the sample unit may fall. If the structural index is > 50%, (structural distresses are causing more than 50% of the total VPCI deduct value), then the sample unit is assigned to the Surface Restoration work type. If the structural index is less than or equal to 50%, the sample unit is assigned to the Restoration of Skid

Resistance work type on the basis that the VPCI is being influenced primarily by surface distresses which can be addressed by this work type.

If the VPCI value of the sample unit ranges from 41 to 50, there are three brackets into which the sample unit may fall. If the structural index is > 75%, the sample unit is assigned to the Road Reconstruction category as there is clearly significant structural damage causing the VPCI to be in this bracket. If the structural index is less than or equal to 75%, and the surface index is > 40%, the sample unit is assigned to the Restoration of Skid Resistance work type on the basis that the surface distresses are significantly influencing the VPCI and may be addressed by this work type. Otherwise, the sample unit is assigned to the Surface Restoration work type which covers a range of treatment types between Restoration of Skid Resistance and Road Reconstruction.

Finally, if the VPCI value of the sample unit is less than or equal to 40, the sample unit is assigned to the Reconstruction work type.

In this way, every sample unit can be uniquely assigned to one of the available work type categories. The remedial work category allocation strongly reflects the methodology used in 1996, with modifications to the categories based on the VPCI outputs rather than the manual windshield PCI outputs.

In the 2004 study, the ride quality data is also used to modify the results derived from the visual survey. In particular, road segments with poor or very poor ride quality characteristics are moved into the Road Reconstruction category, notwithstanding relatively low levels of visual distress. This reflects the reality that a road may be in need of reconstruction or overlay due to pavement deformation, particularly for example on peat foundations, while the pavement surface has been relatively well maintained through Surface Restoration or Restoration of Skid Resistance activities. Only the Road Reconstruction activities can restore the ride quality of the pavement section to an acceptable level.

The intervention levels based on IRI are customised for each road class, with a lower intervention level for regional roads than for local tertiary roads. This reflects the higher traffic volumes, speeds and level of comfort expected by the road user on higher road classes. Values used in this report are:

Road Class	Road Reconstruction indicated if IRI value is greater than
Regional Roads	8
Local Primary Roads	11
Local Secondary Roads	14
Local Tertiary Roads	17

Table 6.1 IRI Intervention Levels for Road Reconstruction

SECTION 7: REPORTING OF NATIONAL RESULTS

7.1 GENERAL STATISTICS

Table 7.1 shows the final lengths of roadway by road class that were surveyed, post-processed, validated and produced PCI, IRI and distress data. Over 8,000 kilometres of roadway were actually surveyed, but not all of the data was useable due to impassable road conditions, sample units where PCI could not be carried out due to lighting conditions (into direct sunlight after a rain shower), mismatches between road schedule names etc. A total of 76,538 valid sample units, each 100 metres in length, are available for analysis with the length breakdown as shown in Table 7.1.

Class	Length (km)	Width (m)
R	1724	6.1
LP	2007	4.6
LS	2324	3.8
LT	1598	3.3

Table 7.1 2004 National Summary; Lengths and Widths

Table 7.1 also shows the national average road width by road class based on data supplied by Local Authorities. It can be seen that there is a clear downward progression in average road width as the road class decreases, from 6.1 metres on regional (R) roads to 3.3 metres on Local Tertiary (LT) roads.

Table 7.2 shows the average PCI and IRI by road class. Two measures are shown for each parameter; the average value based on pavement length, and the average value based on pavement area (or weighted by road width). It can be seen that there is generally little difference between the two measures, typically 0 or 1 PCI point, and 0.1 or 0.2 IRI points. In the remainder of the report, the PCI and IRI parameters based on pavement area are used, as the final remedial works out-turn is an area-based measurement.

Class	PCI	IRI	PCI-AREA	IRI-AREA
R	67	5.5	68	5.3
LP	59	7.9	60	7.7
LS	55	9.4	55	9.3
LT	49	12.0	50	11.8

Table 7.2 2004 National Summary; Condition Parameters

It is clear from Table 7.2 that there is a consistent downward progression through the road classes in average PCI, from 68 on R roads down to 50 on LT roads. The IRI ride quality average values show a similar trend. The smoothest roads (lowest IRI) are on the R roads with an average value of 5.3 m/km, while the LT roads show the highest average value at 11.8 m/km, more than double the value for the regional roads. The differences in PCI and IRI by road class are large, and reflect clearly different conditions nationally by road class.

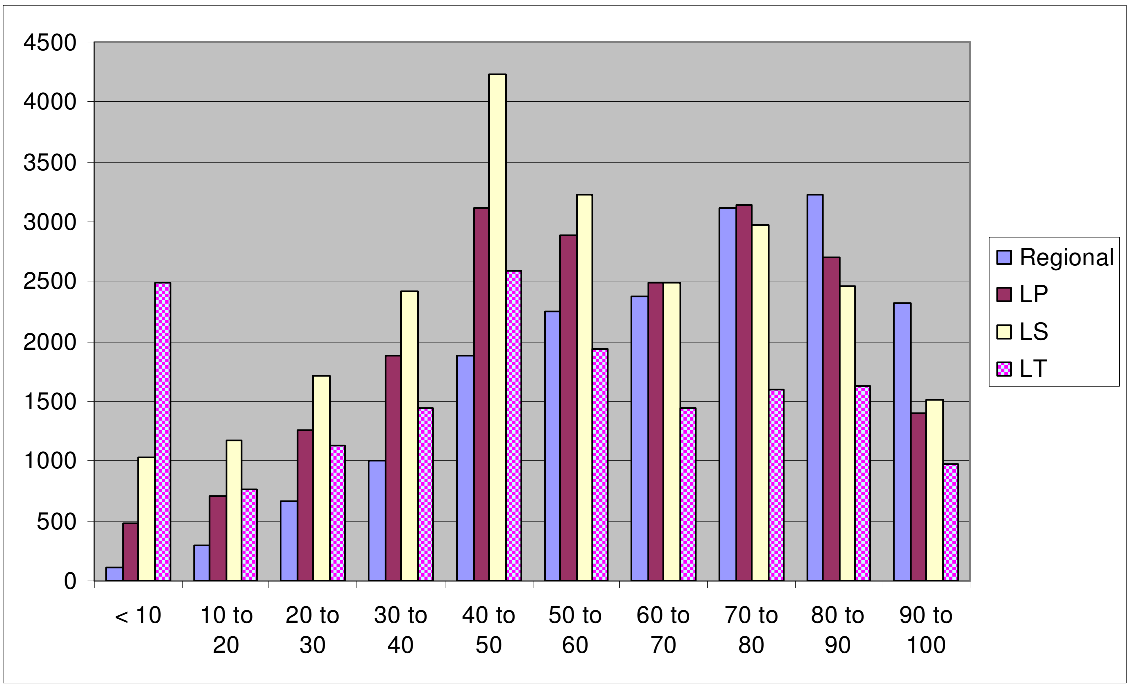

Figure 7.1 PCI Frequency Distribution by Road Class

Figure 7.1 shows the distribution of sample units in each bracket of 10 PCI points for the four road classes. The Regional road distribution is the smoothest, with relatively low numbers in the lower PCI brackets, and the number in each bracket increasing up to a maximum in the 80 to 90 bracket. The LP distribution follows a similar pattern up to a maximum in the 40 to 50 bracket, then begins to decline in higher brackets. However, there is a second rise in numbers at the upper end with another peak in the 70 to 80 bracket. This "double-peak" distribution reflects the impact of expenditure on improving road conditions in recent times.

The LS distribution follows a similar pattern to the LP distribution, but the maximum peak in the 40 to 50 bracket is significantly greater than the second peak in the 70 to 80 bracket. Finally, the LT distribution is most noticeable for the high number of sample units in the PCI less than 10 bracket. Otherwise, the LT distribution increases smoothly to a peak in the 40 to 50 bracket, and then decreases smoothly in the higher brackets. The second peak in the 70 to 80 bracket is much smaller in relative terms compared to the other three road categories.

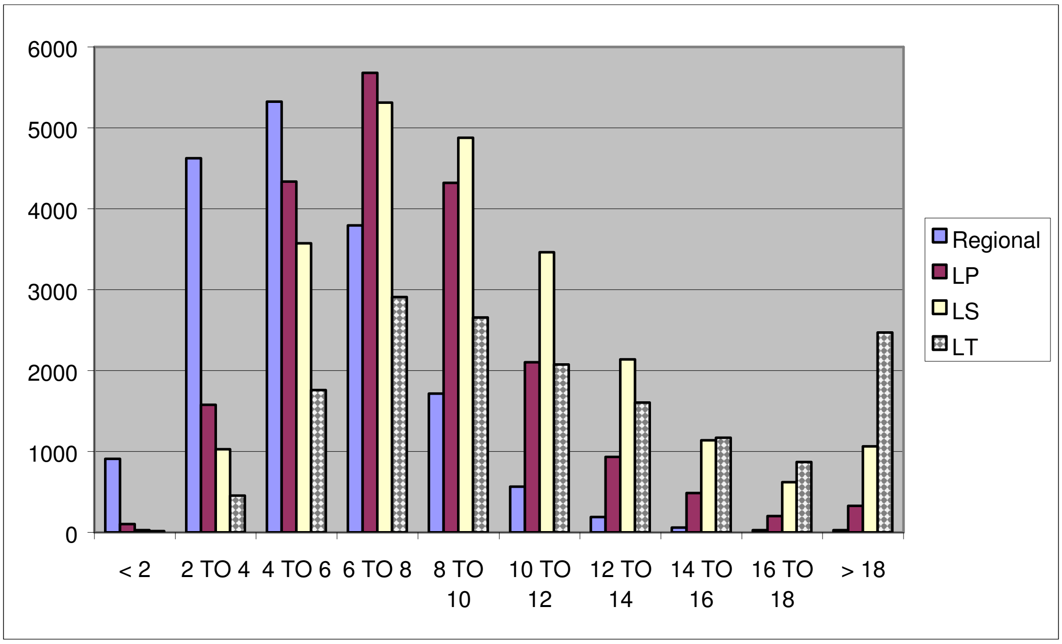

Figure 7.2 IRI Frequency Distribution by Road Class

Figure 7.2 shows the distribution of sample units in each bracket of 2 IRI points. In contrast to the PCI distributions, there are no double peaks for any of the 4 road classes. The Regional road distribution is the most desirable, with a relatively narrow distribution (very few sample units with an IRI of greater than 10) and a peak in the 4 to 6 IRI bracket. The LP distribution is similar but the peak is shifted to the 6 to 8 IRI bracket, and the distribution is noticeably wider. The LS distribution also peaks in the 6 to 8 bracket, but has a much longer tail in the higher IRI brackets. Finally, the LT distribution is clearly the widest distribution with the peak in the 6 to 8 bracket quite similar to the numbers in the 8 to 10 and 10 to 12 brackets. There are also many sample units in the IRI > 18 bracket for LT roads, mirroring the pattern seen in the PCI distribution where there was a large number of LT sample units with a PCI of less than 10.

7.2 DISTRESS DATA SUMMARY

It is also possible to carry out an analysis of the trends shown by the individual distresses identified in the course of carrying out the VPCI analysis. Table 7.3 shows the distress types sorted by number of occurrences. It is clear that Ravelling occurs much more frequently than other distress. Rutting is the second most frequently occurring distress. This is significant as rutting is a structural distress, carrying a relatively high deduct value, and having implications for the maintenance requirements of the section. Patching and Bleeding have a similar rate of occurrence, significantly higher than Edge Breakup. Potholes, Alligator Cracking and Depressions have a relatively low rate of occurrence, with Road Disintegration and Other Cracking having a very low rate of occurrence.

Distress Code	Distress Type	Number of Occurrences
2	Ravelling	66199
5	Rutting	36171
4	Patching	26832
1	Bleeding	23430
10	Edge Breakup	16705
3	Potholes	10338
8	Alligator Cracking	8827
6	Depression	8447
7	Road Disintegration	3692
9	Other Cracking	2800

Table 7.3 Distresses Sorted by Occurrence

Table 7.4 shows the distress type and severity combinations sorted by quantity. The quantity shown is as a percent of the sample unit area. Ravelling, a surface distress and the most commonly occurring distress, also has the highest average quantity when it occurs of almost 25% of the surface area of the sample unit. Road Disintegration occurs very infrequently, but when encountered it takes up a relatively large percentage of the sample unit area. Bleeding, another surface distress, covers 13% of the surface area, when it occurs. Rutting, a relatively frequently occurring distress, also covers a significant percentage of the pavement area when it occurs as does Patching.

Distress Code	Distress Type	Severity	% Sample Unit Area	VPCI deduct value	No. of Occurrences
2	Ravelling	N	24.4%	15.1	66199
7	Road Disintegration	N	19.2%	76.7	3692
1	Bleeding	N	13.1%	11.9	23430
5	Rutting	M	11.5%	40.4	35070
5	Rutting	H	9.9%	49.9	1101
4	Patching	M	9.3%	24.8	4364
8	Alligator Cracking	H	9.1%	49.1	3238
4	Patching	L	8.7%	10.7	706
4	Patching	H	7.8%	36.6	21762
10	Edge Breakup	N	6.2%	28.1	16705
6	Depression	N	5.9%	20.5	8447
8	Alligator Cracking	L	4.5%	15.5	3141
8	Alligator Cracking	M	4.3%	27.8	2448
3	Potholes	L	3.5%	13.1	6519
3	Potholes	M	2.3%	18.5	2720
3	Potholes	H	2.3%	43.9	1099
9	Other Cracking	N	2.3%	11.6	2800

Table 7.4 Distresses Sorted by Quantity

*** L: Low Severity, M: Medium Severity, H: High Severity, N: No Severity Level**

Distress Code	Distress Type	Severity	% Sample Unit Area	VPCI deduct value	No. of Occur-rences
7	Road Disintegration	N	19.2%	76.7	3692
5	Rutting	H	9.9%	49.9	1101
8	Alligator Cracking	H	9.1%	49.1	3238
3	Potholes	H	2.3%	43.9	1099
5	Rutting	M	11.5%	40.4	35070
4	Patching	H	7.8%	36.6	21762
10	Edge Breakup	N	6.2%	28.1	16705
8	Alligator Cracking	M	4.3%	27.8	2448
4	Patching	M	9.3%	24.8	4364
6	Depression	N	5.9%	20.5	8447
3	Potholes	M	2.3%	18.5	2720
8	Alligator Cracking	L	4.5%	15.5	3141
2	Ravelling	N	24.4%	15.1	66199
3	Potholes	L	3.5%	13.1	6519
1	Bleeding	N	13.1%	11.9	23430
9	Other Cracking	N	2.3%	11.6	2800
4	Patching	L	8.7%	10.7	706

Table 7.5: Distresses Sorted by Deduct Value

*** L: Low Severity, M: Medium Severity, H: High Severity, N: No Severity Level**

Table 7.5 shows the same values sorted by average deduct value. Each distress type/severity combination has a unique deduct curve, relating quantity of distress to a deduct value. Higher quantities of distress generate higher deduct values. Distress types that have significant maintenance implications, for example structural distresses, have deduct curves that generate higher deduct values for given quantities of distress.

It is obvious that the structural distresses dominate in Table 7.5, with Road Disintegration clearly having the highest average deduct value. Rutting, Alligator Cracking, Potholes (High Severity), Patching (High Severity) and Edge Breakup all have relatively similar high average deduct values. Ravelling, although occurring very frequently and over relatively large areas when it occurs, has a relatively low average deduct value. This is because Ravelling and Bleeding are surface defects that do not have significant structural maintenance implications.

7.3 COMPARISON BETWEEN 1996 AND 2004 SURVEYS

The VPCI survey methodology used in 2004, while broadly similar in approach to the 1996 windshield survey, has some significant differences in the final calculation of Pavement Condition Index. In addition, the 2004 survey makes use of an additional ride quality parameter, the IRI, to allocate road sections to the various remedial work type categories. This allocation process was described in section 6, and the results are contained in section 9 of this report. Direct comparison over time of PCI with VPCI, or remedial work type category allocation is not valid due to the significant differences.

However, it is possible to directly compare the underlying distress data gathered in 1996 with the 2004 data. Table 7.6 shows this comparison based on occurrences as a percent of the overall number of sample units.

Distress Code	Distress Type	1996	2004
1	Bleeding	33.7%	29.3%
2	Ravelling	45.3%	82.7%
3	Potholes	20.1%	12.9%
4	Patching	46.2%	33.5%
5	Rutting	29.1%	45.2%
6	Depression	9.3%	10.6%
7	Road Disintegration	8.9%	4.6%
8	Alligator Cracking	16.0%	11.0%
9	Other Cracking	3.0%	3.5%
10	Edge Breakup	23.7%	20.9%

Table 7.6: Percent Occurrences, 1996 and 2004

There has been a substantial increase in the occurrence of Ravelling in 2004 compared to 1996. The percentage occurrence of Bleeding is lower in 2004. These differences may reflect the difference in the time of year when the survey was carried out. The 1996 survey was carried out in late Summer/early Autumn when the surface dressing programme would be complete and ground temperatures are relatively high. The 2004 survey was carried out in spring, when ground temperatures are much lower and the incidence of Ravelling is typically higher after the winter season.

There has also been a substantial increase in the occurrence of Rutting between 1996 and 2004. This reflects the much larger traffic volumes, and in particular the much heavier and wider commercial vehicles using the road network over the past 8 years. The economic boom has yielded a very significant increase in the development of towns, villages and one-off housing developments, and heavy commercial vehicles are used to supply materials to these developments. Larger and heavier agricultural vehicles have evolved, and there has been a very significant increase overall in commercial traffic volumes in line with economic growth. The historic pavement structures in place would have been relatively thin layers of granular material, with one or more surface dressings. These structures were barely adequate for light traffic and light commercial vehicles/cars, but are inadequate for the much heavier loadings being imposed by traffic in 2004.

Without the strengthening programme which was put in place since the mid 1990's, the rate of occurrence of all structural distresses in 2004 would have been much higher than in 1996. In fact, the rate of occurrence of Potholes and Road Disintegration has effectively halved over the period from 1996 to 2004, while the rate of occurrence of Patching is also substantially reduced. This reflects the significant investment in the road network with priority obviously being applied to road sections with surface breaks.

Table 7.7 shows the average deduct value by distress type when the distress occurs. Most distress types do not show significant changes. However, the average deduct value for Edge Cracking and Patching is significantly higher in 2004 than in 1996. Again, these changes reflect the impact of the very substantial growth in heavier and wider vehicles using the Non-National road network. The average deduct values for Potholes and Road Disintegration have dropped significantly, and in conjunction with the substantial drop in the rate of occurrence of these distresses, the maintenance investment programme is clearly succeeding in dealing with these surface break distresses notwithstanding the much heavier traffic using the network.

Distress Code	Distress Type	1996	2004

1	Bleeding	11.1	11.9
2	Ravelling	14.8	15.1
3	Potholes	23.2	17.8
4	Patching	20.0	34.0
5	Rutting	39.7	41.0
6	Depression	8.8	20.5
7	Road Disint.	94.0	76.7
8	Allig. Cr.	32.2	31.2
9	Other Cr.	7.6	11.6
10	Edge Cr.	13.1	28.1

Table 7.7: Average Deduct Value, 1996 and 2004

Overall, the distress comparisons show that the Non-National network is very significantly better in 2004 in reducing the incidences of surface breaks (Potholes and Road Disintegration) that produce high levels of road user dissatisfaction. This reduction has occurred in the context of much heavier and more frequent loadings on all road classes of the Non-National network. However, this greater loading has increased the amount of rutting on the network substantially, and this has significant implications for the structural maintenance budgets required going forward.

7.4 CHANGES IN NETWORK LOADING CONDITIONS, 1996 TO 2004

Table 7.8 shows some relevant Irish network statistics based on 2001 data. There were almost 1.4 million cars registered in Ireland in 2001, almost 190,000 light goods vehicles (LGV) and just over 32,500 heavy goods vehicles (HGV). Cars and LGV travel, on average, between 19,000 and 20,000 kilometres per annum. However, HGV travel, on average, almost 74,000 kilometres per annum, thus having a major impact on the road network well out of proportion to the impact implied by the number of vehicles alone. A 2001 National Road Authority study on vehicle-kilometres of travel in Ireland indicated that the Non-National road network carries 59% of all car travel, 56% of all LGV travel, and 43% of all HGV travel, clearly showing the importance of the Non-National road network in the Irish context.

Category	Number	km per vehicle	National %	Non-National %
Car	1384700	19864	41	59
LGV	186978	19275	44	56
HGV	32536	73980	57	43

Table 7.8 National Traffic Patterns, 2001

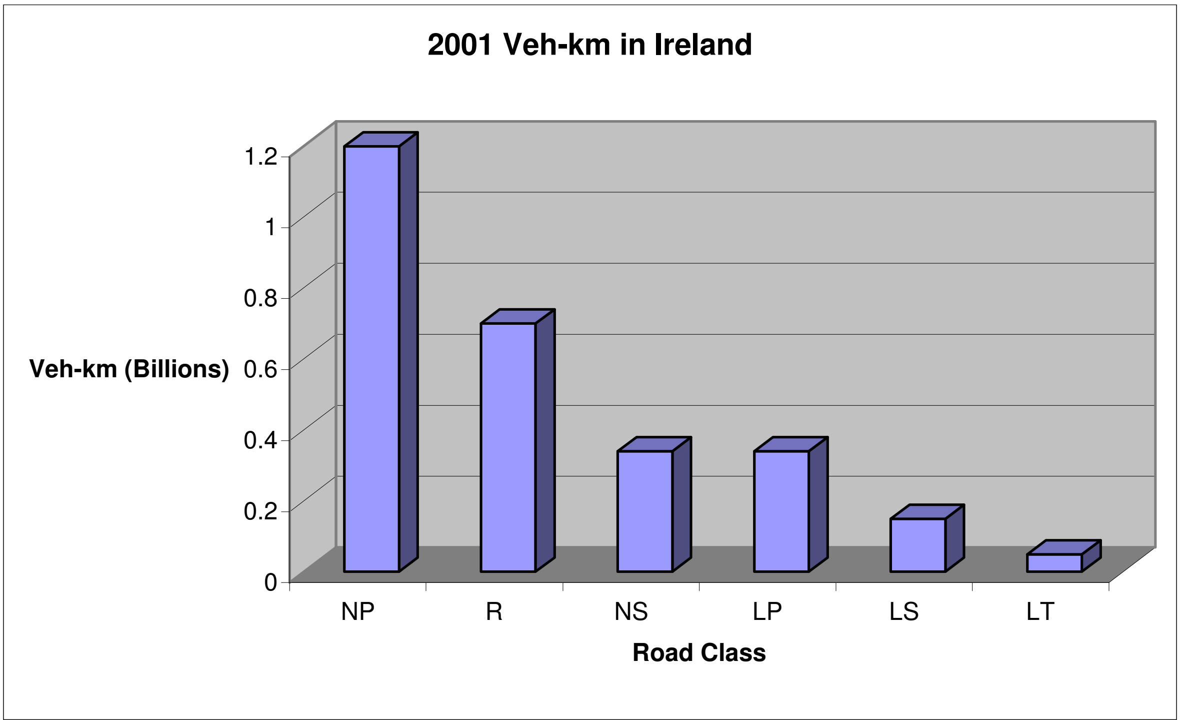

Figure 7.3: Total Vehicle-kilometres of travel by Road Class, 2001

Figure 7.3 shows the breakdown in Vehicle-kilometres of travel by road class. The National Primary road network carries the largest share of travel. The Regional road network carries the second highest proportion, over twice as much as the National Secondary and LP networks which are very similar. The relative importance of the three local road classes is clear in Figure 7.3, with the LP network carrying roughly twice as much as the LS network, and the LS network in turn carrying roughly three times as much as the LT network.

Table 7.9 shows the growth in HGV numbers between 1976 and 2001. It can be seen that there has been a very large growth in HGV numbers since 1995. The HGV numbers grew on average by 6% per annum since 1995. Taking LGV and HGV together, there was an annual growth of 7.6% over this period, exactly the same as the average GDP growth rate of 7.6% per annum from 1996 to 2003. It can be expected that the growth in goods vehicles continued beyond 2001 in line with economic growth.

Year	Number of HGV
1976	15,000
1985	19,000
1989	19,500
1995	23,000
2001	32,536

Table 7.9 Growth in Heavy Good Vehicle Numbers 1976 to 2001

Figure 7.4 shows the changes in the distribution of HGV unladen weights between 1995 and 2001. It is very clear that there has been a noticeable shift in the distribution towards heavier vehicles. The number of vehicles in the lower weight categories have grown between 1995 and 2001, but the numbers are still quite close. However, from the 10,000 kg category and above, the 2001 numbers are very significantly higher than the 1995 numbers. In conjunction with Table 7.9, it can be seen that there has been a large annual increase in the number of HGV, and this increase has been predominantly in the provision of much larger and more damaging HGV. The combination of growth in numbers and damaging power has dramatically increased the structural loading on the network between 1995 and 2001.

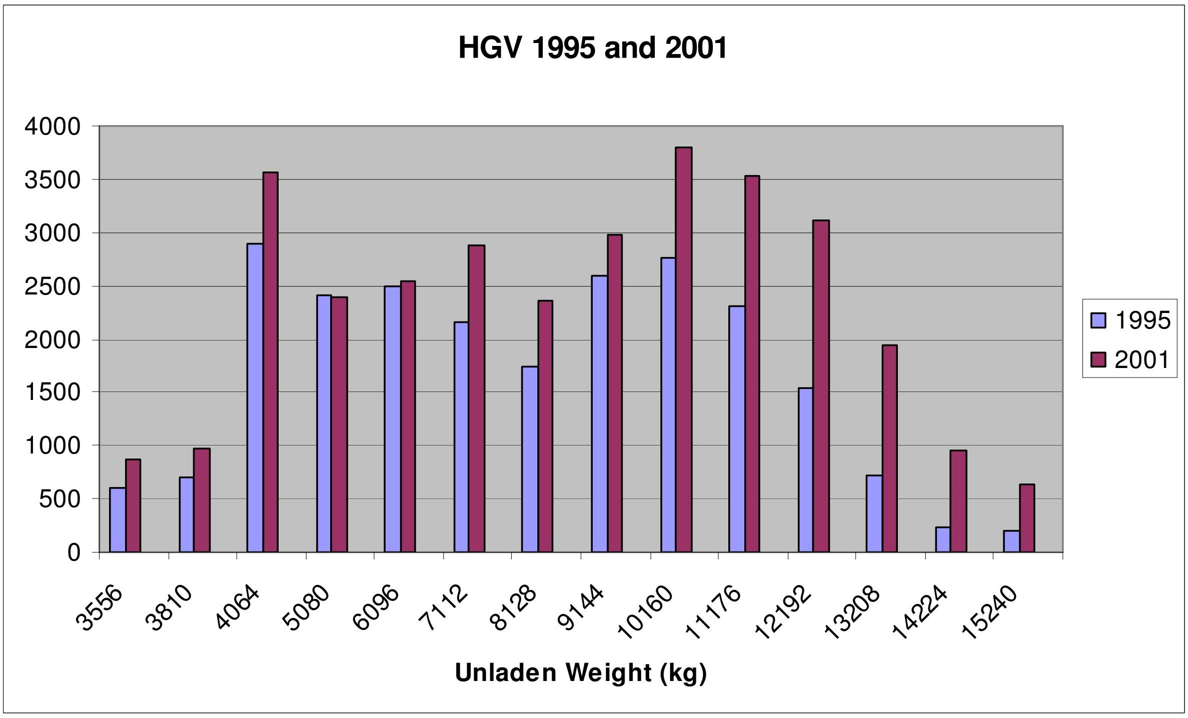

Figure 7.4: Distribution of HGV Unladen Weights – 1995 and 2001

Figures 7.5 and 7.6 further emphasise the impact of the changes in vehicle numbers and load capacity on the road network. Figure 7.5 shows the growth in tonnage of goods handled by Roll On/Roll Off (RO/RO) traffic between 1995 and 2002, based on Central Statistics Office (CSO) data. The total tonnage carried has grown from 3.9 million tonnes in 1995 to almost 9.5 million tonnes in 2002 or almost 2.5 times the 1995 level. This growth is much larger than the GDP or vehicle growth, at an average annual growth of 13.5% over the 7 year period.

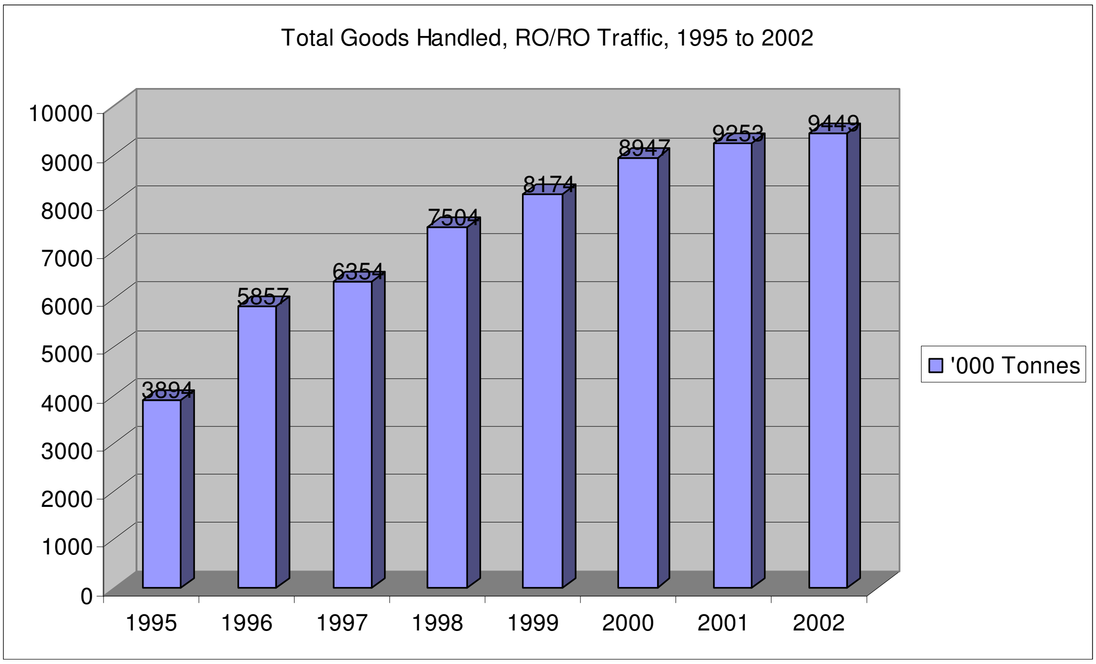

Figure 7.5: Total Goods Handled, RO/RO Traffic, 1995 to 2002

Figure 7.6 shows the growth in the number of house completions per annum between 1995 and 2003. This can be used as a surrogate measure of the impact of the economic growth on the road network, given the requirement to transport materials to service the completion of the houses. Over the 8 year period, the number of house completions grew from just over 30,500 to just under 69,000. This translates into an annual average growth rate of 10.5%, again well in excess of the GDP growth rate. Overall, it can be concluded that the economic boom in Ireland since the last condition survey in 1996 has fundamentally changed the loading regime on the Non-National road network, with much higher and more frequent loadings by heavier vehicles being the norm in 2004.

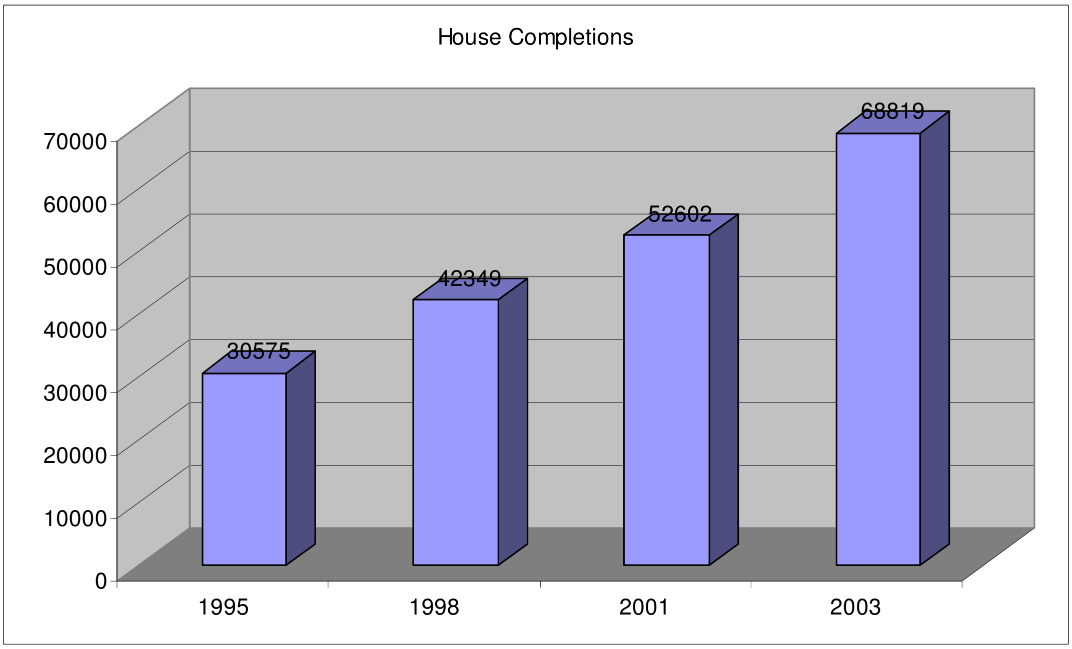

Figure 7.6: Number of House Completions, 1995 to 2003

SECTION 8: REPORTING OF RESULTS BY COUNTY

8.1 GENERAL STATISTICS BY COUNTY

Table 8.1 shows the average road width by road class in each local authority. Cork is treated as being made up of 3 divisions, reflecting the internal road management structure in Cork. This is also consistent with the reporting of results from the 1996 survey. It can be seen that average road width by road class varies substantially across the local authorities, with the 3 Dublin road authorities of Dun Laoghaire-Rathdown (DR), Fingal (F) and South Dublin (SD) having higher average widths than other counties.

County	R	LP	LS	LT
Carlow	6.6	4.6	4.2	3.2
Cavan	6.3	4.5	3.6	3.2
Clare	5.8	4.1	3.3	3.1
Cork-North	6.3	5.2	4.0	3.8
Cork-South	6.6	5.0	3.7	3.2
Cork-West	6.5	4.4	3.2	2.9
Donegal	5.8	4.2	3.7	3.5
Dun L/Rathdown	8.7	7.5	7.7	5.8
Fingal	7.1	5.9	4.0	4.8
Galway	5.6	4.2	3.2	3.0
Kerry	5.1	4.3	3.9	3.6
Kildare	6.3	4.7	4.0	3.8
Kilkenny	6.2	4.8	4.0	3.3
Laois	6.8	4.9	4.5	3.8
Leitrim	6.1	3.8	2.9	2.8
Limerick	5.6	4.4	3.9	3.1
Longford	6.7	4.6	3.5	2.8
Louth	7.1	5.2	4.3	3.2
Mayo	5.6	4.4	3.5	3.3
Meath	6.3	4.5	4.2	3.5
Monaghan	6.2	4.9	3.8	3.1
North Tipp	5.9	4.2	3.9	3.4
Offaly	6.1	4.4	3.6	3.5
Roscommon	5.7	4.2	3.3	2.9
Sligo	6.2	4.0	3.3	3.4
South Dublin	7.2	8.0	5.9	7.0
South Tipp	6.0	5.0	4.3	3.3
Waterford	6.8	5.1	3.8	4.3
Westmeath	7.1	5.0	3.8	3.2
Wexford	6.0	4.7	4.2	3.6
Wicklow	5.8	4.9	3.9	2.9

Table 8.1 Average Road Widths by County

Table 8.2 shows the average PCI and IRI based on length and weighted by area for Regional roads in each county. Tables 8.3, 8.4 and 8.5 show similar average values for Local Primary (LP), Local Secondary (LS) and Local Tertiary (LT) roads. It can be seen that there is generally relatively little difference between the statistics based on length and area weighting, although there are more substantial variations on the LT roads. In the remainder of the report, the PCI and IRI parameters based on pavement area are used, as the final remedial works out-turn is an area-based measurement.

It can be seen from the tables that there are significant variations in average road condition as measured by PCI and IRI across the local authorities.

County	PCI-Area	IRI-Area	PCI	IRI
Carlow	66	3.9	66	3.9
Cavan	77	4.6	77	4.6
Clare	67	6.3	67	6.4
Cork-North	66	5.5	66	5.6
Cork-South	56	6.1	55	6.2
Cork-West	66	6.7	66	6.8
Donegal	70	6.6	70	7.1
Dun L/Rathdown	77	4.2	77	4.2
Fingal	70	4.3	69	4.5
Galway	63	4.9	63	5.0
Kerry	67	5.2	67	5.2
Kildare	74	4.2	73	4.2
Kilkenny	76	4.2	75	4.2
Laois	66	5.1	66	5.2
Leitrim	71	4.1	70	4.3
Limerick	76	5.4	77	5.4
Longford	73	4.8	72	4.9
Louth	65	3.8	63	4.0
Mayo	69	5.9	68	5.9
Meath	61	5.3	61	5.4
Monaghan	79	3.4	79	3.4
North Tipp	74	6.3	73	6.4
Offaly	58	5.5	58	5.7
Roscommon	73	6.4	72	6.6
Sligo	53	6.2	53	6.3
South Dublin	73	4.0	74	4.0
South Tipp	64	5.2	64	5.2
Waterford	74	5.6	74	5.8
Westmeath	65	4.0	66	4.0
Wexford	53	5.7	53	5.8
Wicklow	67	5.5	67	5.7

Table 8.2 Condition Parameters - Regional Roads

County	PCI-Area	IRI-Area	PCI	IRI
Carlow	64	6.8	63	6.8
Cavan	68	6.7	67	6.9
Clare	62	7.8	62	7.9
Cork-North	76	7.0	76	7.2
Cork-South	60	8.4	60	8.5
Cork-West	58	8.5	58	8.7
Donegal	64	11.3	63	11.7
Dun L/Rathdown	59	4.7	60	4.6
Fingal	65	5.7	63	5.9
Galway	58	5.4	58	5.4
Kerry	58	6.9	58	7.0
Kildare	64	6.3	64	6.2
Kilkenny	71	6.1	71	6.1
Laois	53	6.8	54	6.9
Leitrim	49	8.7	48	8.9
Limerick	70	7.1	69	7.1
Longford	68	6.5	68	6.6
Louth	51	6.5	51	6.5
Mayo	62	7.8	62	7.9
Meath	62	6.8	62	6.8
Monaghan	58	6.7	57	6.8
North Tipp	57	8.2	56	8.2
Offaly	41	7.3	41	7.4
Roscommon	58	8.7	58	8.8
Sligo	40	8.0	40	8.0
South Dublin	64	4.6	65	4.6
South Tipp	56	8.0	56	8.0
Waterford	61	8.8	61	9.0
Westmeath	48	5.7	47	5.9
Wexford	45	8.0	44	8.2
Wicklow	66	8.5	66	8.6

Table 8.3 Condition Parameters - LP Roads

County	PCI-Area	IRI-Area	PCI	IRI
Carlow	65	8.9	65	8.9
Cavan	63	8.0	62	8.2
Clare	63	8.6	63	8.7
Cork-North	50	10.1	50	10.2
Cork-South	46	11.6	46	11.7
Cork-West	52	12.2	53	12.2
Donegal	64	14.3	65	14.5
Dun L/Rathdown	69	5.3	68	5.3
Fingal	52	6.6	51	6.8
Galway	53	6.5	54	6.7
Kerry	57	8.0	57	8.0
Kildare	59	7.9	59	7.9
Kilkenny	65	8.2	64	8.3
Laois	56	7.1	57	7.1
Leitrim	39	10.6	38	10.8
Limerick	69	7.9	69	7.9
Longford	64	7.8	63	7.9
Louth	49	8.5	49	8.8
Mayo	57	8.9	57	8.8
Meath	62	7.4	62	7.3
Monaghan	57	8.0	56	8.0
North Tipp	54	8.6	53	8.7
Offaly	49	8.0	48	8.1
Roscommon	53	10.4	52	10.7
Sligo	37	9.3	37	9.3
South Dublin	68	6.5	68	7.0
South Tipp	50	10.4	50	10.4
Waterford	57	11.6	56	11.8
Westmeath	42	7.5	42	7.6
Wexford	39	9.6	37	9.8
Wicklow	60	11.0	60	11.2

Table 8.4 Condition Parameters - LS Roads

County	PCI-Area	IRI-Area	PCI	IRI
Carlow	57	11.3	57	11.4
Cavan	62	9.0	61	9.2
Clare	52	10.5	52	10.5
Cork-North	48	12.9	49	12.8
Cork-South	42	14.5	43	14.6
Cork-West	46	14.2	46	14.1
Donegal	46	20.7	47	20.4
Dun L/Rathdown	70	5.8	67	6.3
Fingal	66	7.1	62	7.9
Galway	50	8.4	51	8.5
Kerry	53	10.9	52	10.9
Kildare	60	9.0	60	9.3
Kilkenny	41	16.3	41	16.2
Laois	52	8.9	53	8.7
Leitrim	31	14.7	31	14.8
Limerick	55	11.9	55	12.0
Longford	58	9.9	58	10.0
Louth	36	14.5	36	14.7
Mayo	55	12.2	55	12.5
Meath	58	8.9	58	8.9
Monaghan	53	10.6	52	10.8
North Tipp	42	12.6	45	11.4
Offaly	41	8.9	40	9.0
Roscommon	44	13.4	43	13.4
Sligo	36	10.7	36	11.0
South Dublin	44	9.8	44	9.8
South Tipp	46	12.9	46	12.8
Waterford	49	13.8	45	14.8
Westmeath	35	8.8	34	8.9
Wexford	29	13.2	29	13.7
Wicklow	46	18.5	46	18.7

Table 8.5 Condition Parameters - LT Roads

SECTION 9: REMEDIAL WORKS REQUIREMENTS

9.1 NATIONAL REQUIREMENTS

Section 6 laid out the basis for assignment of road sample units to the different remedial works categories based on VPCI and IRI criteria. Table 9.1 shows the percentage of total pavement area assigned to each of the 4 remedial work categories by road class based on the VPCI criteria only. This table is based on principles similar to those used in 1996.

	Remedial Work Type Percentages			
Road Class	**Routine Maint.**	**Skid Resist.**	**Surf. Rest.**	**Reconstruction**
R	26.4%	34.1%	24.9%	14.6%
LP	15.9%	31.0%	28.4%	24.7%
LS	13.3%	24.8%	31.3%	30.5%
LT	12.8%	19.3%	27.2%	40.7%

Table 9.1 Remedial Work Types - VPCI only

Table 9.2 shows the percentage of total pavement area assigned to each of the 4 remedial work categories by road class using both the VPCI and IRI criteria. Effectively, additional road lengths have been included under the Road Reconstruction category if the IRI on the sample unit exceeds a maximum threshold level, even though the VPCI criteria would not have assigned the sample unit to the Road Reconstruction category ordinarily. Only Road Reconstruction remedial works will improve the IRI under the DEHLG remedial works category definitions. As a result, the percentage in Road Reconstruction category in Table 9.2 is higher than in Table 9.1, with consequent reductions in the percentages in the Routine Maintenance, Skid Resistance Restoration and Surface Restoration categories.

It should be noted that the percentage length identified as needing restoration of skid resistance (Skid Resist.) in Tables 9.1 and 9.2 is based on identification of surface defects. Additional sections may also require restoration of skid resistance on the basis of low surface friction values, but are not included as surface friction was not a parameter measured in the 2004 survey.

	Remedial Work Type Percentages			
Road Class	**Routine Maint.**	**Skid Resist.**	**Surf. Rest.**	**Reconstruction**
R	24.7%	29.6%	21.7%	23.9%
LP	14.4%	28.1%	25.5%	31.9%
LS	12.6%	23.2%	29.3%	34.9%
LT	12.4%	18.1%	25.7%	43.9%

Table 9.2 Remedial Work Types - VPCI plus IRI thresholds

The maximum threshold levels applied in this report vary by road class, reflecting the reality of a higher level of expectancy of comfortable ride speed by the road user on different road classes. The use of IRI in this way is common internationally, and is also used by the National Roads Authority in the management of the national road network, but it is an innovation in the management of Non-National roads in Ireland. Accordingly, reasonably loose standards are applied initially. The threshold levels applied are shown in Table 9.3.

Road Class	Road Reconstruction indicated if IRI value is greater than
Regional Roads	8
Local Primary Roads	11
Local Secondary Roads	14
Local Tertiary Roads	17

Table 9.3 IRI Intervention Levels for Road Reconstruction - Present

It is recommended that tighter IRI standards should be aimed for and applied over time to have a specific, measurable performance parameter reflecting road user expectations. It is proposed that over time, the maximum threshold levels should move towards the following standards, shown in Table 9.4.

Road Class	Road Reconstruction indicated if IRI value is greater than
Regional Roads	6
Local Primary Roads	8
Local Secondary Roads	10
Local Tertiary Roads	12

Table 9.4 IRI Intervention Levels for Road Reconstruction - Future

Ultimately, application of these maximum threshold levels would lead to significant improvements in the overall ride quality levels on all road classes, and could also form a basis for further improvements in the future.

9.2 REMEDIAL REQUIREMENTS BY COUNTY

Tables 9.5 to 9.8 show the percentage of total pavement area assigned to each of the 4 remedial work categories by road class for each local authority using only the VPCI criteria. Tables 9.9 to 9.12 show the equivalent percentages based on both the VPCI and IRI criteria.

Appendix B contains details of the confidence interval widths calculated about the average percentage values shown in Tables 9.9 to 9.12. In general, it can be seen that the maximum half width estimate is c. 0.03 to 0.04, very substantially below the half width of 0.1 specified. The half width estimates in the 3 Dublin local authorities, Dun Laoghaire/Rathdown, Fingal and South Dublin, are substantially higher than other local authorities. This reflects the relatively small number of road sections and short road lengths in these authorities, particularly on Local Tertiary roads. In addition, there is more widespread use of concrete road surfaces in the urban sections. Any concrete segments surveyed were not included in the final calculations as it was not possible to calculate a PCI value based on the VPCI methodology which had been developed and adapted in Ireland for bituminous surfaces. The smaller number of sample units surveyed is reflected in the half width estimates.

Figure 9.1 shows a thematic diagram for Regional roads. The percentage of surface area for each local authority in the Restoration of Skid Resistance category was obtained from Table 9.5, and sorted in increasing order. There are a total of five groupings, with the 6 counties having the lowest percentage of surface area in the Restoration of Skid Resistance category being placed in grouping 1, the next 6 counties in grouping 2 etc. A similar process was followed for Regional roads in the Surface Restoration (Figure 9.2) and Road Reconstruction (Figure 9.3) categories.

Figures 9.4 to 9.6 contain similar thematics for Local Primary roads, while Figures 9.7 to 9.9 and Figures 9.10 to 9.12 show similar thematics for Local Secondary and Local Tertiary roads respectively.

	Remedial Work Type Percentages			
County	Routine Maint.	Skid Res.	Surf. Rest.	Reconstruction
Carlow	19.2%	22.3%	47.9%	10.6%
Cavan	35.6%	54.5%	6.6%	3.4%
Clare	24.5%	38.9%	23.3%	13.3%
Cork-North	21.9%	30.7%	32.1%	15.3%
Cork-South	13.1%	33.1%	24.0%	29.8%
Cork-West	22.9%	32.8%	27.3%	17.0%
Donegal	44.8%	22.5%	11.0%	21.6%
Dun L/Rathdown	44.3%	30.3%	19.1%	6.3%
Fingal	34.2%	34.4%	16.9%	14.4%
Galway	24.4%	21.5%	34.4%	19.7%
Kerry	26.2%	28.5%	27.8%	17.5%
Kildare	35.1%	28.0%	28.7%	8.3%
Kilkenny	38.8%	37.7%	20.0%	3.5%
Laois	21.8%	29.5%	37.3%	11.4%
Leitrim	15.2%	61.3%	19.1%	4.3%
Limerick	31.5%	27.6%	39.6%	1.2%
Longford	47.0%	40.5%	2.6%	9.9%
Louth	24.9%	23.3%	32.2%	19.5%
Mayo	34.8%	37.2%	14.6%	13.4%
Meath	15.9%	11.5%	47.3%	25.3%
Monaghan	54.4%	34.6%	4.3%	6.8%
North Tipp	24.9%	65.6%	6.3%	3.2%
Offaly	9.6%	41.0%	28.6%	20.7%
Roscommon	21.3%	64.0%	10.9%	3.8%
Sligo	0.6%	54.6%	18.7%	26.1%
South Dublin	36.3%	31.2%	23.9%	8.6%
South Tipp	26.3%	23.1%	27.6%	23.0%
Waterford	33.1%	40.5%	21.3%	5.2%
Westmeath	12.3%	48.7%	29.4%	9.6%
Wexford	12.5%	12.0%	33.9%	41.6%
Wicklow	19.2%	19.0%	51.1%	10.7%

Table 9.5 Percent area of R Roads requiring each remedial work type based on VPCI only

	Remedial Work Type Percentages			
County	**Routine Maint.**	**Skid Res.**	**Surf. Rest.**	**Reconstruction**
Carlow	14.8%	18.8%	51.4%	15.0%
Cavan	18.2%	54.8%	15.2%	11.7%
Clare	19.2%	29.3%	32.5%	19.0%
Cork-North	38.6%	29.2%	24.3%	7.9%
Cork-South	15.2%	32.5%	29.8%	22.5%
Cork-West	12.0%	34.3%	25.3%	28.4%
Donegal	34.9%	22.3%	13.9%	29.0%
Dun L/Rathdown	18.1%	28.7%	19.9%	33.3%
Fingal	29.3%	32.0%	18.5%	20.2%
Galway	7.0%	29.5%	42.7%	20.7%
Kerry	14.9%	24.2%	31.7%	29.2%
Kildare	18.2%	30.6%	34.0%	17.2%
Kilkenny	26.7%	45.6%	20.0%	7.7%
Laois	11.4%	24.0%	33.1%	31.5%
Leitrim	5.0%	25.8%	41.5%	27.7%
Limerick	24.3%	24.2%	43.0%	8.6%
Longford	16.2%	62.2%	14.0%	7.6%
Louth	8.8%	18.8%	25.8%	46.6%
Mayo	15.3%	42.8%	24.6%	17.3%
Meath	11.3%	20.0%	53.1%	15.6%
Monaghan	8.9%	45.3%	21.4%	24.4%
North Tipp	4.9%	55.0%	18.3%	21.8%
Offaly	1.4%	17.9%	25.1%	55.6%
Roscommon	7.1%	43.6%	27.7%	21.7%
Sligo	0.6%	23.8%	21.2%	54.4%
South Dublin	17.9%	44.6%	21.3%	16.3%
South Tipp	11.5%	29.1%	26.7%	32.7%
Waterford	23.7%	30.6%	20.1%	25.6%
Westmeath	1.9%	25.6%	42.4%	30.0%
Wexford	8.3%	8.8%	27.4%	55.5%
Wicklow	14.0%	20.5%	55.5%	10.0%

Table 9.6 Percent area of LP Roads requiring each remedial work type based on VPCI only

	Remedial Work Type Percentages			
County	**Routine Maint.**	**Skid Res.**	**Surf. Rest.**	**Reconstruction**
Carlow	14.9%	12.0%	61.6%	11.5%
Cavan	24.9%	37.4%	15.1%	22.6%
Clare	22.9%	25.9%	30.2%	21.0%
Cork-North	10.9%	23.6%	25.7%	39.8%
Cork-South	5.1%	26.0%	24.5%	44.3%
Cork-West	8.6%	30.9%	26.3%	34.3%
Donegal	36.2%	23.1%	12.8%	28.0%
Dun L/Rathdown	37.3%	34.9%	3.9%	23.9%
Fingal	18.0%	20.7%	23.2%	38.0%
Galway	7.5%	20.8%	48.5%	23.3%
Kerry	18.2%	18.2%	31.5%	32.1%
Kildare	15.1%	24.8%	34.2%	25.9%
Kilkenny	24.7%	32.1%	25.1%	18.1%
Laois	10.8%	26.8%	36.1%	26.4%
Leitrim	1.9%	8.7%	43.2%	46.2%
Limerick	21.9%	20.3%	49.6%	8.2%
Longford	24.0%	45.2%	9.1%	21.7%
Louth	8.4%	16.8%	25.0%	49.8%
Mayo	11.8%	37.7%	23.1%	27.5%
Meath	15.4%	13.2%	48.9%	22.4%
Monaghan	4.3%	44.6%	32.6%	18.5%
North Tipp	3.1%	39.4%	36.5%	21.0%
Offaly	3.3%	28.9%	28.5%	39.3%
Roscommon	4.7%	29.7%	33.9%	31.7%
Sligo	0.0%	11.4%	33.4%	55.2%
South Dublin	23.8%	44.3%	22.3%	9.6%
South Tipp	9.1%	21.3%	27.8%	41.8%
Waterford	15.1%	29.2%	25.4%	30.2%
Westmeath	0.0%	7.6%	60.9%	31.5%
Wexford	7.2%	6.5%	23.3%	62.9%
Wicklow	11.7%	18.1%	50.1%	20.1%

Table 9.7 Percent area of LS Roads requiring each remedial work type based on VPCI only

	Remedial Work Type Percentages			
County	**Routine Maint.**	**Skid Res.**	**Surf. Rest.**	**Reconstruction**
Carlow	13.5%	12.0%	49.1%	25.5%
Cavan	28.6%	30.3%	15.6%	25.5%
Clare	13.6%	14.4%	32.3%	39.7%
Cork-North	12.7%	18.2%	21.3%	47.8%
Cork-South	10.3%	15.4%	20.7%	53.6%
Cork-West	7.9%	21.5%	22.4%	48.2%
Donegal	29.0%	10.4%	6.7%	53.8%
Dun L/Rathdown	44.3%	22.2%	13.0%	20.5%
Fingal	33.2%	24.4%	21.4%	21.0%
Galway	8.5%	18.1%	40.2%	33.1%
Kerry	15.0%	15.3%	30.1%	39.6%
Kildare	17.7%	29.0%	27.1%	26.2%
Kilkenny	10.2%	17.0%	17.1%	55.8%
Laois	14.1%	15.0%	32.9%	38.0%
Leitrim	1.9%	5.7%	32.3%	60.0%
Limerick	19.4%	11.0%	40.7%	28.9%
Longford	12.4%	47.7%	14.9%	25.0%
Louth	7.9%	8.2%	13.8%	70.1%
Mayo	13.7%	36.7%	19.6%	29.9%
Meath	14.8%	11.7%	48.7%	24.8%
Monaghan	14.0%	26.0%	30.7%	29.3%
North Tipp	0.0%	28.3%	31.7%	40.0%
Offaly	2.2%	15.3%	24.8%	57.7%
Roscommon	3.2%	20.9%	33.3%	42.6%
Sligo	0.0%	12.1%	34.9%	53.0%
South Dublin	0.0%	25.0%	25.0%	50.0%
South Tipp	11.5%	15.8%	20.6%	52.1%
Waterford	10.9%	25.6%	21.2%	42.3%
Westmeath	1.1%	7.9%	38.0%	52.9%
Wexford	3.3%	5.2%	14.7%	76.9%
Wicklow	7.0%	13.9%	35.1%	44.0%

Table 9.8 Percent area of LT Roads requiring each remedial work type based on VPCI only

	Remedial Work Type Percentages			
County	**Routine Maint.**	**Skid Resist.**	**Surf. Rest.**	**Reconstruction**
Carlow	19.2%	20.6%	45.7%	14.5%
Cavan	35.0%	50.2%	5.3%	9.5%
Clare	23.1%	33.6%	17.1%	26.2%
Cork-North	21.2%	26.2%	29.9%	22.6%
Cork-South	12.6%	27.4%	20.7%	39.3%
Cork-West	19.2%	23.2%	20.3%	37.4%
Donegal	39.4%	15.9%	5.6%	39.1%
Dun L/Rathdown	44.0%	27.5%	16.5%	12.0%
Fingal	34.0%	33.6%	15.2%	17.2%
Galway	24.0%	20.0%	33.6%	22.3%
Kerry	25.8%	26.0%	25.6%	22.6%
Kildare	35.1%	26.9%	28.2%	9.8%
Kilkenny	37.9%	35.2%	17.8%	9.1%
Laois	20.8%	27.5%	34.9%	16.9%
Leitrim	15.2%	59.6%	17.1%	8.1%
Limerick	30.1%	24.3%	36.2%	9.4%
Longford	47.0%	36.7%	2.6%	13.7%
Louth	24.9%	22.6%	30.6%	21.9%
Mayo	26.3%	28.6%	10.5%	34.6%
Meath	14.6%	9.8%	40.8%	34.8%
Monaghan	53.9%	34.6%	3.8%	7.7%
North Tipp	24.0%	55.2%	2.2%	18.6%
Offaly	9.6%	37.6%	25.4%	27.4%
Roscommon	16.1%	47.6%	7.4%	28.8%
Sligo	0.6%	43.4%	14.6%	41.4%
South Dublin	36.3%	29.3%	23.9%	10.6%
South Tipp	26.2%	21.9%	26.1%	25.8%
Waterford	28.1%	30.7%	17.2%	24.0%
Westmeath	12.3%	47.6%	29.1%	10.9%
Wexford	11.2%	10.5%	30.9%	47.5%
Wicklow	17.5%	15.8%	43.6%	23.1%

Table 9.9 Percent area of R Roads requiring each remedial work type based on VPCI and IRI criteria

	Remedial Work Type Percentages			
County	**Routine Maint.**	**Skid Resist.**	**Surf. Rest.**	**Reconstruction**
Carlow	14.8%	17.7%	47.9%	19.6%
Cavan	18.1%	54.4%	14.2%	13.4%
Clare	18.9%	27.0%	29.4%	24.7%
Cork-North	35.8%	26.0%	22.0%	16.2%
Cork-South	13.0%	29.2%	25.8%	32.1%
Cork-West	10.6%	31.6%	22.1%	35.7%
Donegal	24.5%	13.0%	6.7%	55.9%
Dun L/Rathdown	18.1%	28.7%	19.9%	33.3%
Fingal	28.9%	31.0%	18.1%	22.1%
Galway	7.0%	29.5%	42.7%	20.8%
Kerry	14.6%	22.0%	30.4%	33.0%
Kildare	18.2%	28.0%	32.7%	21.1%
Kilkenny	26.2%	44.9%	18.0%	10.9%
Laois	11.4%	23.2%	31.8%	33.6%
Leitrim	5.0%	22.8%	35.6%	36.6%
Limerick	24.0%	22.5%	40.4%	13.1%
Longford	16.2%	61.3%	13.7%	8.8%
Louth	8.8%	18.4%	25.3%	47.6%
Mayo	13.4%	33.7%	20.0%	32.9%
Meath	11.1%	18.9%	49.8%	20.2%
Monaghan	8.9%	43.8%	19.8%	27.5%
North Tipp	4.9%	53.1%	16.4%	25.6%
Offaly	1.4%	17.5%	24.5%	56.5%
Roscommon	6.9%	39.6%	24.5%	28.9%
Sligo	0.6%	23.1%	20.5%	55.8%
South Dublin	17.9%	44.6%	20.1%	17.4%
South Tipp	11.0%	27.0%	24.3%	37.7%
Waterford	21.7%	26.9%	17.5%	33.9%
Westmeath	1.9%	25.6%	42.4%	30.0%
Wexford	8.2%	8.1%	25.5%	58.2%
Wicklow	11.5%	15.6%	46.7%	26.2%

Table 9.10 Percent area of LP Roads requiring each remedial work type based on VPCI and IRI criteria

	Remedial Work Type Percentages			
County	**Routine Maint.**	**Skid Resist.**	**Surf. Rest.**	**Reconstruction**
Carlow	14.4%	11.5%	60.5%	13.5%
Cavan	24.9%	37.1%	14.8%	23.1%
Clare	22.9%	25.1%	28.9%	23.1%
Cork-North	10.8%	22.4%	24.2%	42.6%
Cork-South	4.5%	23.0%	21.4%	51.0%
Cork-West	8.1%	26.7%	21.4%	43.8%
Donegal	26.5%	15.3%	7.3%	50.9%
Dun L/Rathdown	37.3%	34.9%	3.9%	23.9%
Fingal	18.0%	20.7%	23.2%	38.0%
Galway	7.5%	20.7%	48.2%	23.6%
Kerry	18.2%	18.0%	30.9%	32.9%
Kildare	15.1%	23.9%	32.8%	28.2%
Kilkenny	24.0%	30.7%	23.6%	21.7%
Laois	10.8%	26.6%	35.9%	26.7%
Leitrim	1.9%	7.9%	40.3%	49.9%
Limerick	21.6%	19.3%	48.7%	10.4%
Longford	24.0%	44.5%	9.0%	22.6%
Louth	8.2%	16.8%	24.1%	50.9%
Mayo	11.2%	34.3%	20.8%	33.7%
Meath	15.4%	13.2%	48.7%	22.6%
Monaghan	4.3%	42.8%	31.5%	21.4%
North Tipp	3.1%	38.9%	35.9%	22.2%
Offaly	3.3%	28.9%	27.8%	40.0%
Roscommon	4.7%	29.2%	31.0%	35.1%
Sligo	0.0%	11.2%	32.4%	56.4%
South Dublin	23.5%	44.3%	21.4%	10.9%
South Tipp	8.8%	20.5%	25.5%	45.2%
Waterford	13.0%	24.5%	20.9%	41.5%
Westmeath	0.0%	7.6%	60.8%	31.6%
Wexford	7.1%	5.9%	22.6%	64.4%
Wicklow	10.4%	14.9%	41.1%	33.6%

Table 9.11 Percent area of LS Roads requiring each remedial work type based on VPCI and IRI criteria

	Remedial Work Type Percentages			
County	**Routine Maint.**	**Skid Resist.**	**Surf. Rest.**	**Reconstruction**
Carlow	13.0%	11.5%	46.3%	29.3%
Cavan	28.6%	30.3%	15.6%	25.5%
Clare	13.6%	14.4%	32.2%	39.8%
Cork-North	12.0%	16.4%	17.9%	53.6%
Cork-South	9.1%	13.7%	16.0%	61.2%
Cork-West	7.7%	19.3%	19.7%	53.3%
Donegal	26.1%	7.7%	4.4%	61.8%
Dun L/Rathdown	44.3%	22.2%	13.0%	20.5%
Fingal	33.2%	24.4%	20.9%	21.4%
Galway	8.5%	18.0%	39.5%	34.0%
Kerry	14.8%	14.7%	29.2%	41.3%
Kildare	17.7%	28.7%	27.1%	26.5%
Kilkenny	9.9%	17.0%	15.2%	57.9%
Laois	14.1%	15.0%	32.9%	38.0%
Leitrim	1.9%	5.5%	31.7%	60.8%
Limerick	19.4%	10.8%	40.2%	29.6%
Longford	12.4%	46.8%	14.9%	25.9%
Louth	5.9%	8.2%	11.8%	74.1%
Mayo	12.9%	32.3%	17.4%	37.3%
Meath	14.8%	11.7%	47.6%	25.9%
Monaghan	13.9%	25.6%	29.5%	30.9%
North Tipp	0.0%	26.4%	31.7%	41.9%
Offaly	2.2%	15.3%	24.8%	57.7%
Roscommon	3.2%	20.2%	31.7%	44.9%
Sligo	0.0%	11.9%	34.3%	53.8%
South Dublin	0.0%	25.0%	25.0%	50.0%
South Tipp	11.3%	13.0%	20.1%	55.6%
Waterford	10.9%	24.3%	19.8%	45.0%
Westmeath	1.1%	7.9%	38.0%	52.9%
Wexford	3.3%	4.7%	14.3%	77.8%
Wicklow	5.2%	10.1%	22.8%	61.9%

Table 9.12 Percent area of LT Roads requiring each remedial work type based on VPCI and IRI criteria

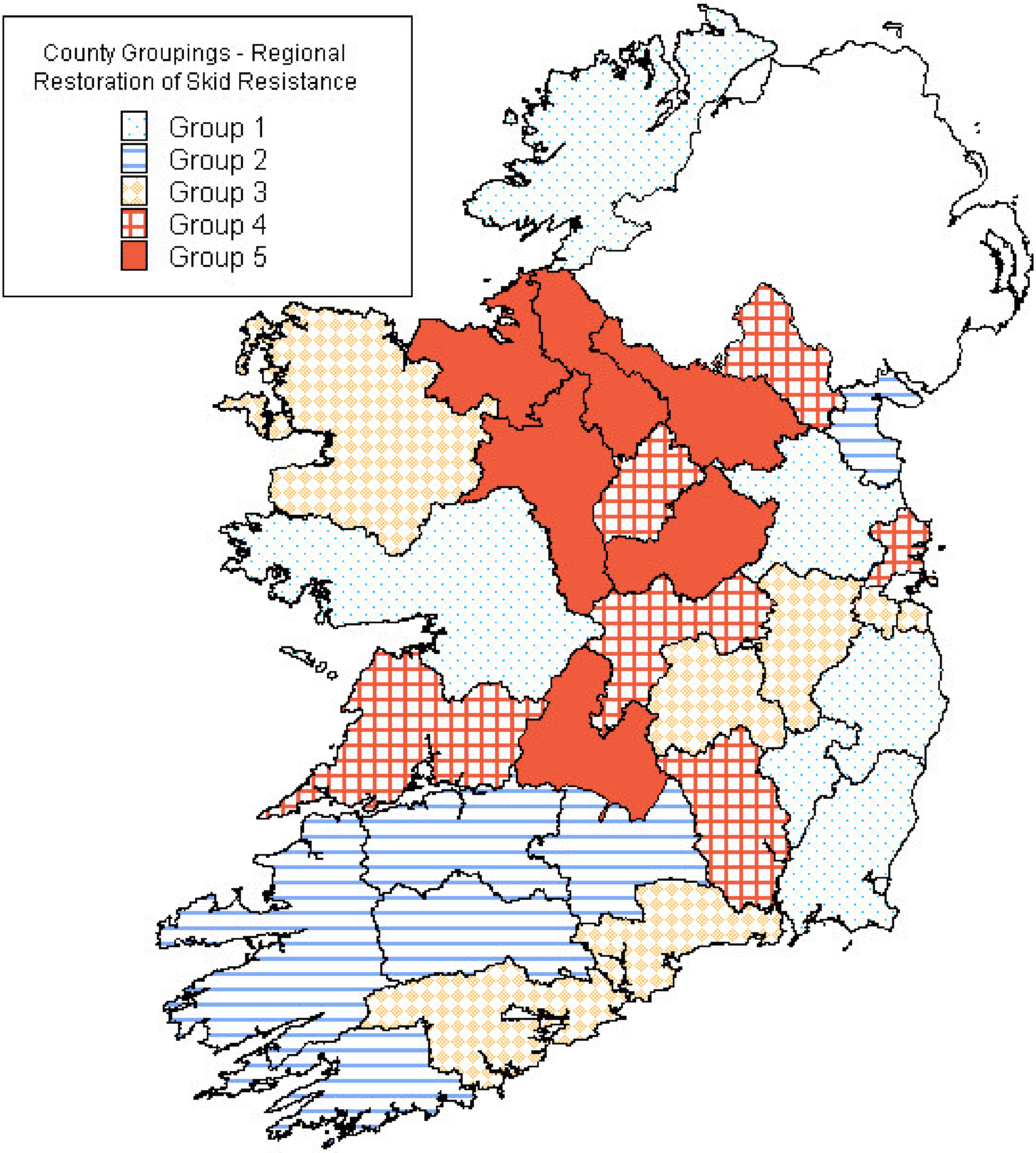

Figure 9.1 Regional – Skid Resistance

*groups ranked 1 to 5 by increasing % area requiring remedial works

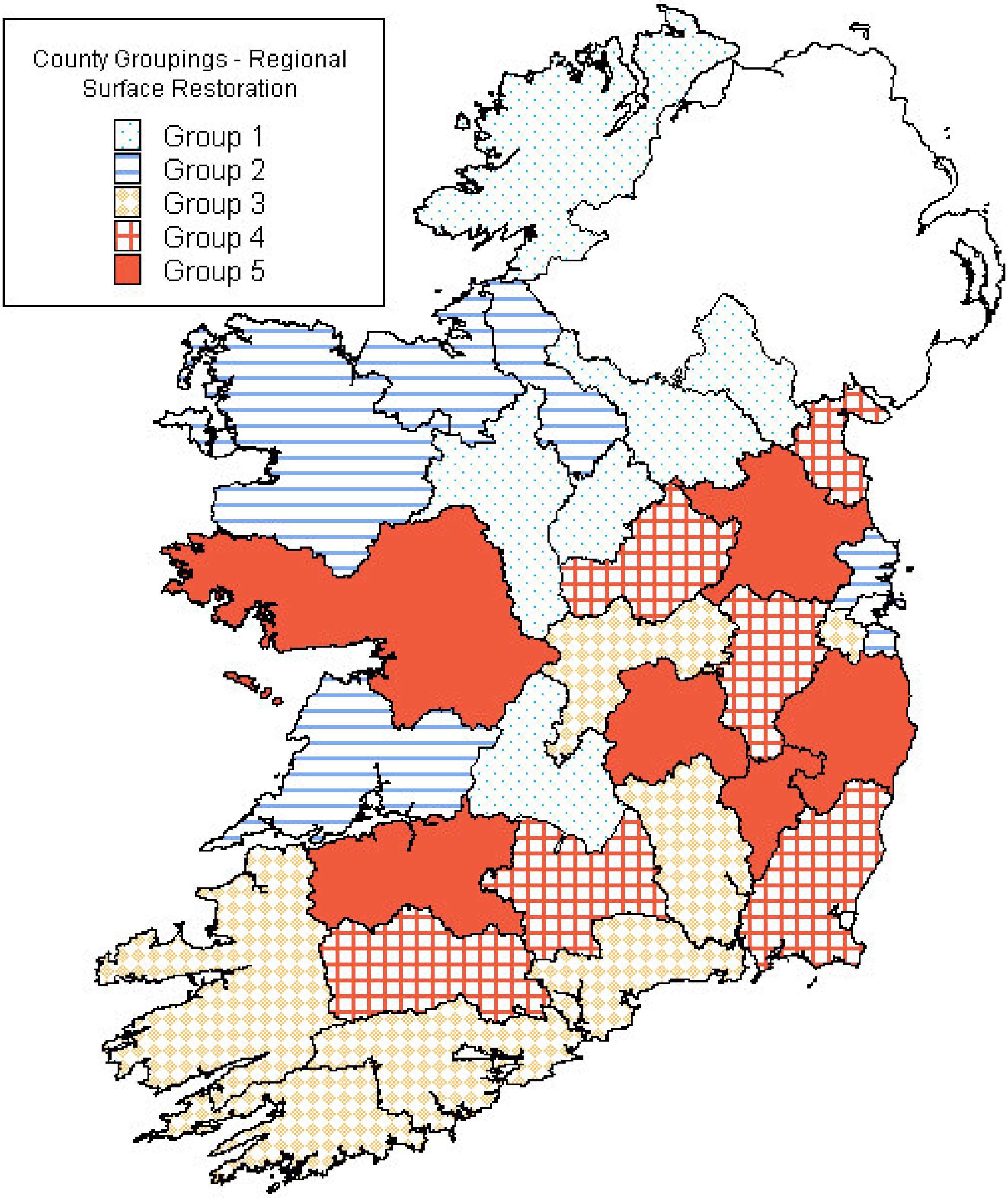

Figure 9.2 Regional – Surface Restoration

*groups ranked 1 to 5 by increasing % area requiring remedial works

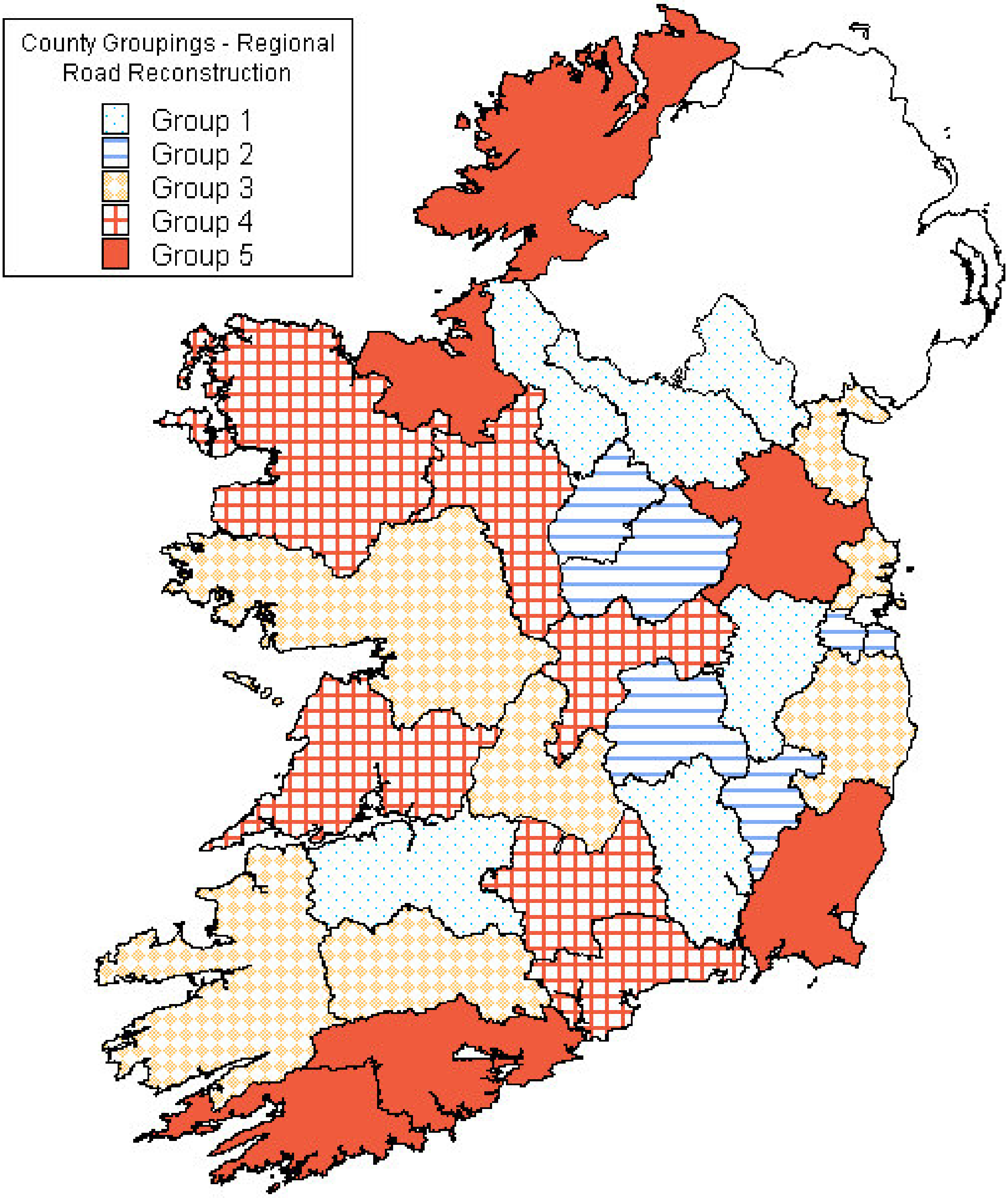

Figure 9.3 Regional – Road Reconstruction

*groups ranked 1 to 5 by increasing % area requiring remedial works

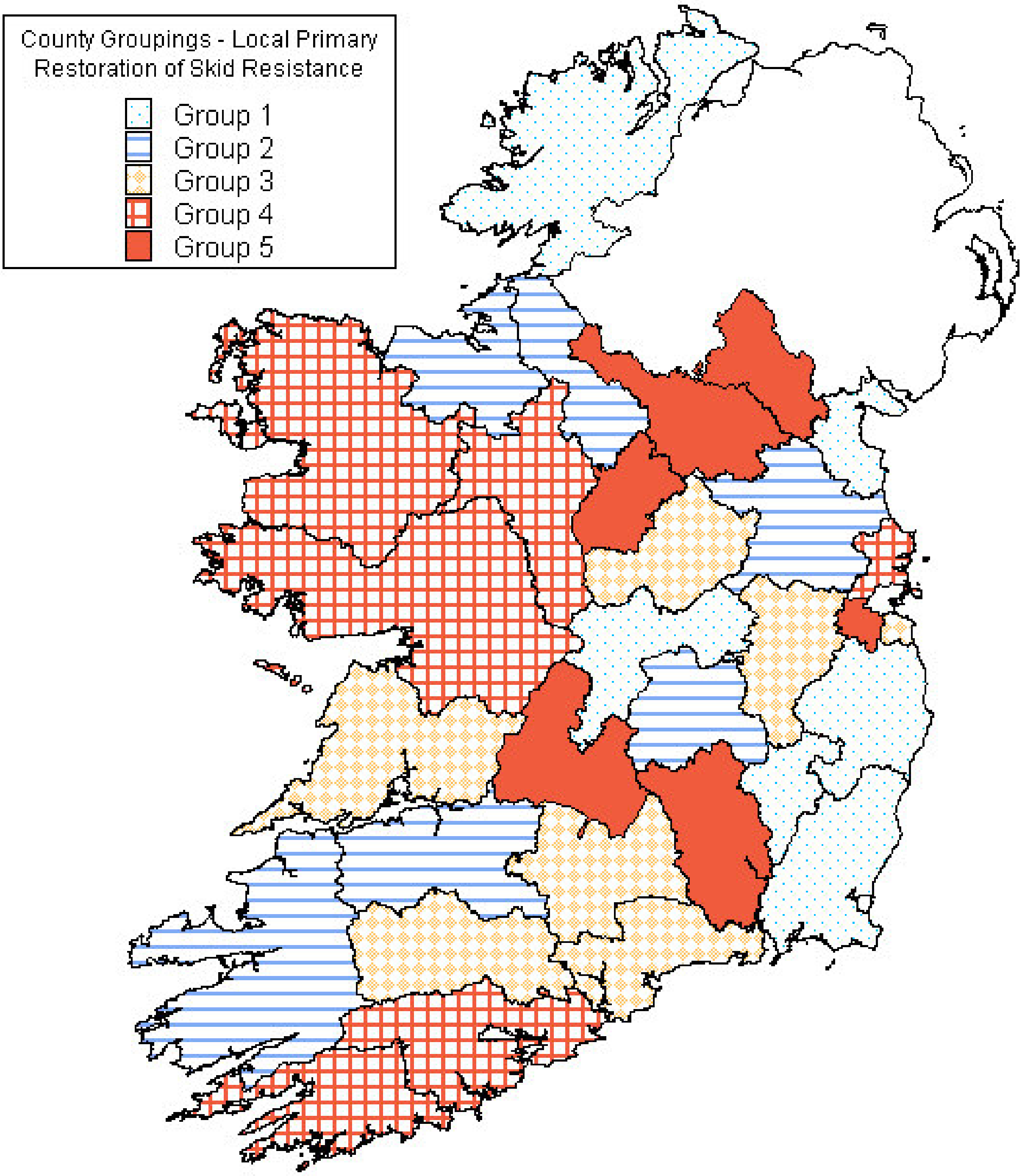

Figure 9.4 Local Primary – Skid Resistance

*groups ranked 1 to 5 by increasing % area requiring remedial works

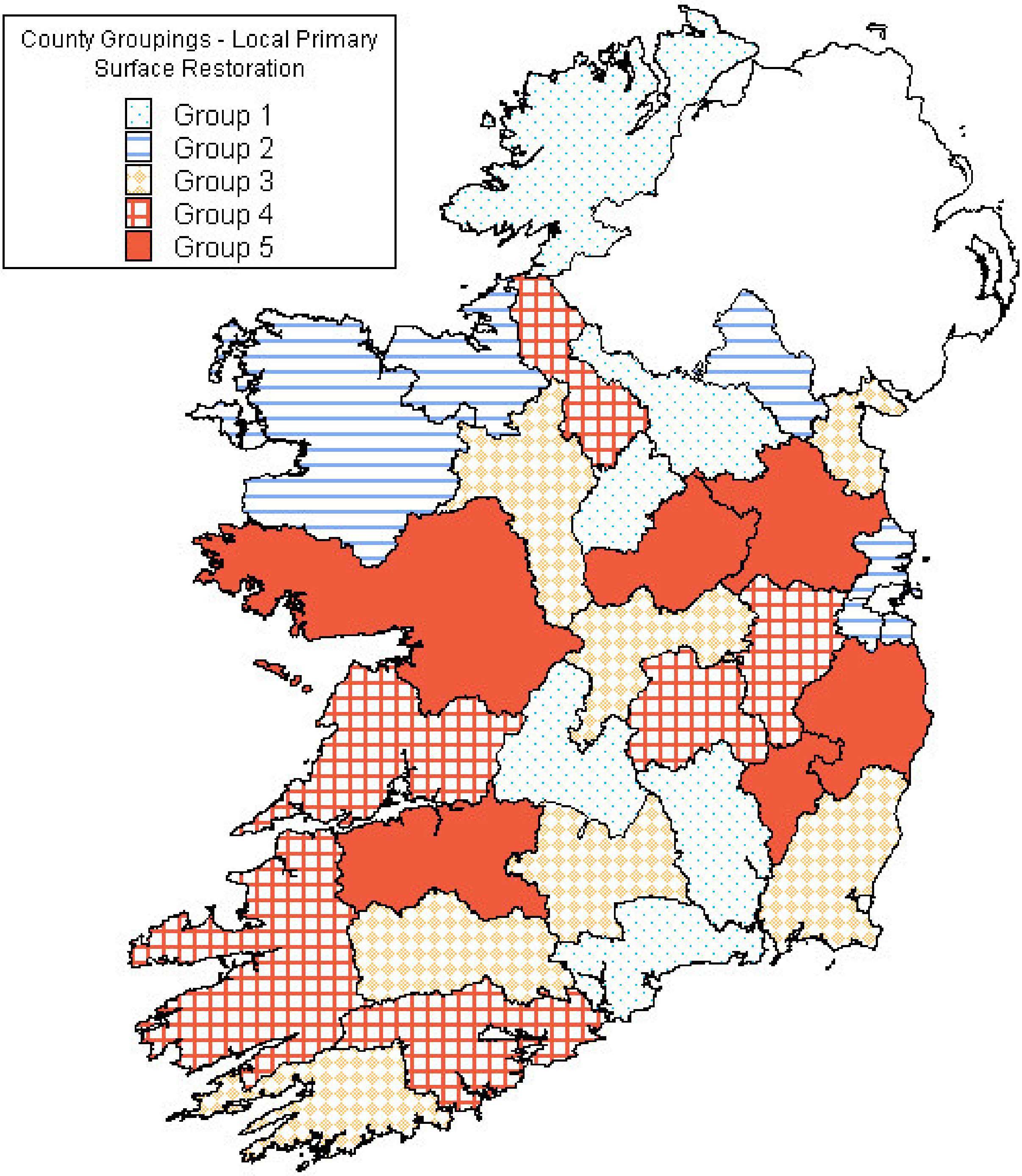

Figure 9.5 Local Primary - Surface Restoration

*groups ranked 1 to 5 by increasing % area requiring remedial works

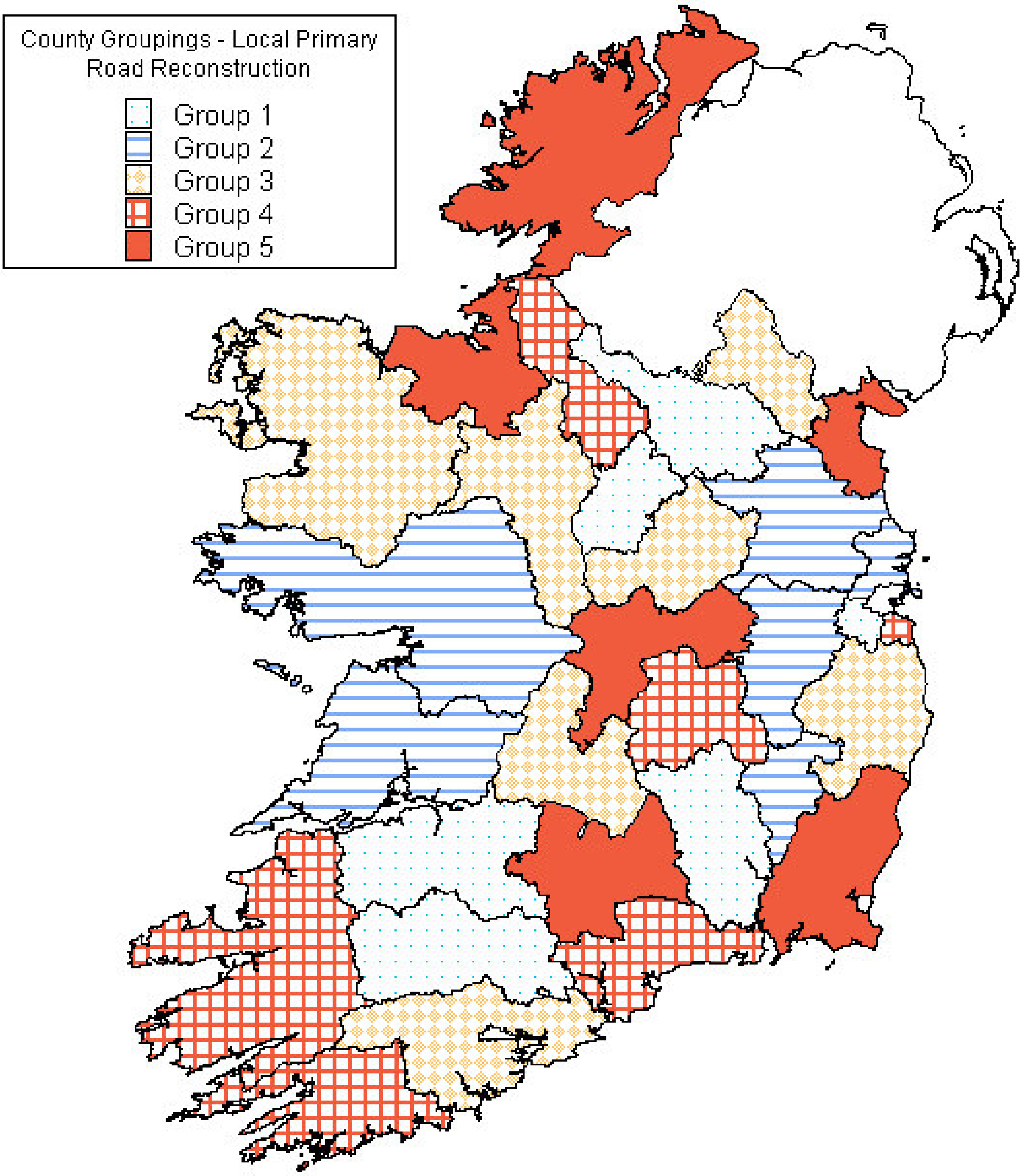

Figure 9.6 Local Primary – Road Reconstruction

*groups ranked 1 to 5 by increasing % area requiring remedial works

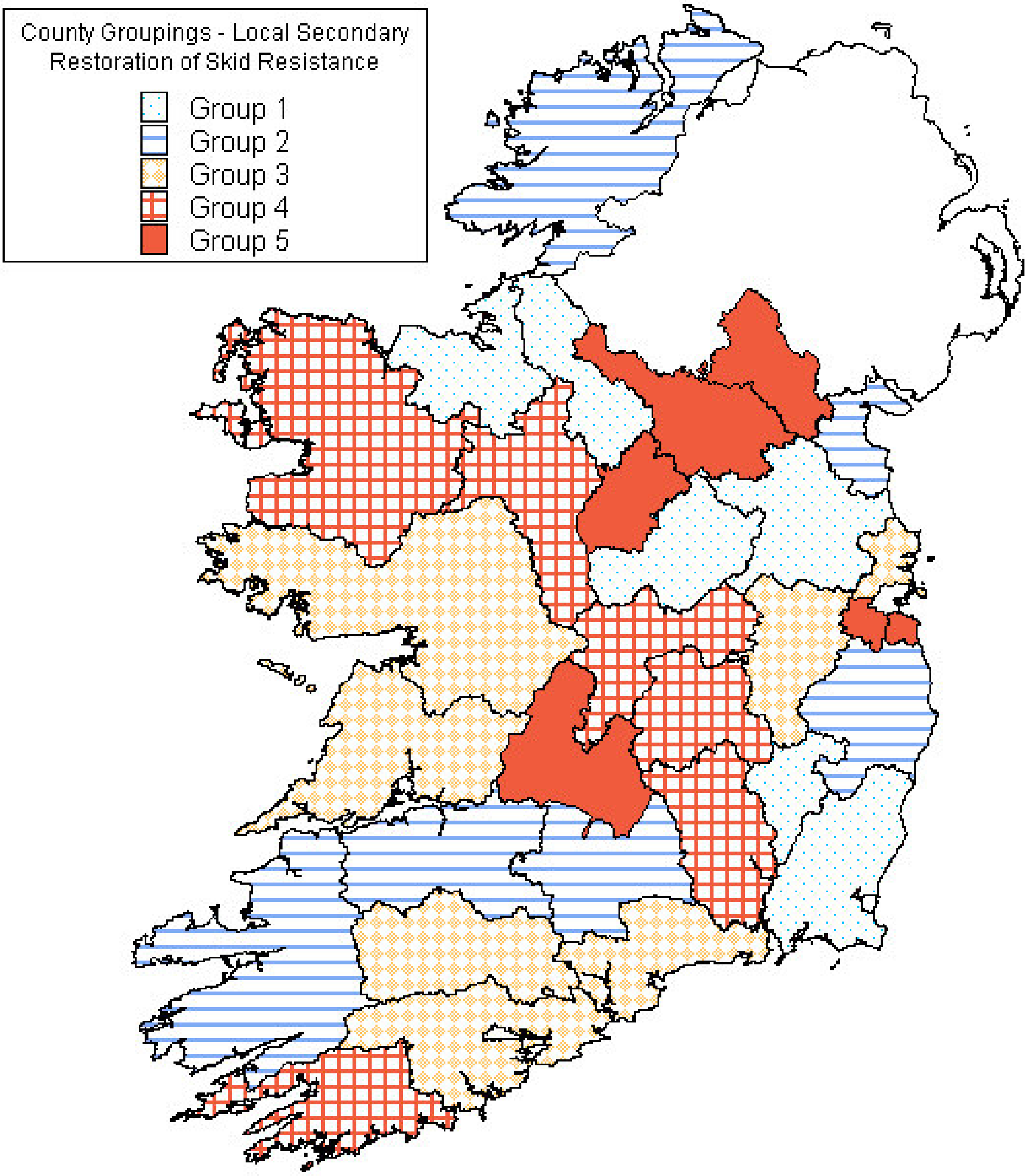

Figure 9.7 Local Secondary – Skid Resistance

*groups ranked 1 to 5 by increasing % area requiring remedial works

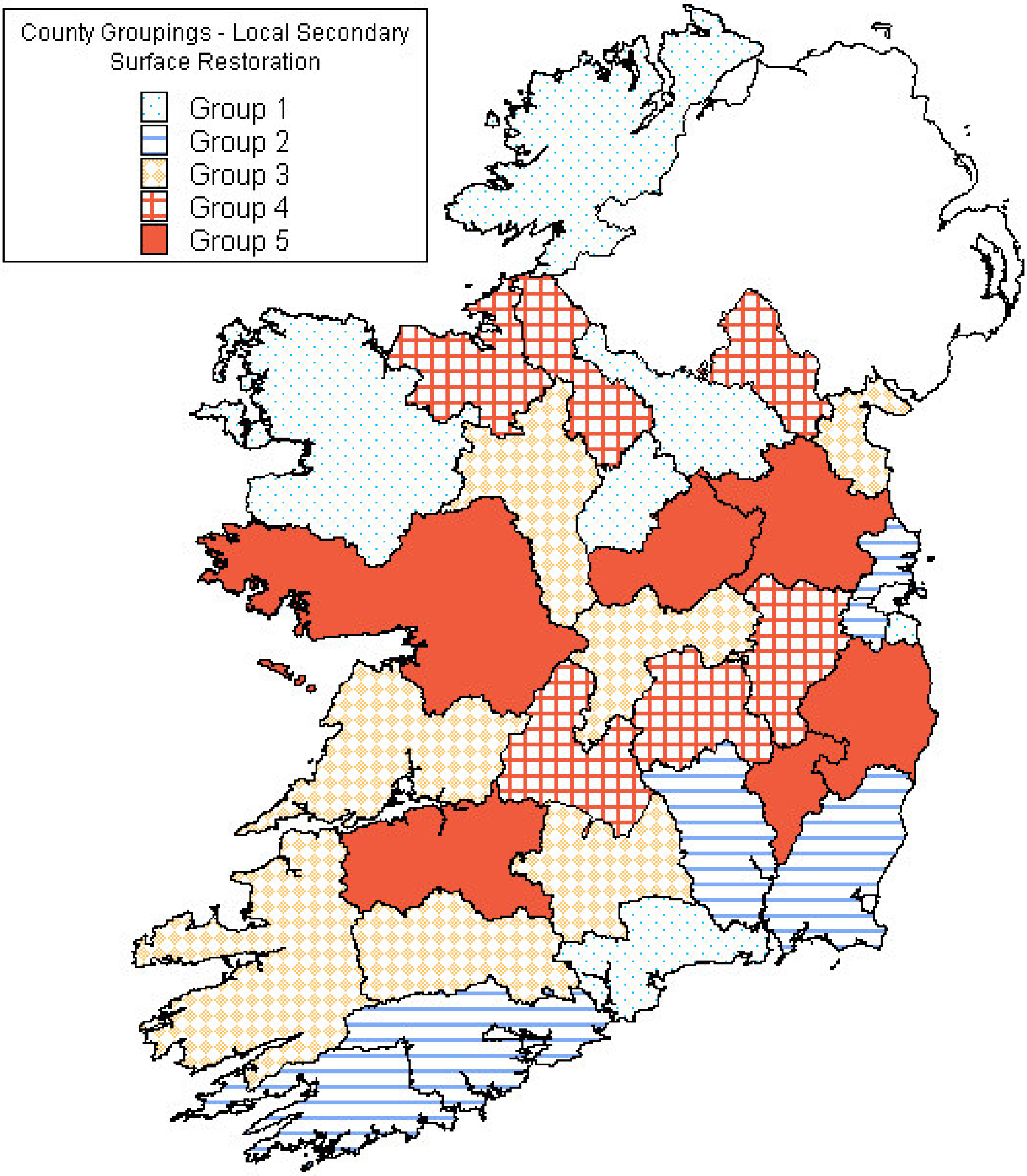

Figure 9.8 Local Secondary – Surface Restoration

*groups ranked 1 to 5 by increasing % area requiring remedial works

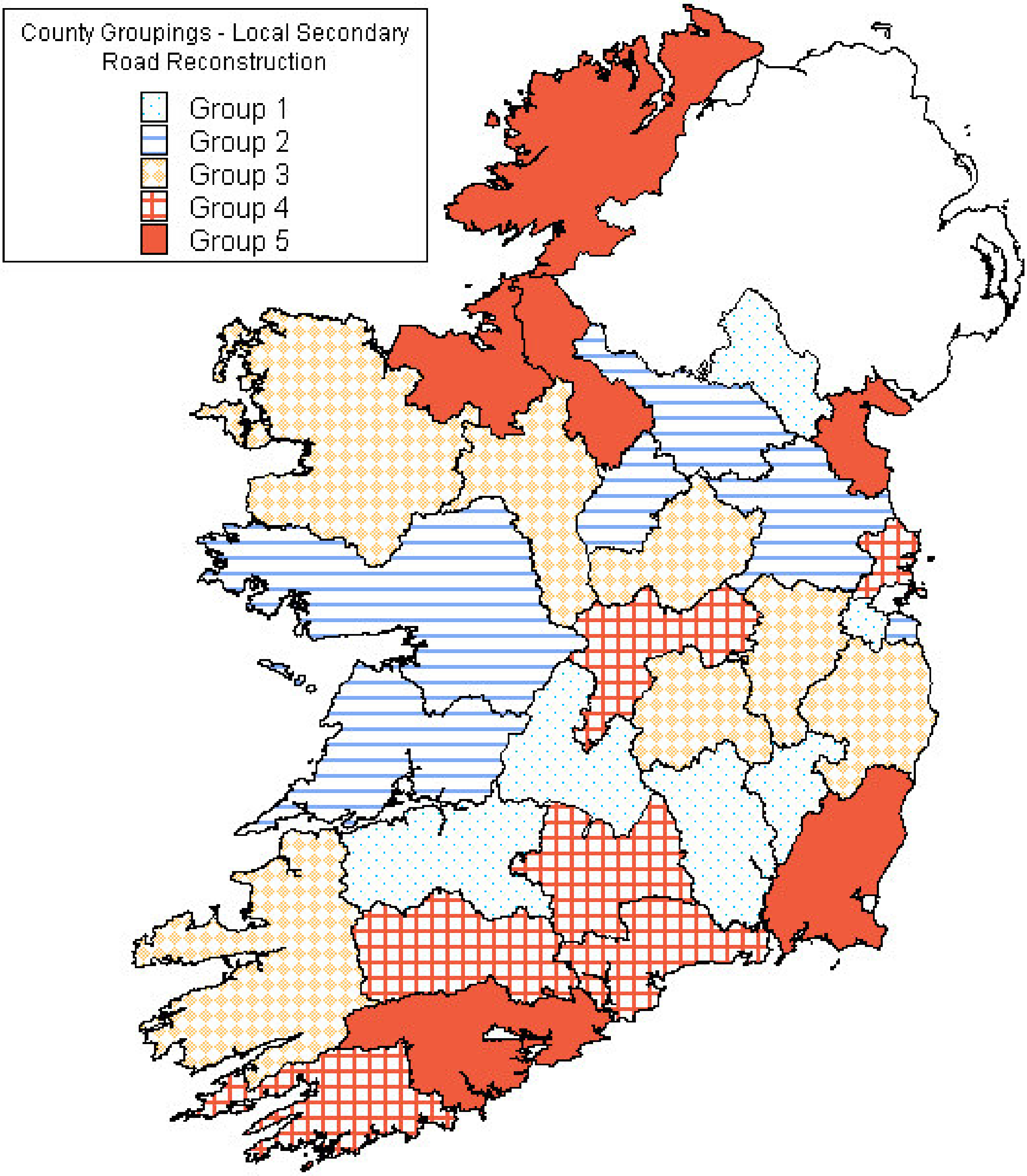

Figure 9.9 Local Secondary – Road Reconstruction

*groups ranked 1 to 5 by increasing % area requiring remedial works

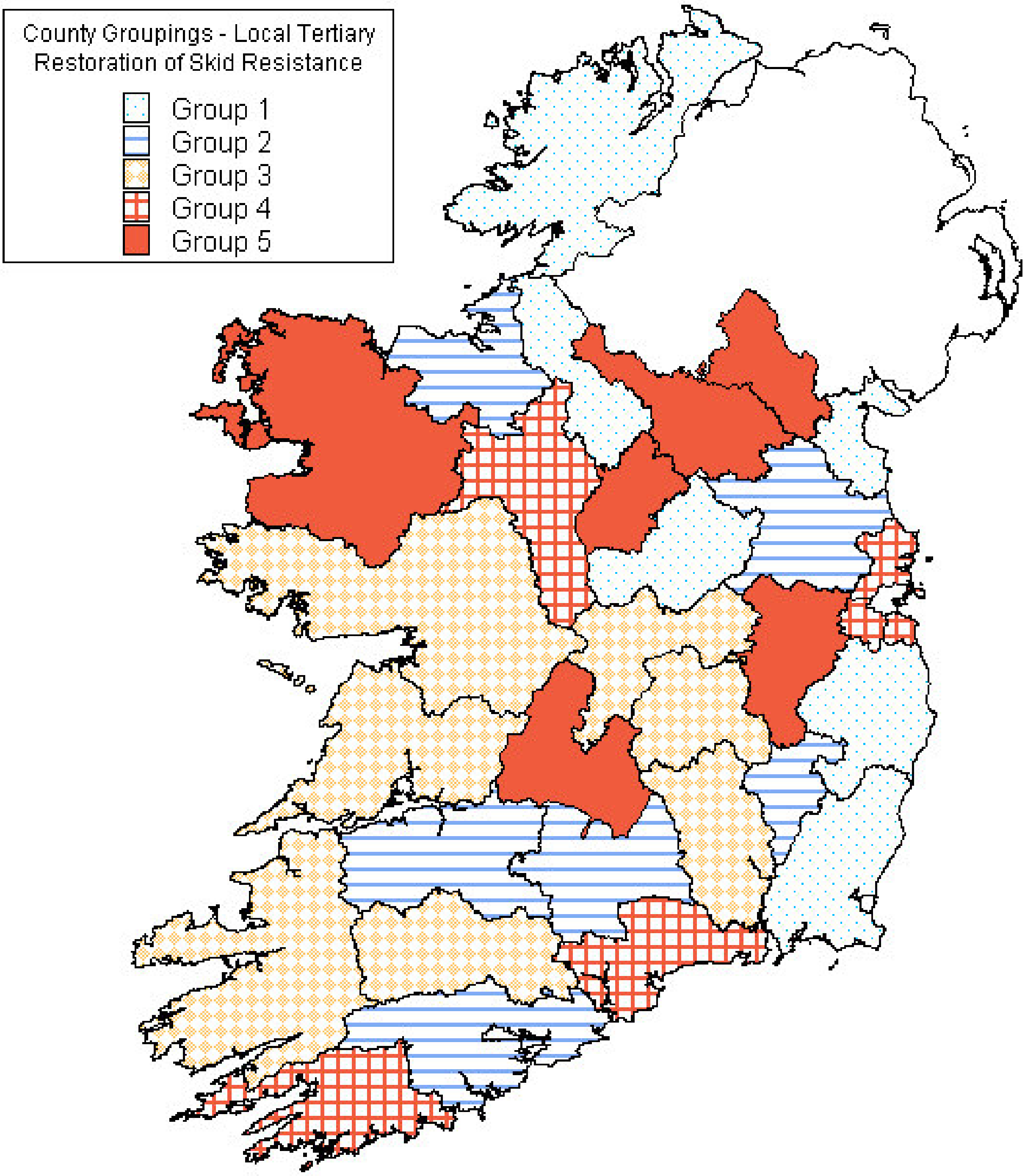

Figure 9.10 Local Tertiary – Skid Resistance

*groups ranked 1 to 5 by increasing % area requiring remedial works

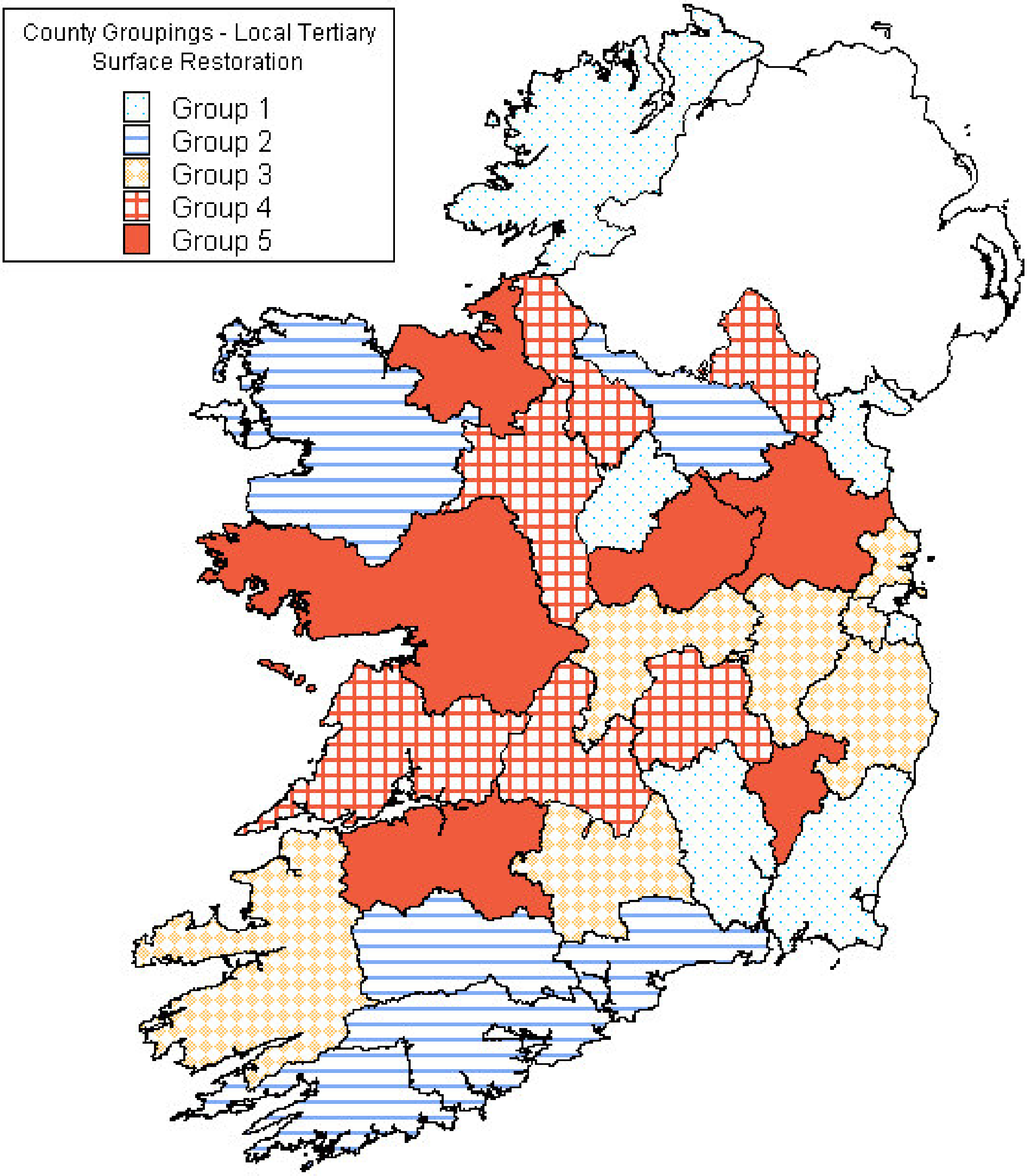

Figure 9.11 Local Tertiary – Surface Restoration

*groups ranked 1 to 5 by increasing % area requiring remedial works

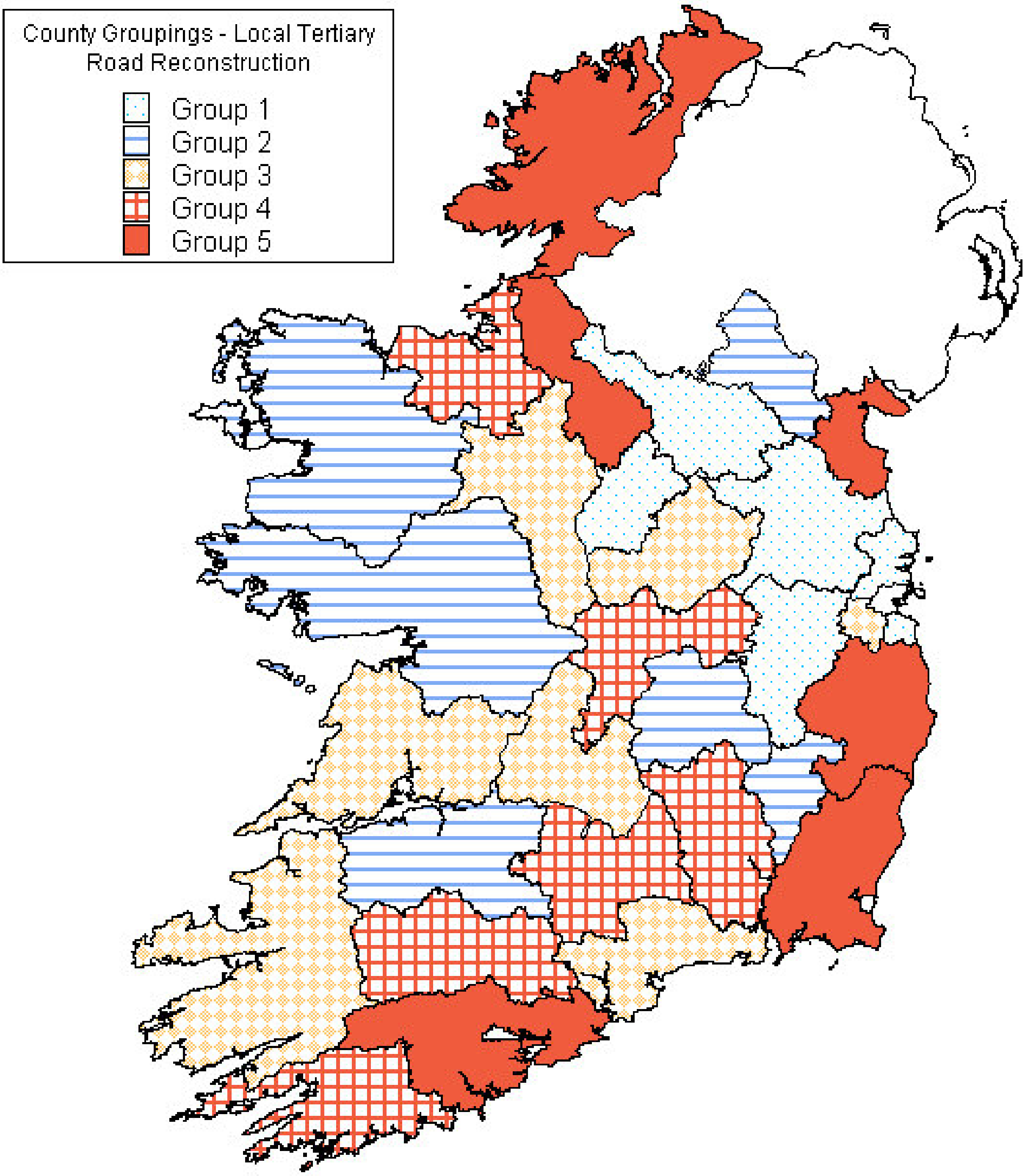

Figure 9.12 – Local Tertiary – Road Reconstruction

*groups ranked 1 to 5 by increasing % area requiring remedial works

APPENDIX A

A.1 SAMPLING METHODOLOGY

An essential requirement of the brief is that the sampling method and size shall be sufficient to achieve an outturn confidence level in the lengths of road requiring remedial works of at least +/- 10% at the 95% level for each county. In order to achieve these confidence levels, the following approach was adopted.

At the most basic level, it is possible to identify all road sections in a particular county, and extract a representative sample from the population by simple random sampling. There are a number of difficulties with this, however, primarily the estimation of the likely variability in road conditions throughout the county. As the sample size chosen is directly related to the variability level assumed, good estimates of the likely variability are essential prior to carrying out the survey. However, such estimates will vary considerably from county to county depending on size, variability in geographical and soil conditions, variability in historical and current maintenance practices and so on.

A.1.1 Two-stage Stratified Sampling

Accordingly, an approach which can reduce the variability expected is desirable. A two-stage stratification below the county level was used. Firstly, the engineering area was adopted as the base unit for sampling. With the adoption of the engineering area as the base unit for sampling, we have a much more uniform size to deal with, relatively independent of county size. From engineering and statistical considerations, the engineering area is a better base unit, as the variability in topographic and soil conditions within an area will be significantly smaller than within a county. In addition, the reality of road conditions within counties is that the conditions can and do vary significantly from area to area as a result of different maintenance practices. Again, adoption of the engineering area as the base unit means that a more accurate estimate of this variability can be used for statistical purposes.

In addition, stratification by road classification is required. The outturn results are reported separately for Regional, Local Primary (LP), Local Secondary (LS) and Local Tertiary (LT) roads. The proposed structure again explicitly incorporates a large part of the variability, and makes a confident estimation of the remaining variability much more straightforward.

Thus, we recommended sampling of the 4 road classes in every engineering area in every county. Strictly, this is not required to guarantee the required confidence levels at county and national level. However, the statistical estimation at county and national level is more straightforward with sampling in each engineering area, and a more uniform degree of confidence in the data by engineering area is much more useful to individual local authorities. Practically, the process is also more defensible when sampling has been carried out on an "equal" basis throughout all counties, with the engineering area providing the basis for "equality".

A.1.2 Simple One-Stage Cluster Sampling

Based on previous experience, a length of 1.5 to 2 kilometres is a reasonable estimation of the typical road section length contained in the local authority road schedules and reflected in the MapRoad databases. The actual division into sections is based on physical locations, usually road junctions, and the length of section does vary significantly around the target length of 2 kilometres.

Prior to selection of the random sections for surveying, a filter was applied to exclude very short sections (prohibitive in time and cost to include) and very long sections (potential to be unrepresentative of the engineering area). Table A.1 shows the average length of road segment, by road class, selected in the 1996 and 2004 surveys, and the average length nationally based on the 2003 complete road schedules for all counties. The average lengths by road class are slightly longer in the surveys due to the exclusion of very short sections, but are comparable and in line with the prior estimates of average length of 1.5 to 2 kilometres.

Source	R	LP	LS	LT
1996 Survey	2063	2069	1742	1080
2004 Survey	2150	2043	1940	1370
2003 National	1840	1749	1451	722

Table A.1: Average Lengths by Road Class

Tables A.2 and A.3 show some further analysis, illustrating the cumulative percentage by road class in various length brackets. It can be seen that the cumulative percentage values for the 2004 survey in Table A.2 are comparable with the cumulative percentage values based on the complete 2003 road schedules nationally shown in Table A.3.

Segment Length	All	R	LP	LS	LT
< 2.5 km	79%	67%	74%	77%	93%
< 3 km	89%	83%	86%	89%	97%
< 3.5 km	95%	91%	94%	96%	99%
< 4 km	98%	95%	97%	99%	100%

Table A.2: Cumulative Percentage for Segment Length Brackets: 2004 Survey

Segment Length	All	R	LP	LS	LT
< 2.5 km	87%	71%	77%	83%	97%
< 3 km	93%	84%	88%	92%	99%
< 3.5 km	96%	91%	94%	96%	100%
< 4 km	98%	95%	97%	98%	100%

Table A.3: Cumulative Percentage for Segment Length Brackets: 2003 National

After random selection, each road section was then divided into sample units of 100 metres in length. The pavement conditions prevailing in each 100 metres were assessed using pavement distress data and ride quality data, and classified into an appropriate remedial works category. The proportion of the length of each pavement section that belongs to each remedial works category can then be calculated by simple aggregation of the results from each sample unit.

In theory, it is possible to enumerate each sample unit of 100 metres within each engineering area, and to select a simple random sample from these. This approach would yield the smallest total number of sample units to be inspected. Logistically and practically however, this would be extremely costly and time-consuming to carry out. Instead, a simple one-stage cluster sampling procedure was adopted. Each pavement section, 2 kilometres in length approx., is regarded as being a cluster of sample units, with a typical cluster size of 20 (20 * 100 metres = 2 kilometres, the total section length). All sample units within each road section are then surveyed.

This approach requires the sampling of a slightly greater number of sample units in total, because of the homogeneity of conditions that may apply within each section. However, it has many advantages in ease of identification for initial survey and subsequent auditing, cost of collection of data and the usefulness of the data for area engineer and local authority purposes beyond the needs of this national study.

A.1.3 Final Derivation of Sampling Requirements

Conservative estimates of the average number of sample units for each engineering area/road class combination were derived from the local authority information provided. These estimates ensure that the results for each road class will be statistically valid with a high degree of confidence at engineering area level in each county, maximising the utility of the results to the local authorities. These estimates were then used in conjunction with the planning equation to determine the number of sample units required to be inspected for each engineering area/road class combination to allow a statistically valid estimation of the proportion of road length and area falling into each remedial work type category within the limits set by the DEHLG.

The calculation of the sampling rate required is based on the equations relating to the estimation of population proportion. For any given engineering area, there are 4 road classes. Within each road class, there are 4 possible road remedial work types – surface dressing, surface restoration, road reconstruction and other (usually do-nothing). We are attempting to estimate the proportion of road length in each road class that belongs in each of the 4 road remedial work type categories. The relevant planning formula is

$$n = \frac{z^2 p(1-p)}{h^2 + \frac{z^2 p(1-p)}{N}} \qquad \text{(eqn. A.1)}$$

h, the halfwidth is defined by DEHLG at 10% (0.1 for the formula)

z takes the value of 1.96 based on the DEHLG requirement of a 95% Confidence Interval and on the assumption that the data being sampled follows a normal distribution

p is the planning value for the proportion to be estimated, conservatively p is asssumed to be 0.5, as this produces the maximum value for n, the sample size.

N is the population, the total number of 100 metre sample units in each road class in the engineering area.

n is the number of sample units required to be surveyed

The formula is derived from simple random sampling, but is equally applicable for stratified random sampling when the population size is reasonably large, as it is in this case due to the use of 100 metre sample units.

For planning purposes, it was decided to use a half-width of 0.1 in building the confidence interval for the work type category proportions <u>at engineering area level</u>, reflecting the +/- 10% requirement specified by the DEHLG. This in turn gives a much narrower half-width at county level, with the half-width at county level depending upon the number of engineering areas in the county – the greater the number of engineering areas, the narrower the half-width and the tighter the confidence interval is around the estimated proportion.

County	R	LP	LS	LT
South Dublin	25	27	114	12
DLR	34	32	29	103
Fingal	66	91	70	91
Carlow	53	109	112	95
Cavan	57	101	193	57
Clare	75	137	176	101
Cork	63	151	232	106
Donegal	115	330	345	210
Galway	64	116	206	119
Kerry	56	148	129	194
Kildare	97	83	261	81
Kilkenny	52	132	225	66
Laois	94	207	200	148
Leitrim	84	170	145	129
Limerick	93	201	283	102
Longford	50	139	169	116
Louth	65	98	156	63
Mayo	64	136	186	255
Meath	79	92	128	186
Monaghan	48	88	96	163
North Tipp	85	227	188	115
Offaly	85	123	139	113
Roscommon	57	184	262	164
Sligo	54	150	241	193
South Tipp	85	184	178	92
Waterford	59	148	169	38
Westmeath	57	127	223	92
Wexford	110	242	305	143
Wicklow	85	93	181	34

Table A.4 – Average Road Class Length by Engineering Area in each County

Table A.4 shows the average road length (kilometres) of each of the four road classes in a typical engineering area for every county. It is clear that the average engineering area road lengths vary very considerably from one county to another. Conservative estimates of the average number of sample units for each engineering area/road class combination were derived from this table, with values chosen to represent the lower ranges of average road length in each road class. The final values selected were 55 kilometres for Regional roads, 100 kilometres for Local Primary Roads, 150 kilometres for Local Secondary Roads and 90 kilometres for Local Tertiary Roads.

These estimates were then used in conjunction with equation A.1 to determine the number of sample units required to be inspected for each engineering area/road class combination to allow a statistically valid estimation of the proportion of road length and area falling into each remedial work type category within the limits set by the DEHLG. Table A.5 shows the results. These are in turn then applied as a sampling percentage to the national lengths in each road category to indicate, in Table A.6, the over-all lengths to be surveyed in the 2004 Pavement Condition Survey.

Road Class	Kilometres	Sample Units	Samples Reqd.	Actual %	Recomm. %
Regional	55	550	82	14.91	15
LP	100	1000	88	8.80	9
LS	150	1500	90	6.00	6.25
LT	90	900	87	9.67	9.75

Table A.5 – Recommended Sampling Rates

Road Class	Kilometres	Recomm. %	Survey Km
Regional	11349	15	1702
LP	23611	9	2125
LS	32021	6.25	2001
LT	20169	9.75	1966
Total	**87150**		**7795**

Table A.6 – Lengths to be surveyed

APPENDIX B

B.1 CONFIDENCE INTERVAL WIDTHS

As described in Appendix A, it was decided to use a half-width of 0.1 in building the confidence interval for the work type category proportions at engineering area level, reflecting the +/- 10% requirement in the RFP. This in turn gives a much narrower half-width at county level, with the half-width at county level depending upon the number of engineering areas in the county. The greater the number of engineering areas, the narrower the half-width and the tighter the confidence interval is around the estimated proportion.

Appendix B contains details of the actual confidence interval widths calculated about the average percentage values shown in Tables 9.9 to 9.12 in the main report. In general, it can be seen that the maximum half width estimate is c. 0.03 to 0.04, very substantially below the half width of 0.1 specified. The half width estimates in the 3 Dublin local authorities, Dun Laoghaire/Rathdown, Fingal and South Dublin, are substantially higher than other local authorities. This reflects the relatively small number of road sections and short road lengths in these authorities, particularly on Local Tertiary roads. In addition, there is more widespread use of concrete road surfaces in the urban sections. Any concrete segments surveyed were not included in the final calculations as it was not possible to calculate a PCI value based on the VPCI methodology which had been developed and adapted in Ireland for bituminous surfaces.

County	Routine Maint.	Skid Resist.	Surf. Rest.	Reconstruction	Maximum
Carlow	0.05	0.05	0.06	0.04	0.06
Cavan	0.04	0.04	0.02	0.02	0.04
Clare	0.03	0.03	0.02	0.03	0.03
Cork-North	0.03	0.04	0.04	0.03	0.04
Cork-South	0.02	0.03	0.03	0.03	0.03
Cork-West	0.03	0.03	0.03	0.04	0.04
Donegal	0.03	0.02	0.01	0.03	0.03
Dun L/Rathdown	0.07	0.06	0.05	0.05	0.07
Fingal	0.06	0.06	0.04	0.05	0.06
Galway	0.03	0.03	0.03	0.03	0.03
Kerry	0.03	0.03	0.03	0.03	0.03
Kildare	0.04	0.04	0.04	0.02	0.04
Kilkenny	0.04	0.04	0.03	0.02	0.04
Laois	0.04	0.04	0.05	0.04	0.05
Leitrim	0.03	0.04	0.03	0.02	0.04
Limerick	0.03	0.03	0.03	0.02	0.03
Longford	0.06	0.06	0.02	0.04	0.06
Louth	0.05	0.05	0.06	0.05	0.06
Mayo	0.03	0.03	0.02	0.03	0.03
Meath	0.03	0.02	0.04	0.04	0.04
Monaghan	0.04	0.04	0.02	0.02	0.04
North Tipp	0.04	0.04	0.01	0.03	0.04
Offaly	0.02	0.04	0.04	0.04	0.04
Roscommon	0.03	0.04	0.02	0.04	0.04
Sligo	0.01	0.05	0.04	0.05	0.05
South Dublin	0.08	0.07	0.07	0.05	0.08
South Tipp	0.03	0.03	0.03	0.03	0.03
Waterford	0.04	0.04	0.03	0.04	0.04
Westmeath	0.03	0.05	0.05	0.03	0.05
Wexford	0.02	0.02	0.03	0.04	0.04
Wicklow	0.03	0.03	0.04	0.03	0.04

Table B1: Confidence Interval Halfwidths: Regional Roads

County	Routine Maint.	Skid Resist.	Surf. Rest.	Reconst.	Maximum
Carlow	0.04	0.04	0.06	0.04	0.06
Cavan	0.03	0.04	0.03	0.03	0.04
Clare	0.02	0.03	0.03	0.03	0.03
Cork-North	0.04	0.04	0.04	0.03	0.04
Cork-South	0.02	0.03	0.03	0.03	0.03
Cork-West	0.02	0.03	0.03	0.03	0.03
Donegal	0.02	0.02	0.01	0.02	0.02
Dun L/Rathdown	0.08	0.10	0.09	0.10	0.10
Fingal	0.06	0.06	0.05	0.06	0.06
Galway	0.02	0.03	0.03	0.03	0.03
Kerry	0.02	0.02	0.03	0.03	0.03
Kildare	0.05	0.05	0.05	0.05	0.05
Kilkenny	0.03	0.04	0.03	0.02	0.04
Laois	0.03	0.04	0.05	0.05	0.05
Leitrim	0.02	0.04	0.04	0.04	0.04
Limerick	0.03	0.03	0.03	0.02	0.03
Longford	0.04	0.05	0.04	0.03	0.05
Louth	0.04	0.05	0.06	0.07	0.07
Mayo	0.02	0.03	0.02	0.03	0.03
Meath	0.03	0.04	0.05	0.04	0.05
Monaghan	0.03	0.04	0.04	0.04	0.04
North Tipp	0.02	0.04	0.03	0.03	0.04
Offaly	0.01	0.03	0.04	0.04	0.04
Roscommon	0.02	0.03	0.03	0.03	0.03
Sligo	0.01	0.04	0.03	0.04	0.04
South Dublin	0.08	0.10	0.08	0.07	0.10
South Tipp	0.02	0.03	0.03	0.03	0.03
Waterford	0.03	0.03	0.03	0.03	0.03
Westmeath	0.01	0.04	0.05	0.04	0.05
Wexford	0.02	0.02	0.03	0.03	0.03
Wicklow	0.03	0.03	0.04	0.04	0.04

Table B2: Confidence Interval Halfwidths: LP Roads

County	Routine Maint.	Skid Resist.	Surf. Rest.	Reconstruction	Maximum
Carlow	0.04	0.03	0.05	0.04	0.05
Cavan	0.03	0.03	0.02	0.03	0.03
Clare	0.03	0.03	0.03	0.03	0.03
Cork-North	0.02	0.02	0.02	0.03	0.03
Cork-South	0.01	0.02	0.02	0.02	0.02
Cork-West	0.01	0.02	0.02	0.03	0.03
Donegal	0.02	0.02	0.01	0.03	0.03
Dun L/Rathdown	0.13	0.12	0.05	0.11	0.13
Fingal	0.06	0.06	0.07	0.08	0.08
Galway	0.01	0.02	0.03	0.02	0.03
Kerry	0.03	0.03	0.03	0.03	0.03
Kildare	0.02	0.03	0.03	0.03	0.03
Kilkenny	0.03	0.03	0.03	0.02	0.03
Laois	0.03	0.04	0.04	0.04	0.04
Leitrim	0.01	0.02	0.04	0.04	0.04
Limerick	0.03	0.03	0.03	0.02	0.03
Longford	0.04	0.05	0.03	0.04	0.05
Louth	0.03	0.04	0.05	0.05	0.05
Mayo	0.02	0.03	0.03	0.03	0.03
Meath	0.03	0.03	0.04	0.04	0.04
Monaghan	0.02	0.05	0.05	0.04	0.05
North Tipp	0.01	0.04	0.04	0.03	0.04
Offaly	0.02	0.04	0.04	0.05	0.05
Roscommon	0.01	0.03	0.03	0.03	0.03
Sligo	0.00	0.02	0.04	0.04	0.04
South Dublin	0.06	0.07	0.05	0.04	0.07
South Tipp	0.02	0.03	0.03	0.03	0.03
Waterford	0.03	0.03	0.03	0.04	0.04
Westmeath	0.00	0.02	0.03	0.03	0.03
Wexford	0.02	0.02	0.03	0.03	0.03
Wicklow	0.02	0.03	0.04	0.04	0.04

Table B3: Confidence Interval Halfwidths: LS Roads

County	Routine Maint.	Skid Resist.	Surf. Rest.	Reconstruction	Maximum
Carlow	0.03	0.03	0.05	0.05	0.05
Cavan	0.05	0.05	0.04	0.05	0.05
Clare	0.03	0.03	0.04	0.04	0.04
Cork-North	0.02	0.03	0.03	0.04	0.04
Cork-South	0.02	0.02	0.03	0.04	0.04
Cork-West	0.02	0.03	0.03	0.03	0.03
Donegal	0.03	0.02	0.02	0.04	0.04
Dun L/Rathdown	0.09	0.08	0.06	0.08	0.09
Fingal	0.07	0.06	0.06	0.06	0.07
Galway	0.02	0.03	0.03	0.03	0.03
Kerry	0.02	0.02	0.03	0.03	0.03
Kildare	0.04	0.05	0.05	0.05	0.05
Kilkenny	0.03	0.04	0.04	0.05	0.05
Laois	0.03	0.03	0.04	0.04	0.04
Leitrim	0.01	0.02	0.04	0.04	0.04
Limerick	0.04	0.03	0.05	0.04	0.05
Longford	0.03	0.05	0.04	0.05	0.05
Louth	0.04	0.05	0.05	0.07	0.07
Mayo	0.01	0.02	0.02	0.02	0.02
Meath	0.02	0.02	0.03	0.03	0.03
Monaghan	0.02	0.03	0.03	0.03	0.03
North Tipp	0.00	0.07	0.08	0.08	0.08
Offaly	0.01	0.03	0.04	0.05	0.05
Roscommon	0.01	0.03	0.03	0.04	0.04
Sligo	0.00	0.03	0.05	0.05	0.05
South Dublin	0.00	0.20	0.20	0.23	0.23
South Tipp	0.03	0.03	0.04	0.05	0.05
Waterford	0.04	0.06	0.05	0.07	0.07
Westmeath	0.01	0.03	0.06	0.06	0.06
Wexford	0.01	0.02	0.03	0.03	0.03
Wicklow	0.03	0.04	0.06	0.07	0.07

Table B4: Confidence Interval Halfwidths: LT Roads

APPENDIX C

C.1 REPEAT SURVEY IN LONGFORD

It was decided to carry out a second fully independent survey in one local authority to determine the repeatability of the survey results. Longford was chosen, and the second survey was carried out towards the end of the project in October, 2004. A second set of road sections in every engineering area for all four road classes was randomly selected and surveyed. Table C.1 shows a comparison of the road segment statistics for the initial and repeat surveys. It can be seen that the number of road segments and average segment lengths surveyed in the initial and repeat surveys are almost identical for the three local road categories. The number of segments and average length on Regional roads are significantly different, primarily because the typical Regional road segment in Longford is much longer than in the other road classes. By random selection, a smaller number of segments with significantly longer lengths were selected to meet the required target length of 15% of Regional roads in the Phase 1 survey.

	Phase 1		Phase 2	
R Class	**# Segments**	**Avg. Length**	**# Segments**	**Avg. Length**
LP	16	2200	15	2146
LS	23	1970	22	2000
LT	22	1500	22	1445
R	6	3833	9	2444

Table C.1: Summary Statistics

Table C.2 shows a further breakdown of statistics by engineering area and road class. Again, it can be seen that while there are some differences in the number of sample units surveyed in each engineering area, in general there is good consistency between the initial and repeat surveys within each engineering area.

		Sample Units	
R Class	**E Area**	**Phase 1**	**Phase 2**
LP	1	162	152
LP	2	72	70
LP	3	115	100
LS	1	215	195
LS	2	83	114
LS	3	155	131
LT	1	148	146
LT	2	70	71
LT	3	126	101
R	1	73	98
R	2	33	41
R	3	124	81

Table C.2: Summary Statistics by Engineering Area

Table C.3 shows a comparison of average road widths derived at county level from the initial and repeat surveys. It can be seen that the average road width is very consistent across the three local road categories, with a significantly bigger difference in average width on the Regional road category.

	Road Width	
R. Class	**Phase 1**	**Phase 2**
LP	4.6	4.6
LS	3.5	3.3
LT	2.8	3.0
R	6.7	6.2

Table C.3: Road Width Comparisons

Table C.4 shows a comparison of the average Pavement Condition Index (PCI) values computed for each road category in both the initial and repeat surveys. The values are calculated directly from the sample units, and also weighted by sample unit area to be consistent with the national survey. Again it can be seen that there appears to be very good consistency in results on the three local road categories, and a significantly greater difference in average value in the Regional road category.

	PCI-AREA		PCI	
R. Class	**Phase 1**	**Phase 2**	**Phase 1**	**Phase 2**
LP	68	69	68	69
LS	64	66	63	66
LT	58	63	58	62
R	73	80	72	79

Table C.4: Average PCI Comparisons

Table C.5 shows a comparison of the average International Roughness Index (IRI) values computed for each road category in both the initial and repeat surveys. Again, values are computed based directly on the number of sample units, and also weighted by sample unit area. The average values are very consistent across the three local road categories, and show a significantly greater difference in the Regional road category. The pattern is consistent across the PCI and IRI values, with the repeat survey in October showing higher average PCI values and lower average IRI values. Both of these trends indicate better average conditions on the Regional roads in the repeat survey compared with the initial survey.

	IRI-AREA		IRI	
R. Class	**Phase 1**	**Phase 2**	**Phase 1**	**Phase 2**
LP	6.5	6.5	6.6	6.5
LS	7.8	7.5	7.9	7.7
LT	9.9	9.8	10.0	10.4
R	4.8	3.4	4.9	3.5

Table C.5: Average IRI Comparisons

A standardised t-test was set up to statistically compare the average PCI and IRI values. This test allows one to determine if the differences in average values are statistically significant. Table C.6 shows the standardised t-test results. If the standardised t-test result is less than 1.96, the results from the initial and repeat surveys are not statistically different with a 95% confidence level. Examining the results, it can be seen that the t-test results for the three local road categories are less than 1.96 for both the PCI and IRI statistics. On the Regional roads, the t-test statistics are greater than 1.96 for both the PCI and IRI statistics, indicating that the results are statistically different for this road category.

This difference can be attributed to the much longer average section lengths on Regional roads in the Longford road schedule (3127 metres in Longford compared with an average of 1840 metres for Regional roads nationally). As a consequence, far fewer Regional road sections were required to be surveyed to meet the 15% target length. Accordingly, the random selection of a small number of road sections in very good condition in the second survey had a very large influence on average road conditions measured.

R. Class	PCI	IRI
LP	0.44	0.85
LS	1.94	1.39
LT	1.57	0.81
R	3.91	9.5

Table C.6: Standardised t-test Results

The results from the initial (Phase 1) and repeat (Phase 2) surveys were combined and average results computed from the combined survey. Effectively, the combined survey can be taken to represent the results that would have been obtained from a much greater sampling rate, double the sampling rate used in the national survey. Table C.7 shows a comparison of the average values obtained. It can be seen that the average values derived from the initial survey are very similar to the results obtained from the combined survey, indicating that the sampling rate used in the national survey is appropriately large enough to give good estimates of average pavement condition at county level.

	PCI		IRI	
R. Class	**Phase 1**	**P1+P2**	**Phase 1**	**P1+P2**
LP	68	68	6.6	6.5
LS	63	64	7.9	7.8
LT	58	60	10.0	10.2
R	72	76	4.9	4.2

Table C.7: Comparison of Initial Survey with Combined Surveys

The survey results illustrate the desirability of adopting a maximum section length of approximately 3 kilometres in cases where road schedules are to be used subsequently for surveys that involve sampling. Overall, the exercise confirmed the repeatability of the approach taken to sampling and data collection in the project.